Pebble Project
Environmental Baseline Studies
2004 through 2008

CONSOLIDATED STUDY PROGRAM

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Pebble Project
Environmental Baseline Studies
2004 through 2008

CONSOLIDATED STUDY PROGRAM

1. INTRODUCTION

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Figure 1-3, Consolidated Study Program 2004–2008, Location of Cominco Sampling Stations and Bird Observations (pre-2004)

1. INTRODUCTION

1.1 Purpose

The purpose of this document is to summarize the study program for the environmental and socioeconomic baseline studies for the Pebble Partnership's Pebble Project. It is composed of 19 sections, one for this introduction and one for each of the 18 disciplines of study. Each section (except this introduction) is a compilation of the study plans for 5 years of study. Together they are referred to as the consolidated study program (also referred to as the consolidated study plan), 2004 through 2008.

The study program encompasses proposed and/or completed work from 2004 through 2008. As each year of baseline work is completed, new study plans that build successively on work from previous years are developed.

1.2 Background

The Pebble Deposit is a copper, gold, molybdenum, and silver deposit located in southwestern Alaska north of Iliamna Lake (Figure 1-1). Starting in 2001, the Pebble Partnership began extensive studies to collect geological information. In 2004, environmental, socioeconomic, and engineering studies were initiated to collect baseline data.

The design of the Pebble Project requires planning and coordination of all aspects of the project from its initial stages through final closure. In this context, environmental stewardship is a fundamental ingredient in the design and overall feasibility of the project.

1.3 Goals and Objectives

The primary goal of this study program is to describe the Pebble Partnership's baseline environmental program for the purpose of characterizing the natural environment. These studies are more than a compilation of data documenting baseline conditions. They also include elements for analyzing the information for future needs. The specific objectives of this document are to:

- Describe the study program for characterizing baseline environmental conditions.
- Define the methods and approach for data gathering and analysis for review by others.
- Define the objectives of each environmental component of the baseline studies.

1.4 Project Study Areas

The study areas for the majority of the environmental disciplines have evolved over time as data were collected. In 2004/2005, the studies centered on the area immediately around the general deposit location as it was then delineated (Figure 1-2), a general transportation corridor study area, and Iliamna and

Iniskin bays in Cook Inlet, as shown on Figure 1-1. By 2006/2007, the study area had been expanded considerably around the deposit area, into Iliamna Lake, and along the shores of Cook Inlet.

1.5 Approach

There are several environmental aspects in the study area (including physical, chemical, biological, and human) that require consideration by experts from a variety of disciplines. The overall approach of these studies is to collect information on all environmental and social aspects and integrate these studies across scientific disciplines to characterize baseline conditions.

The disciplines (and the associated consultants) required to characterize the environmental baseline conditions of the Pebble Project are listed in Table 1-1. Consultants responsible for characterizing biophysical and cultural conditions collect data through detailed surveys and mapping, followed by analyzing the collected information. Consultants responsible for collecting site-condition information, such as provided by meteorology and hydrology data, collect the data through site installations and regular monitoring programs.

This appendix is a product of the Pebble Partnership and is a consolidation of the study plans provided by its consultants, focusing on the study plans for collecting the social and environmental baseline data, the majority of which were initiated in 2004.

1.6 Previous Studies

Cominco geologists first defined the geologic resource, conducted engineering studies, and collected environmental baseline data for the Pebble Project in the 1980s and 1990s. The locations where Cominco collected environmental baseline data are shown in Figure 1-3. The Cominco baseline environmental studies included the following:

- Hydrometeorology studies.
  - Miscellaneous stage discharge data for 10 stations (1991-1993).
  - Additional continuous and hourly stage data for Upper and Lower Talarik Creek and South Fork Koktuli River (1991-1993).
  - Long-term regional climate station data at Iliamna (46 years) and Port Alsworth (34 years) plus 1993 weather station data for the vicinity of Pebble Deposit and Iniskin Bay.
  - Long-term United States Geological Survey stream flow station data (Tanalian River near Port Alsworth, the Tazimina River near Nondalton, and the Newhalen River near Newhalen).
- Freshwater and marine fisheries studies.
  - Koktuli River Float Survey reports (1977, 1981, 1982, 1983, 1984, 1986, 1987, 1988).
  - Lower Talarik Creek rainbow trout report (1997).
  - Baseline Fisheries Investigations reports (1991 & 1993).
  - Miscellaneous water quality sampling (1991-1993).

  - Williamsport Marine Baseline and environmental impact statement report (United States Army Corps of Engineers/Kenai Peninsula Borough, 2001).

- Terrestrial and marine wildlife studies.
  - Caribou Use of Pebble Mine Site (1992, Alaska Department of Fish and Game).
  - Status and Seasonal Movements of Caribou Near Pebble Mine Site (1992-93, van Daele).
  - Moose/Caribou Observations (1991, Alaska Department of Fish and Game).
  - Wildlife Reconnaissance Assessment (1990 & 1991, Terra Nord).
  - Mulchatna Caribou Management report (1992-1994, Alaska Department of Fish and Game).
  - Caribou Radio Tracking report (1993, Cominco).
  - Investigation of Wildlife Use and Harvest at Pebble Mine (1993).
  - Bear Den Survey report (1992).
  - Moose Survey report (1992).
  - Caribou Survey reports (1991 & 1992).
  - Marine Biota and Habitat Surveys (Williamsport environmental impact statement)

Cominco's work provided the basis for the initial scoping-level project assessment by Pebble Partnership in 2000. Based on this assessment, the Pebble Partnership initiated the additional studies described in this appendix to the environmental baseline document.

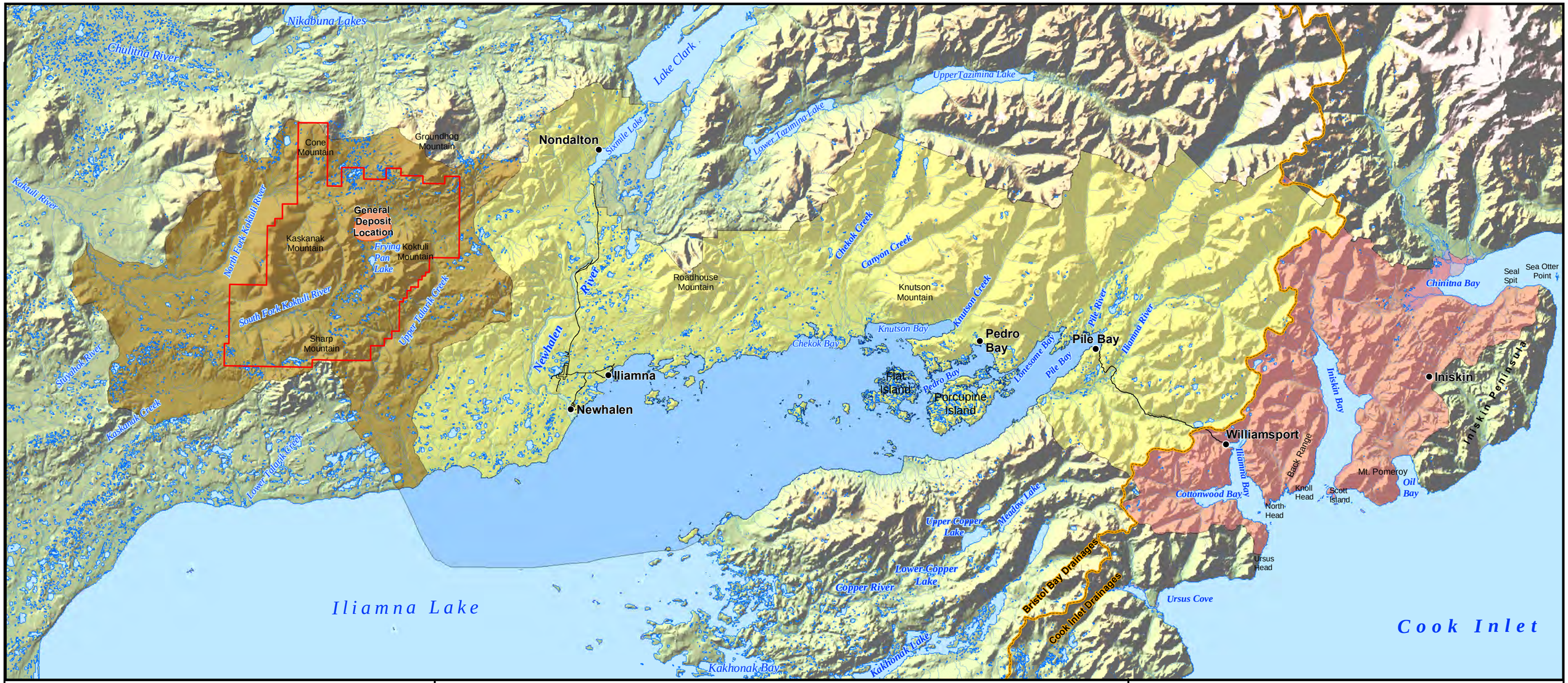
TABLE

TABLE 1-1
Disciplines and Consulting Firms for the Pebble Project Environmental Baseline Studies Program

Discipline	Consultant(s)
Climate and Meteorology	Hoefler Consulting Group, CH2M Hill
Geology and Mineralization	Knight Piésold, Thomas Hamilton, SLR International Corp.
Physiography	Knight Piésold
Soils	Three Parameters Plus, Inc.
Geotechnical Studies, Seismicity and Volcanism	Knight Piésold, Water Management Consultants Inc., Schlumberger Water Services, Frontier Geosciences Inc.
Surface Water Hydrology	*Mine Study Area* — Knight Piésold; HDR Alaska, Inc.; ABR, Inc.; APC Services, LLC , CH2M Hill *Transportation Corridor/Cook Inlet Study Areas* — Bristol Environmental and Engineering Services Corp.
Groundwater Hydrology	*Mine Study Area* — Water Management Consultants; Schlumberger Water Services; SLR International Corp., Bristol Environmental and Engineering Services Corp., HDR Alaska, Inc., CH2M Hill
Water Quality (Surface Water, Groundwater, and Marine)	*Mine Study Area* — Water Management Consultants; Schlumberger Water Services; HDR Alaska, Inc.; APC Services, LLC; SLR International Corp.; CH2M Hill *Transportation Corridor/Cook Inlet Study Areas* — Bristol Environmental and Engineering Services Corp., Pentec Environmental/Hart Crowser, Inc.
Trace Elements and Other Naturally Occurring Constituents	*Mine Study Area* — SLR International Corp.; HDR Alaska, Inc.; CH2M Hill *Transportation Corridor/Cook Inlet Study Areas* — Bristol Environmental and Engineering Services Corp., SLR International Corp., Pentec Environmental/Hart Crowser, Inc.
Geochemical Characterization	*Mine Study Area* — SRK Consulting, Inc.
Noise	Michael Minor & Associates
Vegetation	Three Parameters Plus, Inc.; HDR Alaska, Inc.
Wetlands	Three Parameters Plus, Inc.; HDR Alaska, Inc.
Fish and Aquatic Invertebrates (Freshwater and Marine)	R2 Resource Consultants, Inc.; HDR Alaska, Inc.; Buell & Associates; Bailey Environmental; Northern Ecological Services; EcoFish; Inter-fluve; Pacific Hydrologic, Inc.; Pentec Environmental/Hart Crowser, Inc.
Wildlife and Habitat (Terrestrial and Marine)	ABR, Inc.; Bristol Environmental and Engineering Services Corp.; Pentec Environmental/Hart Crowser, Inc.; RWJ Consulting
Threatened and Endangered Species	ABR., Inc.
Land and Water Use	Kevin Waring Associates
Transportation	Kevin Waring Associates
Power	Kevin Waring Associates

Discipline	Consultant(s)
Socioeconomics	Kevin Waring Associates, McDowell Group
Cultural Resources	Stephen R. Braund & Associates
Subsistence and Traditional Knowledge	Stephen R. Braund & Associates
Visual Resources	Land Design North
Recreation	Kevin Waring Associates
Analytical Quality Assurance/Quality Control	Shaw Alaska. Inc.; Argon, Inc.
Iliamna Lake Studies	HDR Alaska, Inc.
Data Management	Resource Data Inc.; DES.IT; Shaw Alaska, Inc.; Argon, Inc.
Analytical Laboratories	SGS North America; Columbia Analytical Services;; SGS CEMI; SGS Lakefield; TestAmerica Laboratories, Inc.; University of Waterloo; ACZ Laboratories, Inc.; Texas A&M University; Frontier GeoSciences
Aerial Photography	Aerometric, Eagle Mapping, Kodiak Mapping, Dudley Thompson Mapping

FIGURES



THE pebble PARTNERSHIP

Figure 1-1
Pebble Project
Environmental Baseline Studies
Generalized Study Areas

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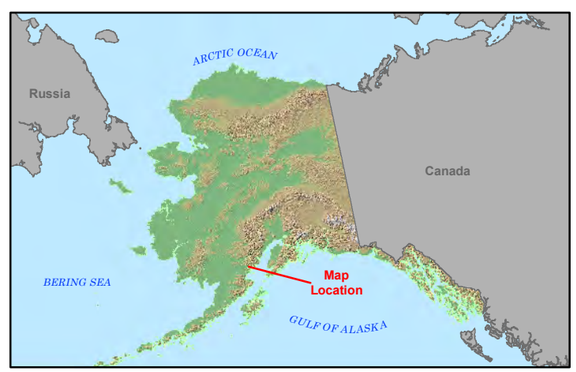
Version: 2	Author: PLP - JG, RDI - LS

Legend

- General Deposit Location
- Pebble Claim Block
- Mine Study Area
- Bristol Bay Transportation Corridor Study Area
- Cook Inlet Study Area
- Iliamna Lake Study Area
- Bristol Bay/Cook Inlet Drainages Boundary
- Communities
- Existing Roads



0 5 10 15 20 Miles

0 5 10 15 20 25 30 Kilometers

Scale 1:400,000

Alaska State Plane Zone 5 (units feet) 1983 North American Datum

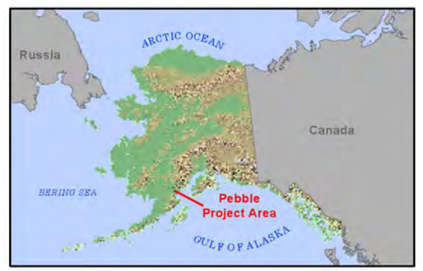
155°48'0"W
155°36'0"W
155°24'0"W
155°12'0"W
155°0'0"W
59°48'0"N
59°36'0"N
Black Lake
Frying Pan Lake
Chiquita Lake
North Fork Koktuli River
South Fork Koktuli River
Upper Talarik Creek
Newhalen River
Sixmile Lake
Nondalton
Iliamna
Newhalen
Iliamna Lake

THE pebble PARTNERSHIP

Figure 1-2
Consolidated Study Program,
2004-2008
Mine Study Area

Legend

- General Deposit Location
- 2007/2008 Field Study Area
- 2006 Field Study Area
- 2004/2005 Field Study Area
- Existing Roads
- Communities



0 2 4 6 8 Miles
0 5 10 Kilometers

Scale 1:200,000

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

N

File: RDI_PLP_DepositLocation_11X17_1of1_D02.mxd	Date: June 3, 2009
Version: 2	Author: RDI-LS, MRA

155°36'0"W 155°24'0"W 155°12'0"W 155°0'0"W

60°0'0"N

59°48'0"N

North Fork Koktuli River

South Fork Koktuli River

Upper Talarik Creek

Approximate

Groundhog Mountains

Figure 1-3

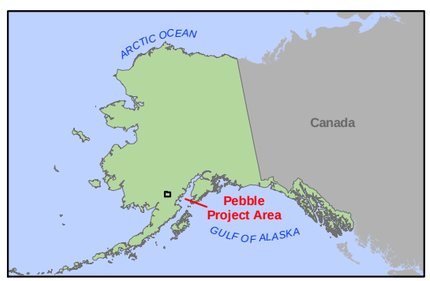
Consolidated Study Program, 2004-2008
Location of Cominco Sampling Stations
and Bird Observations (pre-2004)

LEGEND

- Surface Water Stations
- Fisheries Sampling Sites
- General Deposit Location
- Meteorological Station (approximate)

Tundra Swan and Bird Observations

- Adults/Cygnets, 1991
- Adults/Cygnets, 1992
- Single Adult, 1992
- Two Adults, 1992
- Peregrine Falcon Sighting



N

Feet
0 7,200 14,400 21,600 28,800

Meters
0 1,900 3,800 5,700 7,600

Scale 1:146,151

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

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Version: 4, Rev.	**Author: CH - BMS / EVW**

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Pebble Project
Environmental Baseline Studies
2004 through 2008

CONSOLIDATED STUDY PROGRAM

2. METEOROLOGY

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Figure 2-1, Consolidated Study Program, 2004-2008, Location of Pebble Deposit and Transportation Corridor/Port Site Meteorological Stations and Particulate Matter Monitoring Station

ACRONYMS

ADEC	Alaska Department of Environmental Conservation
°C	degrees Celsius
EPA	Environmental Protection Agency (U.S.)
Hoefler	Hoefler Consulting Group
PM	particulate matter
PSD	prevention of significant deterioration
QA	quality assurance
QAPP	quality assurance project plan

2. METEOROLOGY

Hoefler Consulting Group (Hoefler) was the lead consultant for the meteorology component of the environmental baseline study for the Pebble Project from 2004 through 2008.[1] This chapter describes the study program for the meteorology study from 2004 through 2008.

2.1 Objectives of Study

The objectives of the meteorology baseline study are to collect the necessary data to accomplish the following:

- Characterize baseline conditions for meteorology.
- Contribute to water balance studies and other environmental disciplines.

2.2 Proposed Study Plan

2.2.1 Study Area/Scope

The study area for the meteorological study has expanded over time, as data have been collected and based on feedback from the Pebble Partnership and reviewing agencies. The meteorology study collected various data from among 10 locations within the Pebble Project area: the deposit site, Iliamna Airport, and the Iliamna and Iniskin bay areas (referenced as port site stations). (See Figure 2-1.)

The general scope of the meteorological baseline study primarily involves collecting continuous records of meteorological data, including precipitation, temperature, temperature difference, wind speed and direction, evaporation, relative humidity, barometric pressure, and solar radiation. Some stations collect only a subset of these parameters, depending on the station configuration and on project needs (as described under Methods/Approach, below).

2.2.2 Methods/Approach

The methods and approach for collecting meteorological data were generally the same for all locations in the meteorology study, and are consistent with Alaska Department of Environmental Conservation (ADEC) and Environmental Protection Agency (EPA) guidance documents.

A key procedure in the ADEC guidelines is to develop a quality assurance project plan (QAPP) for data collection. The QAPP was developed for the meteorological study and is provided as an appendix to Chapter 2 of the *Pebble Project Environmental Baseline Document, 2004 through 2008.* It includes the ADEC quality assurance (QA) plan for meteorological monitoring and is based on the following ADEC guidance documents:

[1] CH2M Hill led the meteorology study for the Pebble Project in 2004; in late 2004, the Hoefler Consulting Group replaced CH2M Hill as the lead consultant.

- *Elements for Ambient Air Monitoring Quality Assurance Project Plan (QAPP)* (September 2004).
- *Ambient Air and/or Meteorological Monitoring QAPP Checklist* (September 2004).
- *PSD* [prevention of significant deterioration] *Quality — Ambient Air Quality and Meteorological Monitoring Data Report Format* (Revised January 2005).

The QAPP is also consistent with the following EPA guidance documents:

- *Ambient Monitoring Guidelines for Prevention of Significant Deterioration* (EPA-450/4-87-07).
- *Quality Assurance Handbook for Air Pollution Measurement Systems Volume IV-Meteorological Measurements* (EPA/600/R-94/038d-April 1994).
- *Meteorological Monitoring Guidance for Regulatory Modeling Applications* (EPA 454/R-99-005, February 2000).

Meteorological instrumentation manufactured by Met One Instruments, R.M. Young, Climatronics, ETI, Novalinks, and Campbell Scientific is being used at all stations. All instrumentation meets or exceeds EPA PSD-quality specifications for meteorological data collection. The following meteorological parameters are measured at all monitoring stations:

- Wind speed (meters per second, at 10 meters for all stations except Pebble 3, where wind speed is measured at 3 meters).
- Wind direction (degrees).
- Standard deviation of wind direction fluctuations (degrees).
- Air temperature at 2 meters (degrees Celsius [°C]).

The following additional parameters are measured at all PSD-quality monitoring stations (i.e., Pebble 1, Pebble 4, Pebble 5, Pebble 6, Port Site 1, AC Point, and Williamsport):

- Air temperature at 10 meters (degrees Celsius).
- Air temperature difference (degrees Celsius).
- Relative humidity (percent).
- Barometric pressure (millibars).
- Solar radiation (watts per square meter).

Total precipitation (millimeters of liquid water) is collected at Pebble 1, Pebble 3 and Pebble 4.

In addition, evaporation data are collected at Pebble 1 and Pebble 4 when the air temperature is greater than 0°C.

Upper air meteorological data, including mixing height and winds aloft, were not included in this data collection program. Instead, discussions have been conducted with ADEC and EPA, and a determination was made that representative upper air data from another location can be used for the project as currently envisioned.

The meteorological parameters that have been monitored and the period of record for each station are listed in Table 2-1.

2.2.3 Major Tasks and Activities

The complete record from 2004, 2005, 2006, 2007, and 2008 of meteorological monitoring parameters for all stations is shown in Table 2-1. A summary of the tasks completed in 2004, 2005, 2006, 2007, and 2008 is provided in Table 2-2. The chronology of installation of each of the meteorological stations is listed in Table 2-3.

2.2.3.1 Tasks and Activities for 2004

The main activity for 2004 was to install two meteorological monitoring stations (3-meter towers, meteorological instrumentation, communication equipment, instrument shelters, and electrical power supplies) at the Pebble Deposit. The use of two stations was desired to provide information regarding variations within the watershed at the Pebble Deposit, which is important for conducting water balance studies. Both stations were also installed to obtain data for characterizing baseline meteorological conditions.

One station (Met Station 1, renamed Pebble 1, as shown on Figure 2-1) was located in the general vicinity of the Pebble Deposit. A second station (Met Station No. 2, renamed Pebble 2, as shown on Figure 2-1) was located farther to the south downstream of Frying Pan Lake.

After the installation, the following additional tasks and activities were conducted in 2004:

- Conducted an initial performance audit after completion of each installation to ensure the sensors were operating within EPA and ADEC guidelines. During installation, a local field operator was trained to conduct a review of the site in accordance with EPA and ADEC guidelines as described in the standard operating procedures in the approved monitoring plan.
- Operated the Pebble 1 and Pebble 2 meteorological stations and collected data.
- Remotely accessed the collected meteorological data daily via modem and performed a review of the data to detect problems. The local field operator conducted routine inspections of the stations' equipment to verify proper operation of the equipment and security of the site. During these inspections, the operator performed maintenance on the power supply, verified proper operation of the instruments, performed routine quality control checks, and observed general conditions of the site. Troubleshooting and additional technical support were provided as needed to achieve maximum data recovery and to compile a quality data set.

Because both stations are in start-up mode, the data collected in 2004 were not validated and therefore are not being used for the meteorological baseline study.

2.2.3.2 Tasks and Activities for 2005

Both stations installed in 2004 began collecting validated data in January 2005. Both stations were designed and operated consistent with PSD guidelines, except that the wind and temperature instrumentation were located at the 3-meter level (PSD guidelines required this instrumentation at the

10-meter level). Because PSD-quality data may at some time be required for modeling purposes and to support air quality permit applications, the Pebble Partnership consulted with EPA, ADEC, and National Park Service representatives regarding the configuration and the location of the monitoring stations.

Based on those discussions, the Pebble Partnership elected to upgrade Pebble 1 to a PSD-quality station (to include 10-meter level wind instrumentation, 10-meter temperature instrumentation, the temperature difference between 2 and 10 meters, and solar radiation).

It was further decided to locate a new monitoring station near Iliamna and Iniskin bays (identified as Port Site 1 on Figure 2-1). This station was installed in July 2005 and was equipped with PSD-quality monitoring instrumentation (i.e., 10-meter tower, meteorological instrumentation, communications equipment, instrument shelters, and electrical power supplies).

Also in October 2005, the equipment at Pebble 2 was dismantled and moved to a new site located 0.6 mile north of its original location (identified as Pebble 3 on Figure 2-1). Pebble 3 began operating in November 2005 as a non-PSD station.

The following other tasks and activities were conducted in 2005:

- Continued operating the Pebble 1 at its original location
- Conducted an initial performance audit after completing the installation of the new Port Site 1 and the relocated station at Pebble 3 to ensure the sensors and systems were operating within EPA and ADEC guidelines. During installation, a local field operator was trained to inspect and maintain the sites in accordance with EPA and ADEC guidelines as described in the standard operating procedures in the approved monitoring plan.
- Remotely accessed the meteorological data from all stations daily and reviewed the data to detect any problems. The local field operator conducted routine inspections of the stations' equipment to verify proper operation of the equipment and security of the sites. During these inspections, maintenance was performed on the power supply, proper operation of the instruments was verified, routine quality control checks were performed, and general conditions of the sites were observed. Troubleshooting and additional technical support were provided as needed to achieve maximum data recovery and to compile a quality data set.
- Processed and validated data on a weekly basis. Weekly processing ensured problems associated with data collection were addressed in a timely manner. Data processing, validation, and screening were performed in accordance with the EPA and ADEC guidance documents and as described for QA in the QAPP.
- Summarized the data in quarterly data reports that included documentation of the QA activities performed during the reporting period. QA activities included calibrations, audits, and data completeness checks.
- For each station, a minimum of three audits were conducted over the course of the 12-month monitoring period in accordance with EPA criteria (EPA, 1994; 2000). EPA guidance suggests conducting audits within 30 days of station start-up, every 6 months during operation, after major downtime or repairs, if the station is relocated, and within 30 days before station shutdown.

2.2.3.3 Tasks and Activities for 2006

The main task for the 2006 study plan was to install, in May 2006, a PSD-quality meteorological monitoring station, designated Pebble 4 (see Figure 2-1), at the same location as the discontinued Pebble 2 station.

With this addition, meteorological data were being collected at four locations during 2006. PSD-quality meteorological data were being collected at the Pebble 1, Pebble 4 (starting in June 2006), and Port Site 1 meteorological stations. Non-PSD-quality data were being collected at Pebble 3.

In addition to this installation, the QAPPs for the Pebble 1, Pebble 4 and Port Site 1 monitoring stations were submitted to ADEC for review and approval. Other tasks and activities conducted in 2006 were consistent with those completed in 2005.

2.2.3.4 Tasks and Activities for 2007

Meteorological data were collected at nine locations during 2007 (Figure 2-1). The collection of PSD-quality meteorological data continued at the existing Pebble 1, Pebble 4, and Port Site 1 meteorological stations. Four new PSD-quality meteorological stations were installed in June and July 2007: one each in the North Fork Koktuli basin (Pebble 5), in the Upper Talarik Creek basin (Pebble 6), at Williamsport (Williamsport), and on Iliamna Bay (North Head). It was proposed to begin collecting "official" data in September and October 2007 at those new stations, although actual data collection began before that date. The collection of non-PSD-quality data continued at Pebble 3, and a new non-PSD station was located in the North Fork Koktuli basin (Pebble 5A on Figure 2-1). Data collection at Pebble 5A began in September 2007.

2.2.3.5 Tasks and Activities for 2008

Meteorological data were collected at 10 locations during 2008 (Figure 2-1). The collection of PSD-quality meteorological data continued at the existing Pebble 1, Pebble 4, North Fork Koktuli Basin (Pebble 5), Talarik Creek Basin (Pebble 6), Williamsport, North Head, and Port Site 1 meteorological stations (Figure 2-1). The collection of non-PSD-quality data continued at Pebble 3 and North Fork Koktuli Basin (Pebble 5A). Additional precipitation data were collected at six additional locations to support the small pools study.

In addition to the meteorological monitoring stations, particulate matter (PM) monitoring for PM-10 and PM-2.5 was conducted at one site in the village of Iliamna.

2.3 References

Environmental Protection Agency (EPA). 1994. Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV, Meteorological Methods (with revisions to March 2008). EPA/600/R-94/038d. Office of Air Quality Planning and Standards, North Carolina.

———.. 2000. Meteorological Monitoring Guidance for Regulatory Modeling Applications. EPA-454/R-99-005. Office of Air Quality Planning and Standards, North Carolina.

TABLES

Table 2-1a
Pebble Project Meteorological Monitoring Stations - Mine Study Area
Period-of-Record Index

| Parameter | Year | Period-of-Record By Monitoring Station | | |

Table 2-1b
Pebble Project Meteorological Monitoring Stations - Transportation Corridor Study Area
Period-of-Record Index

| Parameter | Year | Period-of-Record By Monitoring Station | | |

Table 2-2
Pebble Project Environmental Baseline Studies
Meteorological Study Summary, 2004-2008
Consultant: Hoefler Consulting Group

2004 Data Collected or Tasks Completed	2005 Data Collected or Tasks Completed	2006 Data Collected or Tasks Completed	2007 Data Collected or Tasks Completed	2008 Data Collected or Tasks Completed
Mine Study Area				
Information Gathering	Information Gathering	Information Gathering	Information Gathering	Information Gathering
Scope, Schedule, Field Monitoring Plan	Scope, Schedule, Field Monitoring Plan	Scope, Schedule, Field Monitoring Plan	Scope, Schedule, Field Monitoring Plan	Scope, Schedule, Field Monitoring Plan
	Prepared Meteorology Chapter of 2005 Study Plan	Prepared 2006 Study Plan Summary	Prepare 2007 Study Plan Summary	
	Site Visit with ADEC and EPA to Finalize PSD-Quality Meteorological Monitoring Station Locations	Continue Monitoring at Pebble 1 and Pebble 3	Continue Monitoring at Pebble 1, Pebble 3, and Pebble 4	Continue Monitoring at Pebble 1, Pebble 3, Pebble 4, Pebble 5 and 5A, and Pebble 6
Install Meteorological Monitoring Stations at the Pebble Deposit (Pebble 1) and at Pebble 2.	Upgraded Pebble 1 to PSD-Quality. Moved the Equipment at Pebble 2 to a New, Nearby Location (Renamed Pebble 3)	Installed Webcam at Pebble 1. Installed Pebble 4, a New PSD-Quality Meteorological Monitoring Station at the Pebble 2 Site. Enabled real-time data availability at Pebble 1 and Pebble 4.	Install Pebble 5 and Pebble 6, New PSD-Quality Meteorological Monitoring Stations in the North Fork Koktuli and Upper Talarik Basins, Respectively	Install Particulate Matter (PM-10 and MP-2.5) Monitoring Station in Iliamna
		Submitted First Annual Data Report for Pebble 1 to ADEC for Review and Approval	Submit Second Annual Data Report for Pebble 1 and First Annual Data Report for Pebble 4 to ADEC for Review and Approval	Submit the Calendar Year 2007 Annual Data Reports for Pebble 1 and Pebble 4 to ADEC for Review and Approval
		Drafted Chapter 2, Climate and Meteorology, of Environmental Baseline Document	Update Chapter 2, Climate and Meteorology, of Environmental Baseline Document to Include One Additional Year of Data	Draft Chapter 2, Climate and Meteorology, of the Supplemental Environmental Baseline Document to Include 2007 Data
		Submitted Quality Assurance Project Plan (QAPP) to ADEC for Review and Approval	Update QAPP to Include Pebble 5 and Pebble 6	Update QAPP to Include Particulate Matter (PM-10 and MP 2.5) Monitoring Station in Iliamna
Communication and Data Management	Communication and Data Management	Communication and Data Management	Communication and Data Management	Communication and Data Management
Coordination with NDM and Agencies	Coordination with NDM and Agencies	Coordination with NDM and Agencies	Coordination with NDM and Agencies	Coordination with PP and Agencies
Transportation Corridor/Cook Inlet Study Areas				
Information Gathering	Information Gathering	Information Gathering	Information Gathering	Information Gathering
Scope, Schedule, Field Monitoring Plan	Scope, Schedule, Field Monitoring Plan	Scope, Schedule, Field Monitoring Plan	Scope, Schedule, Field Monitoring Plan	Scope, Schedule, Field Monitoring Plan
	Prepared Meteorology Chapter of 2005 Study Plan	Prepared 2006 Study Plan Summary	Prepare 2007 Study Plan Summary	
	Site Visit with ADEC and EPA to Finalize PSD-Quality Meteorological Monitoring Stations Locations	Continued Monitoring at Port Site 1	Continue Monitoring at Port Site 1	Continue Monitoring at Williamsport, North Head and Port Site 1
	Installed a PSD-Quality Meteorological Monitoring Station at the Port Site (Port Site 1)		Install New PSD-Quality Meteorological Monitoring Stations at Williamsport and East Side of Iliamna Bay (AC Point) (site changed to Knoll Head at installation)	Install precipitation and evaporation monitoring equipment at Port Site 1.
		Submitted First Annual Data Report for Port Site 1 to ADEC for Review and Approval	Submit Second Annual Data Report for Port Site 1 to ADEC for Review and Approval	Submit the Calendar Year 2007 Annual Data Report for Port Site 1 to ADEC for Review and Approval
		Drafted Chapter 26, Climate and Meteorology, of Environmental Baseline Document	Update Chapter 26, Climate and Meteorology, of Environmental Baseline Document to Include One Additional Year of Data	Draft Chapter 26, Climate and Meteorology, of Supplemental Environmental Baseline Document to Include 2007 Data
		Submitted QAPP to ADEC for review and approval	Update QAPP to Include Williamsport and AC Point.	
Communication and Data Management	Communication and Data Management	Communication and Data Management	Communication and Data Management	Communication and Data Management
Coordination with NDM and Agencies	Coordination with NDM and Agencies	Coordination with NDM and Agencies	Coordination with NDM and Agencies	Coordination with PP and Agencies

ADEC = Alaska Department of Environmental Conservation
EPA = U.S. Environmental Protection Agency

TABLE 2-3
Chronology of Installation and Type of Meteorology Monitoring Stations, 2004-2008

Location ID	Installation Year Station Type					Comments
	2004	2005	2006	2007	2008	
Pebble 1	non-PSD	non-PSD/PSD	PSD	PSD	PSD	Identified as Met Station 1; data collected in 2004 but not validated. Validated non-PSD quality data collected in 2005 until upgraded with 10-meter tower and related instrumentation in June 2005. PSD-quality data collected beginning July 2005
Pebble 2	non-PSD	-	-	-	-	Identified as Met Station 2; data collected in 2004 but not validated. Validated non-PSD quality data collected in 2005, until station shut down in October 2005 to move instrumentation to Pebble 3
Pebble 3	-	non-PSD	non-PSD	non-PSD	non-PSD	Instrumentation from Pebble 2 installed and operations begun in November 2005 as non-PSD quality station to support engineering design
Pebble 4	-	-	PSD	PSD	PSD	Installed May 2006 at same location as Pebble 2
Pebble 5	-	-	-	PSD	PSD	Installed June/July 2007
Pebble 5A	-	-	-	non-PSD	non-PSD	Installed June/July 2007 to support engineering design
Pebble 6	-	-	-	PSD	PSD	Installed June/July 2007
Port Site 1	-	PSD	PSD	PSD	PSD	Installed July 2005
Williamsport	-	-	-	PSD	PSD	Installed June/July 2007
North Head	-	-	-	PSD	PSD	Installed June/July 2007
Iliamna	-	-	-	-	PM	Installed August 2008

- = Station not installed or discontinued.

non-PSD = Station configuration not compliant with prevention of significant deterioration standards.

PM = Particulate matter monitoring station.

PSD = Station configuration complies with prevention of significant deterioration standards.

FIGURE

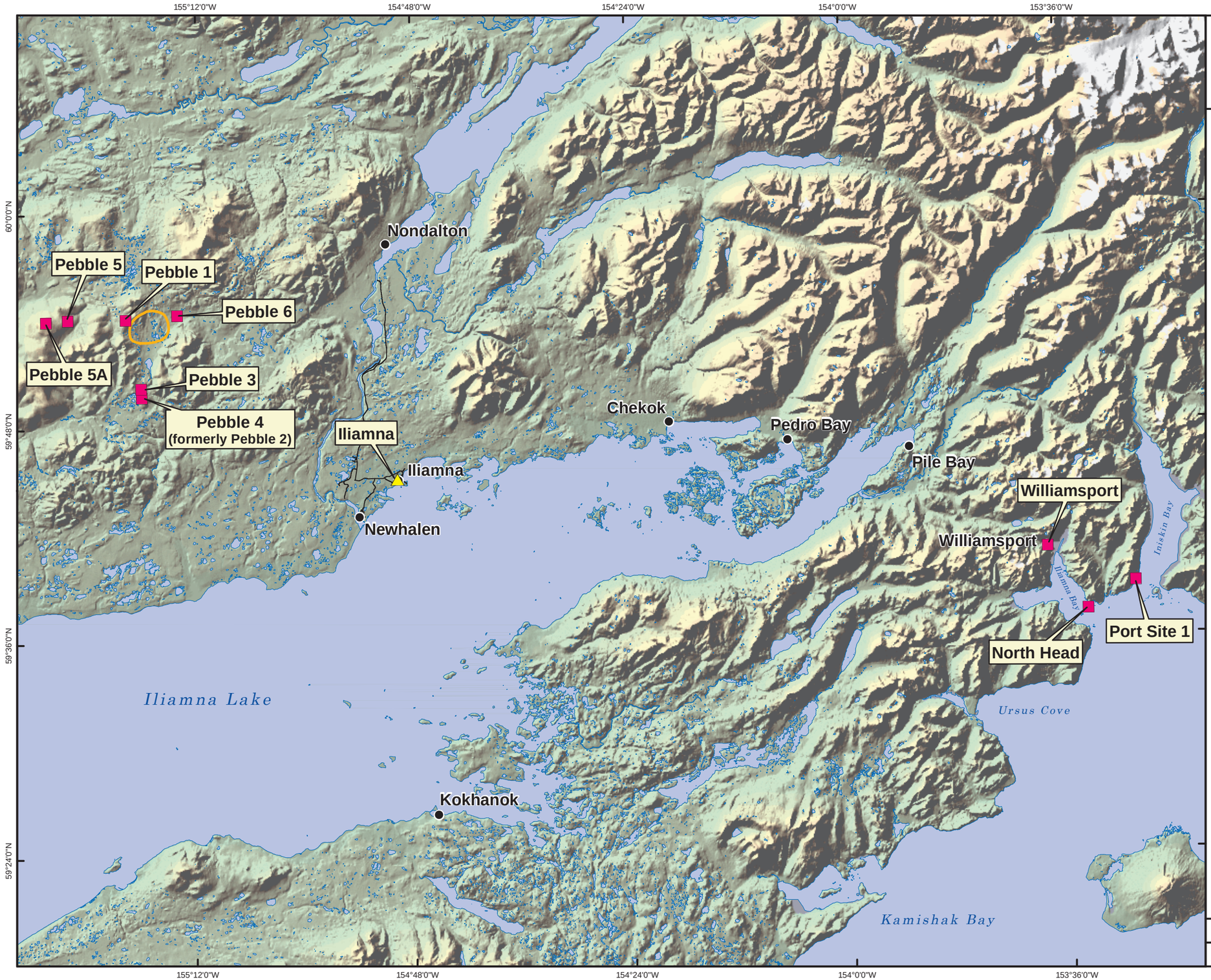

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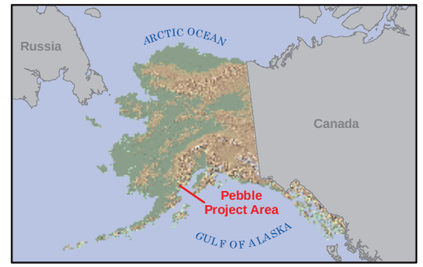
Figure 2-1
Consolidated Study Program, 2004-2008
Location of Pebble Deposit and Transportation Corridor/Port Site Meteorological Stations and Particulate Matter Monitoring Station

Legend

- Meteorological Stations
- PM Station
- General Deposit Location
- Communities



0 5 10 15 Miles

0 5 10 15 20 Kilometers

Scale 1:400,000

N

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: RDI_Hoefler_MET_11X17_1of1_D12.mxd	Date: May 5, 2008
Version: 12	Author: RDI-MRA, LS

Pebble Project
Environmental Baseline Studies
2004 through 2008

CONSOLIDATED STUDY PROGRAM

3. NOISE

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Table 3-1, Pebble Project Environmental Baseline Studies, Study Summary for Noise, 2004-2008

LIST OF FIGURES (following table)

Figure 3-1, Consolidated Study Programs, 2004-2008, General Study Area for Noise

ACRONYMS

ANSI	American National Standards Institute
ADOT&PF	Alaska Department of Transportation & Public Facilities
L_{eq}	equivalent continuous sound level measured during the measurement period
L_{01}	sound level is exceeded 1% of the time during the measurement period (i.e., a measure of the loudest sound level measured during the measurement period)
L_{05}	sound level is exceeded 5% of the time
L_{10}	sound level is exceeded 10% of the time
L_{50}	sound level is exceeded 50% of the time (i.e., a measure of the median sound level during the measurement period)
L_{9}	sound level is exceeded 90% of the time (i.e., a measure of the nominal background sound level during the measurement period)
L_{max}	maximum RMS (root-mean-square) sound level during the measurement period
L_{min}	minimum root-mean-square sound level

3. NOISE

Michael Minor and Associates is the lead consultant for the noise component of the environmental baseline study. This chapter outlines the objectives, area, scope, and methodology for collecting existing noise data in and around the communities near the Pebble Deposit.

3.1 Objectives of Study

The objective of the baseline noise study is to quantify the existing noise levels and sources in and around the communities near the Pebble Deposit.

3.2 Proposed Study Plan

3.2.1 Study Scope/Area

The scope of the baseline noise study primarily involves collecting ambient noise levels at several locations in populated areas near the Pebble Deposit. Preliminary noise monitoring sites were selected during initial scoping with the Pebble Partnership project staff.

Ambient noise levels can vary greatly depending on the time of day and time of year the measurements are taken. Noise monitoring was therefore divided into two sessions, one during winter months and one during summer months. This method was selected to capture noise-producing activities in the winter (such as snow machines) as well as in the summer (such as motorboats and vehicles). Noise monitoring also included a variety of data sampling, including short-term monitoring during several different times throughout the day (including noise source identification) and unattended long-term noise monitoring, which provides a snapshot of 24-hours (or more) of continuous noise level data.

There are no noise-sensitive human receivers near the Pebble Deposit; therefore, noise monitoring was primarily performed in populated areas near the deposit and in communities along the shore of Iliamna Lake. As many as 14 sites in three communities were selected initially: several sites located in or near the community of Iliamna, two sites located on the road between Iliamna and Nondalton, and an additional three sites located in Pedro Bay. Noise monitoring sites at these communities are described below:

3.2.1.1 Iliamna

- On the existing road between Iliamna and Nondalton at the south end of Sixmile Lake:
  - At the Newhalen River crossing, as proposed by the Alaska Department of Transportation and Public Facilities (ADOT&PF).
  - Residences closest to this proposed river crossing.
- Iliamna Airport.
- Iliamna—Newhalen Post Office.

- Iliamna Community.
  - Roadhouse Inn residence.
  - Waterfront near rental units used for summer fishing.
  - Iliamna Trading Company Store.

3.2.1.2 Newhalen

- Newhalen Public School, near the Tribal Headquarters.
- Newhalen residences on the north edge of town.

3.2.1.3 Pedro Bay

- Tribal Center.
- The closest residences to the transportation corridor route proposed by ADOT&PF.
- Pedro Bay School.
- Southern end of Pedro Bay.

In 2007, additional sites were identified for sampling in and near the community of Nondalton.

3.2.2 Methods/Approach

All noise measurements are taken in accordance with the American National Standards Institute (ANSI) procedures for community noise measurements.

The measurement locations are at least 5 feet from any solid structure to prevent acoustical reflections and at a height of 5 feet above the ground as required by ANSI Standards.

The equipment used is Bruel & Kjaer Type 2231 Sound Level Meter(s) equipped with a Bruel & Kjaer BZ-7101 Statistical Analysis Module or Bruel & Kjaer Type 2238 Sound Level Meter(s). The meter(s) are calibrated prior to and after the measurement period using a Bruel & Kjaer Type 4231 Sound Level Calibrator. Complete system calibration is performed by Bruel & Kjaer Instruments. System calibration is traceable to the National Institute of Standards and Testing. All noise monitoring systems meet or exceed ANSI Type 1 noise measurement system requirements.

Noise is monitored according to two methods:

- 24-hour Noise Monitoring Methodology – Unattended noise-monitoring systems are used to record hourly data for 24 hours (or more) at several of the monitoring sites. Data recorded includes the following hourly noise level information: $L_{eq,}$ L_{01}, L_{05}, L_{10}, L_{50}, L_{90}, L_{max}, and L_{min}. This range of data provides a complete view of the noise environment over the 24-hour measurement period.
- Short-term Noise Monitoring Methodology – Noise level measurements are taken with hand-held instruments at sites not used for long-term noise monitoring. The monitoring is performed at each site during four different times: Morning (7:00 a.m. to 10:00 a.m.), Daytime (2:00 p.m. to 5:00

p.m.), Evening (8:00 p.m. to 11:00 p.m.), and Nighttime (1:00 a.m. to 4:00 a.m). During the short-term measurement sessions, noise sources are identified and traffic counts were taken, when appropriate.

The 24-hour and short-term data are downloaded into Excel spreadsheets for final analysis. Graphs and tables are prepared to aid understanding of the measured noise levels. Data are compared to noise levels measured in other similar communities and to typical noise levels published in *Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety* (EPA, 1974).

3.2.3 Major Tasks/Activities

3.2.3.1 Tasks and Activities for 2004

A specific study plan for noise was not developed in 2004. The discipline was less dependent on the 2004 summer season field work than other disciplines (e.g., hydrology, socioeconomics, etc.), which were the focus of the Pebble Partnership's efforts at that time.

In the fall of 2004, the Pebble Partnership worked on identifying experienced contractors to conduct a noise study, and providing them with an introduction to the Pebble Project, the noise study objectives, and a conceptual plan for the noise study.

3.2.3.2 Tasks and Activities for 2005

The following tasks and activities were conducted in 2005:

- Performed winter baseline noise-level measurements at the above-identified locations at Iliamna, Newhalen and Pedro Bay.
- Reduced the winter 24-hour and short-term data, to include:
  - Exported data into Excel spreadsheets for final analysis.
  - Developed graphs and tables of the data to be used for analysis.
  - Compared measured noise levels with the U.S. Environmental Protection Agency guidelines, noise levels measured in similar communities, and data from other mining projects in Alaska.
- Performed summer baseline noise-level measurements at the same locations as used for the winter noise level measurements.
- Reduced the summer 24-hour and short-term data, as described above.
- Developed plots of data to provide an easy comparison between summer and winter noise levels.
- Identified the major differences in area noise levels and sources during winter and summer months.

3.2.3.3 Tasks and Activities for 2006

No additional noise data were collected in 2006.

Data collected in 2005 were analyzed and summarized in an Initial Environmental Evaluation Report. In addition, a draft Detailed Baseline Noise Report was prepared, which included:

- Summaries of existing noise conditions and noise levels.
- Maps of the existing land use, noise monitoring locations, and sensitive noise receiver locations.
- Comparative tables to aid in the understanding of area noise levels.

3.2.3.4 Tasks and Activities for 2007

Noise data were collected in Nondalton in 2007 using the same methodology as used in 2005.

3.2.3.5 Tasks and Activities for 2008

No additional noise data were collected in 2008.

3.3 References

Environmental Protection Agency (EPA). 1974. Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety. 550/97-74-004. Office of Noise Abatement and Control, Washington, D.C.

TABLE

Table 3-1
Pebble Project Environmental Baseline Studies
Study Summary for Noise, 2004 - 2008
Consultant: Michael Minor & Associates

2004 Data Collected or Tasks Completed	2005 Data Collected or Tasks Completed	2006 Data Collected or Tasks Completed	2007 Data Collected or Tasks Completed	2008 Data Collected or Tasks Completed
No noise study work	Noise study field work in Iliamna, Newhalen, and Pedro Bay	No noise study field work	Noise study field work in Nondalton	No noise study field work
		Data Analysis	Data Analysis	Data Analysis
		Draft Chapter 3, Noise, of Environmental Baseline Document	Update of Draft Chapter 3, Noise, of Environmental Baseline Document	Update of Draft Chapter 3, Noise, of Environmental Baseline Document

FIGURE

156°0'0"W
155°0'0"W
154°0'0"W
153°0'0"W
60°0'0"N
59°30'0"N
59°0'0"N

Port Alsworth
Lake Clark National Park
Lake Clark National Preserve
Lake Clark
Mt. Iliamna
Chulitna R.
Kokhuli River
Nondalton
Six Mile Lake
N. Fork Kokhuli R.
S. Fork Kokhuli R.
Upper Talarik Cr.
Lower Talarik Cr.
Newhalen River
Iliamna
Newhalen
Pedro Bay
Pile Bay
Williamsport
Iliamna Lake
Kokhanok
Cook Inlet
Augustine Island
Igiugig
Kvichak River
Kukaklek Lake
Kamishak Bay
Katmai National Preserve
Katmai National Park
Katmai National Park

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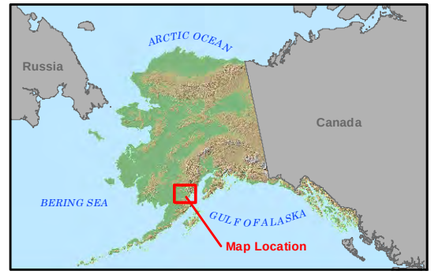
Figure 3-1
Consolidated Study Programs, 2004-2008
General Study Area for Noise

Legend

- General Deposit Location
- Study Area
- National Park and Preserve
- Borough Boundary
- Existing Roads



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0 5 10 15 20 25 Kilometers

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1983 North American Datum

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Version: 10a	Author: RDI-LS/MRA

Pebble Project
Environmental Baseline Studies
2004 through 2008

CONSOLIDATED STUDY PROGRAM

4. SURFACE WATER HYDROLOGY

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ACRONYMS

ABR	ABR, Inc.
ADOT&PF	Alaska Department of Transportation & Public Facilities
APCS	Alaska Peninsula Corporation Services
BEESC	Bristol Environmental & Engineering Services Corporation
CQ	continuous discharge
CSP	consolidated study program
DEM	digital elevation model
FHWA	Federal Highway Administration
GIS	geographic information system
GPS	global positioning system
HDR	HDR Alaska, Inc.
Inter-Fluve	Inter-Fluve, Inc.
IQ	instantaneous discharge
KC	Kaskanak Creek
KP	Knight Piésold Consulting Ltd.
KR	Koktuli River, main stem
MODIS	moderate-resolution-imaging spectroradiometer
NK	North Fork Koktuli River
NRCS	Natural Resources Conservation Service
PVC	polyvinyl chloride
SK	South Fork Koktuli River
SWE	snow/water equivalent
TBM	temporary benchmark
USGS	United States Geological Survey
UT	Upper Talarik Creek
WMC	Water Management Consultants

4. SURFACE WATER HYDROLOGY

The surface water hydrology component of the environmental baseline description for the Pebble Project includes surface hydrology measurements, fluvial geomorphology studies, and snow-course surveys. The work is being carried out as two separate programs: one conducted in the mine study area and another conducted along the transportation corridor/Cook Inlet study areas. The two programs are discussed separately.

There are five consultants for the surface hydrology study. HDR Alaska, Inc. (HDR) led the surface hydrology and fluvial geomorphology studies in the mine study area from 2004 to 2008 and is responsible for most of the field work. (CH2M Hill led the surface hydrology studies in the mine study area in early 2004; in late 2004, HDR Alaska, Inc. replaced CH2M Hill as the lead consultant.) Knight Piésold (KP) has been providing senior overview to the study, and since 2006 has been responsible for data processing and analysis. Bristol Environmental & Engineering Services Corporation (BEESC) is the lead consultant for surface hydrology on the transportation corridor/Cook Inlet study areas. ABR, Inc. (ABR) is the lead consultant for conducting snow-course surveys and modeling snow distribution and ablation for the mine study area. In 2007 Alaska Peninsula Corporation Services (APCS), together with the Pebble Partnership, began surface hydrology baseline studies conducted in the lower reaches of Upper Talarik Creek. The intent of the APCS studies is to provide an additional database of baseline hydrologic conditions hydraulically down-gradient of the current mine study area.

4.1 Mine Study Area Studies

The characterization of baseline surface water hydrology for the mine study area includes both the surface hydrology measurement and snow-course survey programs.

4.1.1 Objectives of Study

The following are objectives of the baseline study for surface hydrology in the mine study area:

- Document baseline hydrologic conditions.
- Collect data for use in studies by other disciplines.

4.1.2 Study Area/Scope

The mine study area is located in southwest Alaska, about 18 miles northwest of the town of Iliamna. The location straddles parts of the Nushagak and Kvichak river regional drainages. These drainages encompass 965 square miles, including the Pebble Deposit, as shown on Figure 4.1-1.

The size of the mine study area is approximately 360 square miles within these two watersheds. It includes the currently known Pebble Deposit and the surrounding area.

The area is drained by the North Fork Koktuli River South Fork Koktuli River, and Upper Talarik Creek, and tributaries of these waterbodies (Figure 4.1-2). They are the main drainages monitored as part of the surface hydrology baseline study. The Kaskanak Creek drainage and its tributaries, southwest of the Pebble Deposit, are also monitored, but primarily to identify potential interbasin transfer from the South Fork of the Koktuli River. Lower Talarik Creek is also shown in Figure 4-1.2, but it is a separate drainage that is not hydrologically connected to Upper Talarik Creek. It is not included in the surface hydrology baseline study.

All surface waters from these drainages flow toward Bristol Bay. The Koktuli River drains to Bristol Bay via the Mulchatna and Nushagak rivers. Upper Talarik Creek drains to Iliamna Lake before reaching Bristol Bay through the Kvichak River. Kaskanak Creek drains directly into the Kvichak River below Iliamna Lake and eventually to Bristol Bay.

The scope of the baseline surface water hydrology study is broad. It includes general studies on water flow characteristics throughout the study area, as well as more detailed studies in specific locations on base flow stream profiles, groundwater/surface water exchange, fluvial geomorphology, and snow distribution mapping. In addition, the study provides critical data in support of other project disciplines. For example, hydrologic data are necessary for calculating site water balances. Hydrologic data also are used to support ongoing groundwater studies (consolidated study program [CSP] 5). Surface hydrology discharge data are used by the surface water quality program (CSP 6) to model water quality conditions in surface water systems. The fluvial geomorphology study characterizes baseline conditions relative to stream channel form, maintenance, and stability. The fish study team uses these data to characterize streambed structure, substrate (i.e., sediment), and habitat.

4.1.3 Methods/Approach

The surface water hydrology studies in the mine study area includes three components: surface water hydrology data collection, fluvial geomorphology studies, and snow-course surveys. The main methods and approaches for each component are discussed separately below. Variations of these methods and approaches, including changes, deletions, and additions, are discussed separately according to the year in which they were implemented, under the major tasks and activities described in Section 4.2.3 of this chapter.

4.1.3.1 Surface Water Hydrology Data Collection

Data for surface hydrology are collected in the field according to standard methods. The detailed methodology is described in the field sampling plan (see Appendix F of the *Pebble Project Environmental Baseline Document, 2004 through 2008)*. An overview of the methodology is provided below.

Site Selection and Nomenclature

Monitoring station sites for measuring surface hydrology were selected based on a number of hydrologic criteria, including the following:

- Locations that coincide with historical (Cominco) monitoring stations.

- Locations upstream, downstream, and in the general vicinity of the Pebble Deposit.
- Major watercourses that may be crossed with streams of hydrologic importance (stations to provide data on groundwater and surface-water interactions).

Additionally, monitoring station sites were selected as part of a coordinated effort involving other baseline study teams, including those studying hydrogeology, water quality, fisheries and aquatic resources, wetlands, and sediment and trace metals.

Each surface hydrology monitoring station has been assigned a unique alphanumeric identifier. The nomenclature for station identifiers is based on drainage, tributary stream within drainage, and sample site within stream, determined as follows:

- Main drainages are identified by a two-character text string:
  - KC = Kaskanak Creek.
  - KR = Koktuli River Main Stem.
  - NK = North Fork Koktuli River.
  - SK = South Fork Koktuli River.
  - UT = Upper Talarik Creek.
- Main stream channels in each drainage are designated as 100, and each tributary to the main stream is numbered sequentially starting at the mouth of the main stream and moving upstream (101, 102 . . . , 135, 136, etc.).
- Monitoring stations within a stream are identified by the original drainage/stream identifier, followed by a sequential (from mouth moving upstream) identifier letter (A, B, C, etc.).

For example, monitoring station "UT119A" refers to the most downstream sample (A) taken from the 19th mapped tributary (119) upstream of the mouth of Upper Talarik Creek (UT). Monitoring station "SK100B" refers to the second-most downstream sample site (B) on the main stem (100) of the South Fork Koktuli Rive (SK).

Table 4.1-2 provides the complete list of stations monitored for the surface water hydrology baseline study, as well as the rationale for selecting each station and a summary of data collected at each station each year. The locations of all stations monitored from 2004 through 2008 are shown on Figure 4.1-2.

Equipment Installation

The hydrologic data-collection equipment installed at each monitoring station depended on whether the station is a continuous-discharge (CQ) or instantaneously measured station. The CQ stations were equipped with continuous-gage instrumentation to continually measure and record stream stage. (“Stage” is the height of a water surface above an established datum plane, a parameter used to establish stream discharge characteristics; also “gage height.”) Instantaneous-discharge (IQ) stations are not continuously equipped, but are monitored periodically using portable field equipment to collect discharge measurements (“discharge”, Q, is defined as the volume flux of water [i.e. the volume of water that passes a given point within a given period of time] in cubic feet per second).

Continuous-discharge stations. CQ monitoring stations have been installed by United States Geological Survey (USGS) and by HDR and APCS field personnel. The USGS personnel installed their standard stream-gaging equipment at three of the CQ monitoring stations. The three sites for the USGS installations were determined during a May 2004 field trip and are identified as SK100B, NK100A, and UT100B on Figure 4.1-2 and in Table 4.1-2. The USGS stations are operated independently by that agency. A discussion of the USGS Station study methods is not provided here; the following discussion pertains only to stations operated by HDR and APCS.

All other CQ stations have been installed and operated by HDR and APCS field personnel. They are installed annually in time to collect CQ data for the spring freshet (usually, April). The equipment remains in place, measuring and recording stage at short intervals until after the October field event, at which time it is removed. CQ records for Alaskan streams are not typically obtained during the winter because stage/discharge relationships are not applicable under ice-affected conditions (Nolan and Jacobson, 2000). Instead, HDR staff estimates winter-discharge hydrographs using IQ measurements in conjunction with meteorological data, winter flow values published by the USGS for Station SK100B, and a general understanding of hydrograph recession patterns elsewhere during winter low-flow conditions.

The equipment used at HDR's CQ stations were MiniTROLL units manufactured by In-Situ, Inc. Each unit consists of a vented 5-pounds-per-square-inch pressure transducer, a temperature sensor, and an integrated electronic datalogger. The pressure transducer in the unit records changes in water surface elevation with an accuracy rating of 0.01 foot. In 2004 and 2005, the units were set to record water surface elevation at 1-minute intervals, for changes in water elevation of 0.01 foot or greater, and/or every 10 minutes, regardless of changes in water elevation. These interval settings, however, generated large, unwieldy volumes of data; therefore, in 2006 the instrumentation was changed to record only every 15 minutes, regardless of water depth. This longer interval reduced the amount of data collected, facilitating the analysis without compromising quality. Temperature is recorded with every depth recording. The manufacturer calibrates each transducer annually.

Prior to field installation, a stilling-well is prefabricated to house each MiniTROLL unit. This work typically consists of drilling holes into a length of polyvinyl chloride (PVC) pipe. The tubular MiniTROLL unit is then placed into the pipe and seated onto a bolt near the bottom. Closed-cell foam pipe insulation serves to tightly secure the unit within the stilling-well. Photo 4.1-1 shows a completed stilling-well setup.

The completed stilling well with its MiniTROLL unit is installed into the stream by securing it to a length of steel angle iron that have been solidly anchored into the streambed. In most cases, the angle iron is driven to a depth of approximately 2 feet below the streambed. Protective conduit is installed above the stilling-well to shield the communications cable and vent tubing. A junction box to protect the cable connection is installed at the top of conduit. The top of the PVC housing remains open, and holes are drilled in the sides of the PVC to allow free water pressure over the sensors. Photo 4.1-2 shows a typical CQ gage stream installation.

A channel cross-section is surveyed at each CQ station. Multiple temporary benchmarks (TBMs) are established at each site. A minimum of one TBM defining the cross-section is established on each bank; sometimes a third TBM is established. Cross-section distances are measured with a survey tape, and a survey level is used for vertical measurements. The elevation of the MiniTROLL datalogger is tied to the

surveyed cross-section by surveying the elevation of the top of the angle iron post and the water surface elevation at the angle iron post. The TBMs at each CQ station provide differential vertical-datum checks to monitor potential movement of the gage equipment at each station. Therefore, CQ-station elevations are assumed local datums and are not interconnected with TBMs at other CQ stations.

Since 2005, staff gages (Photo 4.1-2) also are installed at each CQ station as a quality-assurance measure. Differential (elevation) surveys are performed following installation in the spring and prior to removal in the fall. During monthly field visits, the cross-section at each station is resurveyed and manual readings of the staff gage are recorded and compared with the electronic stage values provided by the MiniTROLL unit. If either of the gages physically moves, the movement will be detected by comparing the two gage readings in the field. If movement was indicated, the gage(s) may be reset with an additional differential survey and a mathematical adjustment is applied to the data.

Instantaneous-discharge stations. Permanent equipment (i.e., dataloggers and sensors) is not installed at the IQ stations. At these stations, field personnel collect only IQ data using portable flow meters. Price AA, Price Pygmy, and Marsh McBirney flow meters are used, depending on stream depths and velocities.

Stage and Discharge Data Collection

USGS field personnel are responsible for downloading the CQ data from the three stations they install and maintain. (HDR personnel measure stage data at these stations.) USGS personnel convert their CQ data into provisional discharge format, and provide it to the Pebble Partnership's surface hydrology study team for subsequent analysis and reporting. The following methods are typically used by HDR field personnel to collect the data from HDR-operated stations.

Continuous-Stage Data. HDR field personnel conduct monthly trips—usually from April to October—to each CQ monitoring station to download raw data for the period since the previous site visit. The values downloaded from each datalogger include date, time, elapsed time (seconds), water temperature (degrees Fahrenheit), and channel pressure (or stage, feet of water) for the period between field visits to the station. The date, time, and channel pressure data for each period of record are copied into a single file for data analysis and adjustment. "Adjusted-stage" data are created by adding the datalogger-depth value recorded at the time of installation to each channel pressure reading. This ensures that all stage readings are positive values.

In 2004, it was noted during the monthly site visits that the MiniTROLL units were experiencing measurement "drift". Drift was identified when it was noticed that the transducer-elevation value recorded during each monthly field visit was different than the value recorded on the installation date. A minor amount of electronic drift is typical for time-series data for pressure transducers. The magnitude of drift—typically less than 0.1 foot—is calculated by comparing the electronic value for the transducer elevation with the values calculated from the differential elevation survey(s). It is corrected mathematically by dividing the total amount of drift (or "shift") by the time elapsed (in days), and an estimated shift in the datalogger for each day is established. The underlying assumption is that drift is steady, rather than irregular, over time. The estimated daily shift is added to each of the adjusted-stage data readings and recorded as shifted-stage values.

Instantaneous Discharge Data. IQ measurements are obtained at every station (including CQ stations) according to field procedures defined by the USGS (Rantz et al., 1982) and the quality assurance project plan (Appendix G of the *Pebble Project Environmental Baseline Document, 2004 through 2008*).

As described above, a choice of three flow meters is used for instantaneous measurements, depending on stream depths and velocities. Measurements are typically taken using top-setting wading rods. If the water is too deep or swift to wade, a boat can be employed to obtain discharge measurements. A sounding weight may also be used with the boat to help stabilize the flow meter. Although less frequently employed, a salt-dilution slug-injection method also can be used at locations that are not amenable to the current-meter method. In a few cases early on in the program, measurements could not be collected because of equipment malfunctions. HDR now keeps backup meters on hand to avoid this issue. At times, dangerous conditions may preclude any measurements.

IQ measurements are collected at all stations, including the CQ stations equipped with continuous monitoring equipment. IQ data are collected at monthly intervals, usually in January and from March through October, of each year. Winter measurements collected in January and March may require measuring IQs through the ice or in ice-free channels. As much as is practical, HDR field personnel attempt to collect these data from all stations. The exact number and locations of the winter measurements are determined in the field according to safety considerations and the effects of icing on channel control. Winter discharge measurements follow the USGS procedures described in *Stream Discharge Measurements Under Ice Cover* (Nolan and Jacobson, 2000).

Water quality samples are collected at all locations at the same time, so that the discharge data can be integrated into water quality interpretations

The IQs collected monthly at all CQ stations are combined with stage data (collected via the installed gaging equipment at those stations) to develop stage/discharge relationships, as described below. IQ data collected at the remaining 13 stations—identified as IQ stations—are provided to the water quality program for flow-integrated water quality analyses.

Stage and Discharge Data Processing

Stage and discharge data must be processed before the annual data can be analyzed. The date and time of the monthly IQ measurement are correlated, within a few minutes, to a pressure transducer reading (i.e., the stage measurement) recorded by the datalogger at the same location. In this way, the actual flow of the stream can be compared to the same point-in-time pressure reading from the datalogger.

In 2004 and 2005, HDR hydrologists used a logarithmic approach for processing the data. In this approach, the paired sets of data for each station are plotted logarithmically: the IQ measurements taken by the field crew on the Y-axis against the corresponding shifted-stage values from the datalogger on the X-axis. In this way, a logarithmic trend line, or "stage-discharge" rating curve, is produced for each station.

The logarithmic trend line describes the relationship between stage and discharge measurements and is used to convert continuous measurements of water depth into a discharge hydrograph for a specific station. An equation is calculated from each station's trend line and is applied to all the continuous

"shifted-stage" values for that station for the monitoring period. This converts the stage data into flow data (or discharge, Q, in cubic feet per second) at every time step.

A rating curve represents the relation between stage (as recorded by the dataloggers) and discharge at a particular location in a stream. A "defining relation" for a curve is typically derived by mathematically fitting a curve to a set of measured concurrent stage and IQ values. Stage/discharge relationships developed for the Pebble Project follows standard methods outlined by Maidment (1993). For example, in a long straight channel where channel friction control dominates, a rating curve has the following form:

$$Q = C(h + a)^n \qquad (1)$$

where: Q = discharge

C and n = constants

h = stage

a = stage at which discharge is zero

Values of n for different cross-section shapes are as follows:

Rectangular: n = 1.67 (assuming width > 20 times depth)

Parabolic: n = 2.17 (assuming width > 20 times depth)

Triangular: n = 2.67

Because natural channels are often approximately parabolic in cross-section, a value of about two for the exponent n is appropriate where there is channel friction control. Where there is a series of natural controls for different ranges of stage, different values of C, a, and n may apply for each range of stage.

When KP hydrologists assumed responsibility for data processing and analysis in 2006, they dropped the mathematical approach described above in favor of a more manual approach. In the manual approach, each set of paired-data points is plotted on a linear graph, and a curve is visually fitted to the points on the graph. Discharge for each stage-reading then is extrapolated directly off the graph.

Once the discharge (Q) for every stage-reading (h) from the datalogger is established, the data are separated into monthly groups. In this format, the daily and monthly means for each continuous-stage monitoring station can be calculated and graphed. This analysis follows the accepted practice of displaying hydrologic data by separating the data into water years. The water year begins on October 1—which usually corresponds to the end of the summer dry period—and ends on September 31 of the following year. To compare flows at different stations or flow regimes between watersheds, the flow data are normalized by dividing by drainage area upstream of the station. Minimum mean daily discharge per unit area is calculated by dividing the lowest mean daily value for a station by its drainage area. A geographic information system (GIS) mapping platform is used to calculate the drainage area based on the length of the stream segment between stations.

4.1.3.2 Baseflow Studies

Baseflow studies were first contemplated in 2005. They consist of a series of IQ measurement along a specified length of a river and its associated tributaries. The measurements are collected during baseflow conditions (i.e., during low streamflow periods) using the same methods described above for the monthly IQ data collection. The resulting discharge profiles are useful in understanding gain and loss for each drainage and the potential for cross-drainage transfer of water. The data may also be used by fish biologists to identify upwelling areas in streams that may coincide with spawning habitat. The locations of the stations chosen for the baseflow study are shown on Figure 4.1-3. Please refer to major tasks and activities for 2005 and subsequent years for more information.

4.1.3.3 Fluvial Geomorphology Studies

Fluvial geomorphology studies were first contemplated in 2007 to characterize baseline hydrologic conditions related to stream-channel form, maintenance, and stability. It was also considered a companion study to and support for an instream-flow study conducted as part of the fish and aquatic invertebrates study (CSP 11). The instream flow study documents fish habitats under current conditions, and the fluvial geomorphology study provides empirical data of baseline geomorphic conditions that are used to develop regime equations to characterize the sensitivity of stream geomorphology to changes in stream hydrology. The instream flow study can then use this information to evaluate existing habitat conditions at measured cross-sections and predict how changes in stage (discharge) affects the hydraulics within the static boundaries of the measured cross-sections. Understanding the degree to which a change in the hydrologic regime would affect channel shape adds a powerful predictive tool to the instream flow study.

The Pebble Project hydrology study team manages this work, which is subcontracted to Inter-Fluve, Inc. (Inter-Fluve). Refer to the major tasks and activities for 2007 for more details on the methods/approach for this study.

4.1.3.4 Snow Surveys and Snow Distribution Mapping

Snow surveys have been performed in the mine study area since 2004. They contribute to concurrent surface hydrology studies by characterizing the distribution, snow/water equivalent (SWE), and ablation rates of late-season (pre-breakup) snow across the landscape in the vicinity of the Pebble Deposit.

The approach to mapping spring snow distribution rely on a combination of detailed field surveys and a terrain model that incorporate the predominant variables (i.e., elevation, aspect, slope, equivalent latitude, shelter, drift, and vegetation canopy) that influence snow accumulation.

Snow-course Surveys

At all snow-course survey plots, snow depth and SWE are measured using standardized snow survey methods and equipment, as described below. To determine the spring snow distribution, snow depths and SWE are measured at stations established along a number of slope/aspect transects (the number of transect locations changes from year to year, depending on the spatial extent of the sampling areas and the target sampling density) and two permanent snow-course survey plots. Sampling along the slope/aspect transects extends from ridge tops to valley bottoms with snow depths and densities measured at 100-foot-elevation intervals. Slope/aspect transects range in length from 0.6 mile to 1.9 miles and encompassed the

predominant elevation spans and aspects present in the major drainage basins in the study area. At each measurement site, SWE data are calculated from up to four measurements of SWE. Percentage of snow cover is visually estimated at each measurement site. Slope and aspect also are determined at each site for use in the snow distribution model. Starting in 2007, supplemental rapid measurements of snow depth (not SWE) were also obtained to better quantify the variation in snow accumulation. Survey-grade global positioning system (GPS) measurements of snowpack elevations also were acquired during field surveys starting in 2007 to characterize the volumes and distribution of snow accumulation zones and to provide precise locations of each sample to support statistical analysis of variability in snow distribution.

Ablation Surveys

Snow ablation rates are measured during late-spring field surveys. Snow-course survey plots are resurveyed biweekly (two to three field visits per season) beginning at the end of April to provide repeated measures of snow during breakup. Digital photographs acquired from helicopters during ablation surveys provides quantitative estimates of snow-covered areas.

Long-term Snow Monitoring

Because snow accumulation has high inter-annual variability, the data from nearby long-term monitoring sites (such as National Resource Conservation Service [NRCS] snow course and snowpack telemetry sites) are often used as proxy data to determine maximum probable spring snow accumulations or to provide more precise inter- and intra-annual evaluations of SWE at the study site of interest. The nearest existing long-term NRCS sites (Figure 4.1-4) were too distant for their records to be used without site-specific verification. Thus, two permanent snow courses were established in the mine study area in 2004. They are subsequently used to generate data for comparison with data from the existing NRCS snow-course sites and as locations within the mine study area distribution survey network. One snow-course survey plot is located at 2,000 feet elevation on a ridge near Groundhog Mountain, and the other at 1,200 feet elevation on a hill in the headwaters of Upper Talarik Creek. Each snow-course survey plot consists of a 1- to 2-mile circuit around a small ridge or knob with 10 to 13 stations located to cover all slope aspects.

Snow Survey Data Analysis

The data collected from the snow surveys, as described above, forms the basis for modeling late-spring snow distribution and ablation rates.

Snow Distribution Modeling. The approach to mapping spring snow distribution combines terrain modeling with detailed field surveys of spring SWE. The terrain model is derived from a detailed digital elevation model (DEM) of the mine study area. The terrain model layers consist of four fixed grids (elevation, slope, aspect, and equivalent latitude) and two sets of direction-dependent grids (shelter and drift). ABR expects to incorporate a layer for vegetation canopy structure when it became available as a product of the wetlands and habitat mapping.

Wind redistribution plays a dominant role in late-season snow distribution; therefore, identifying wind-shelter and drift-formation areas is important to accurately model spring snow distribution (Winstral and Marks, 2002). Two DEM-derived parameters are calculated specifically to address wind redistribution:

- Shelter (Sx) is a continuous parameter that characterizes the exposure of a grid cell to winds from a particular direction.
- Drift (D) is a binary parameter that identifies cells prone to large drift formation using a two-part test: first, an upwind source of snow must exist; second, there must be a flow separation caused by a steep downwind terrain drop-off.

Shelter and drift grids are calculated for the dominant directions of winds capable of transporting snow.

The data analysis includes statistical modeling of snow distribution. Statistics are used for the following:

- Predicting snow distribution under various development scenarios.
- Improving snow-distribution models over the period of baseline data collection.
- Allowing snow-distribution models to be confidently extrapolated to the regional study area.

The modeling work considers ordinary least squares, regression tree, and kriging approaches to snow-distribution modeling.

Ablation Modeling. The ablation model incorporates the snow-course survey data (i.e., the field sample data and the snow-distribution map), satellite-derived snow-covered area maps, local meteorological data, and hydrograph data produced by HDR and KP hydrologists. Ablation-rate maps and ablation curves for monitored basins are then produced.

4.1.4 Major Tasks and Activities

Summaries of tasks and activities for the surface water hydrology and the snow survey programs for 2004 through 2008 are provided below. Table 4.1-1 is a summary of tasks for surface water hydrology from 2004 through 2008, and Table 4.1-2 is an overview of the hydrology sampling locations, the rationale for selecting them, and the sampling conducted throughout the course of the study. Table 4.1-3 is a summary of tasks for the snow surveys, and Table 4.1-4 provides an overview of sampling for the snow surveys at each sampling location from 2004 through 2008.

4.1.4.1 Major Tasks/Activities for 2004

Task 1: Surface Water Field Studies.

Identify Sampling Station Locations. It was understood that the type of station that would be installed where would depend on evolving project needs and on what was learned from the information gathered from the monitoring program. Initially, the locations for comprehensive stations (with or without continuous-stage monitoring) were selected with the intent that they would likely become baseline monitoring stations. The locations for initial monitoring stations were generally selected for specific short-term monitoring purposes (e.g., for establishing a geochemical signature), with the intent that they likely would not be continued as part of the regular monitoring program.

Through this process, the locations of 28 monitoring sites were initially identified, as shown in Table 4.1-2. (The data in Table 4.1-2 indicate that 30 locations were monitored during 2004, but two of the stations are not included in the 2004 total because measurements were made only as part of an initial

data collection effort [i.e., in August, September, and October at NK100B, and in April and May at UT100C].) Of the 28 stations, 14 stations were selected for continuous-stage monitoring. The remaining stations were selected for periodic monitoring for IQ.

Conduct Surface Water Field Studies. The field studies for surface water hydrology focused on characterizing the hydrology of the surface water systems upstream, downstream, and in the general vicinity of the Pebble Deposit. Nine surface water field monitoring events were planned, including breakup (late April), monthly summer monitoring (May through October), and two winter events (January and March of 2005). The work included the following:

- Measuring creek stage and discharge during all monitoring events. Point discharge was measured with a wading rod and current meter, when feasible. At times when high flow precluded wading the creek, flow estimation techniques are used.
- Installing continuous-stage monitoring equipment (i.e., pressure transducer and data logger, as described in Section 4.1.3.1) at designated locations in the major drainages (Upper Talarik Creek, the south and north forks of the Koktuli River, and Kaskanak Creek) to provide site-specific continuous-stage data. These data are used to help characterize baseline flow regimes and develop rainfall/runoff relationships.
- Surface water quality samples were also taken at the same time as surface water hydrology is measured.

Task 2: Snow Surveys

The timing, area, and number of snow surveys has changed from year to year. In 2004, field surveys of snow distribution and snow ablation rates began in mid-April and continued into May, and focused primarily in the immediate vicinity of the Pebble Deposit (Figure 4.1-5).

The major activities of the snow survey are as follows:

- Terrain analysis derived from existing DEM data to identify representative areas of slope, aspect, and elevation in order to develop a balanced field sampling plan.
- Field sampling at 107 stations along 12 slope transects and two snow–course survey plots to directly measure snow depths and SWE shortly before breakup (April 13–18, Figure 4.1-5).
- Repeat visits to stations on the two snow–course survey plots and selected slope transects to directly measure snowpack ablation (May 2–3 and May 15–16).
- Evaluating moderate-resolution-imaging spectroradiometer (MODIS) snow data products to monitor and calculate spring snow ablation rates.
- Comparing ABR's snow-course survey measurements with data from NRCS snow–course survey plots to identify long-term data sets that can be used to estimate the probable range of spring snowpack SWE.

Task 3. Evaluation and Processing of Field Data

The processing of surface hydrology field data, including data collected during snow surveys, included the following:

- Developing stage-discharge relationship for each surface water monitoring station.
- Developing annual hydrographs for each station with continuous monitoring equipment.
- Entering all the snow measurement data collected into an MS Access database suitable for integration into the overall data management system for the mine study area.
- Using field measurements of SWE, terrain model layers, and MODIS-derived snow-covered area for statistical analysis to derive snow distribution and ablation rate maps of the mine study area for 2004.

4.1.4.2 Major Tasks/Activities for 2005

Major tasks and activities for 2005 were planned, in part, to deal with data gaps identified by HDR researchers during their review of the 2004 data. The HDR hydrology team noted both continuous and instantaneous data were lacking for the spring freshet. Likewise, instantaneous data were not collected during the period of relatively high surface water flow events experienced in the fall. These data were not collected in 2004 because streams were too dangerous to wade during high-flow events. Finally, HDR hydrologists noted that continuous-stage monitoring equipment was often installed near the center of the stream during summer months because of baseflow conditions. A similar installation is not practical during spring breakup because floating debris would likely disturb the equipment.

HDR field personnel addressed these issues in 2005. Equipment was set up to capture both spring and fall data. If access was dangerous, discharge data were collected from a boat attached to a line fixed to both shores of the stream. As necessary, the continuous-stage monitoring equipment was set up in more protected locations—nearer the edges of stream channels—to capture data from the spring freshet. The equipment locations were moved (and resurveyed) to a center-stream location once stream flows had adequately receded for summer. In all cases, standard USGS methods as described above were used.

Other planned changes to the program in 2005 included adding one monitoring station to the existing network (Task 1, below), and initiating three studies to assist with characterizing groundwater/surface water exchange: baseflow stream profiling, hyporheic measurements, and groundwater/surface-water exchange measurements. The surface hydrology baseline data collection continued as during 2004.

In 2005, the study area for snow surveys was slightly adjusted in the upper reaches of the North Fork Koktuli River as were some of the specific locations for the surveys (Figure 4.1-5). Two snow-course survey plots were added in 2005 to provide long-term, site-specific data for surface water hydrology studies in the localized area in which they were located. Further details, including the establishment of the permanent snow-course survey plots, are described in Task 5, below.

Task 1: Surface Hydrology Baseline Data Collection

HDR field personnel continued to collect surface hydrology data in the mine study area in 2005. Data were collected during nine field events (January and March through October). One new continuous-stage

monitoring station (designated SK124A) and one new instantaneous-flow station (designated SK100B2) were installed in the South Fork Koktuli River, as shown in Table 4.1-2. (SK100B1 was also installed in the winter of 2005, but is not included here because it generated poor data during the November and December monitoring events. It was re-established in 2006.) These changes brought the number of stations to 31. (This total includes NK100B, which was originally installed in 2004, but only started generating long-term data in 2005; it does not include UT100C, which was also originally installed in 2004 but only intermittently monitored.) Following the additional installations, HDR field personnel were downloading continuous-stage data from dataloggers at 12 stations while USGS personnel continued to download CQ data from their three stations. HDR personnel measured IQ at all stations. The data were collected according to methodology described above.

At the same time, water quality samples were collected at these same stations (Table 4.1-2).

Task 2: Baseflow Stream Profiling

HDR hydrologists completed a series of stream discharge profiles at baseflow conditions during 2005. Like the hyporheic measurements described in Task 3, below, these profiles support the characterization of the hydraulic connections between surface-water and groundwater resources. The profiles consisted of 10 to 15 IQ measurements along the length of the North Fork Koktuli River, South Fork Koktuli River, Upper Talarik Creek, and associated tributaries for up to 45 measurements. The measurements were collected during the low-streamflow (i.e., baseflow) period following spring runoff.

The specific streams to be surveyed during the summer baseflow period were determined based on field observations, experience, and consultation with Water Management Consultants (WMC). For example, reaches of surface water that receive substantial gain from groundwater may be visually indicated in winter months by the presence of open (ice-free) water. Similarly, losing reaches were identified through visual observation during the summer, such as the reach in the South Fork Koktuli River drainage near SK100C (Figure 4.1-3) that went dry in August 2004. Gains or losses can also be estimated from the groundwater data collected by WMC personnel, HDR's surface-water hydrographs, and/or surficial geology information. In preparation for the summer baseflow measurements, these data were reviewed and each stream was traversed by helicopter in January and March to record reaches of open water.

Task 3: Upper Hyporheic Zone Measurements

The upper hyporheic zone (the saturated zone under a river or stream comprising substrate with the interstices filled with water) was monitored to characterize the hydraulic exchange between the underlying groundwater and the in-stream water above. Understanding this relationship is important because temperature and other fluxes within the hyporheic zone are important to the spawning success of salmonids (Rubin, 1995). Comparing the data collected in the hyporheic zone to those for the groundwater below and to the in-stream water column above may contribute to a better understanding of the hydraulic connections between these systems.

HDR hydrologists planned to monitor the hyporheic zone at four locations in the mine study area. Groundwater temperatures would be recorded by continuously logged thermistors located in mini-peizometers, installed to below the groundwater table adjacent to the streams. Groundwater temperature would be recorded at two depths in each piezometer. Water-column temperatures at each location would be recorded as part of the existing surface hydrology baseline data collection. The locations and methods

for installing hyporheic-zone stations and other details for this monitoring program were completed in spring 2005 in consultation with WMC and the Alaska Department of Natural Resources.

The installation of the hyporheic monitoring stations was planned for June 2005. After the stations were installed, HDR field personnel planned to download the thermistor data once per month, according to the same schedule as for other elements of the surface water hydrology study.

Task 4: Groundwater/Surface Water Exchange Measurements

In conjunction with the baseflow stream profiling study described in Task 2, above, it was planned to install mini-piezometers and seepage meters at 12 of the potential 45 stations where HDR field personnel were to measure baseflow. Locations were determined with input from WMC personnel. Field crew installed a pair of mini-piezometers at each station in June 2005. The mini-piezometers were driven into the hyporheic zone (located in-stream) and into the saturated zone (located adjacent to the stream) using a vibrating hammer. They were used to evaluate the direction of groundwater flow (gaining or losing) during baseflow conditions, and were left in place for the duration of this study.

Water levels and water-quality samples were collected from the in-stream column and from each mini-piezometer. The water-quality samples were analyzed for major ions and selected isotopes. The resulting data were provided to WMC hydrogeologists to be used in conjunction with other groundwater and surface-water sample data to interpret groundwater recharge and discharge patterns.

Seepage-meter measurements also were recorded at these stations to document the quantity of groundwater flux into or out of the streambed. Seepage meters were constructed in Anchorage from 55-gallon drums, as described by Lee and Cherry (1978). These meters were sent to the study area for installation.

Task 5: Snow Surveys

Field surveys of snow distribution and snow ablation rates in 2005 began in mid-April and continued into May. More snow tube extensions were used than in 2004, increasing the maximum sampling depth from 90 inches to 150 inches. Seven of the transects surveyed in 2004 were relocated, and a thirteenth transect was added to improve estimates of SWE in low-elevation flats (Figure 4.1-5). The major activities of the snow survey were as follows:

- Field sampling at 128 stations along 13 slope transects and two snow–course survey plots (Figure 4.1-5) to directly measure snow depths and SWE shortly before breakup (April 10–16).
- Repeat visits to stations on the two snow–course survey plots and selected slope transects to directly measure snowpack ablation (April 29–30 and May 13–14).
- Applying MODIS snow data products to monitor and calculate spring snow ablation rates.
- Comparing ABR's snow-course survey measurements with data from NRCS snow–course survey plots to identify long-term data sets that can be used to estimate the probable range of spring snowpack SWE.

Task 6. Evaluation and Processing of Field Data

In 2005, the processing of surface hydrology field data, including those data collected during snow surveys, continued as in 2004.

4.1.4.3 Major Tasks/Activities for 2006

The major tasks and activities for 2006 were the same as for 2005, with the following exceptions: the hyporheic zone and the groundwater/surface water exchange studies were discontinued, because the methodologies were impractical to implement and the data collected were unreliable; HDR field crew also re-established the CQ station, SK100B1(originally installed in 2005), to improve the quality and reliability of data collected from this station, and upgraded NK100B to a continuously gaged station. The number of monitoring stations now numbered 32 (16 continuously gaged and 16 ungaged stations).

Task 1: Surface Hydrology Baseline Data Collection

Baseline data collection for 2006 was primarily designed to increase the period of record and the reliability of the database. Data collection at the 16 continuously gaged stations and 16 ungaged stations continued through 2006 in a manner similar to those in 2004 and 2005.

A proposed change to the methodology for the 2006 surface hydrology study was the addition of a tracer-dilution method to complement the existing method for measuring instantaneous stream discharge (the velocity-area method, using flow meters and stream cross-sections). Although the velocity-area method is often a preferred method of measuring stream discharge, it can be difficult to obtain good velocity readings in small steep streams with turbulent flow. It is also logistically difficult to measure very low flows under ice-covered streams in winter and during bank-full conditions during breakup. Thus, alternative methods such as tracer (i.e., salt) dilution are integrated into a program to improve data reliability.

Tracer dilution is a standard USGS method used to measure instantaneous stream discharge (Capesius et al., 2005). The basic premise is to introduce a known amount of salt at one point in the stream and monitor the concentration wave (measured as electrical conductivity) as it passes a second point downstream where it is assumed the salt is completely mixed in the flow. Streamflow is calculated from the area under the resulting conductivity curve. The salt dilution method uses common table salt (sodium chloride) as the tracer. Salt is preferred as a tracer over other known tracers because it is non-toxic to aquatic organisms at the concentrations and exposure times associated with the measurements. It is also inexpensive, easily obtained, and convenient to work with. Tracer measurements are made with a conductivity meter linked to a datalogger. Detailed salt-dilution methodology was included in the 2006 field sampling plan (Appendix F of the *Pebble Project Environmental Baseline Document, 2004 through 2008)*, which was distributed to field crew at the beginning of the field season.

HDR's field personnel use professional judgment based on site-specific conditions to determine when to apply either the velocity-area or the tracer-dilution method.

Task 2: Baseflow Stream Profiling

The baseflow stream profiling begun in 2005 continued in 2006. To measure baseflow conditions, a series of baseflow stream profiles was completed twice during 2006. These profiles consisted of approximately 10 IQ measurements along each of the North Fork Koktuli River, South Fork Koktuli River, and Upper Talarik Creek for an estimated 30 measurements. The measurements were collected during the post-winter baseflow periods in March or April and following spring runoff in late June or early July.

Measurements were collected according to the same field methods, including the tracer-dilution method, used during the monthly IQ measurements.

Task 3: Snow Surveys

Snow surveys have been performed since 2004 in the mine study area. Field surveys of snow distribution and snow ablation rates in 2006 began in mid-April and continued into May. The location of the snow-course survey plots for the period 2004 through 2006 are illustrated on Figure 4.1-5. In 2006, the transects sampled in 2005 were revisited, and one of the transects sampled in 2004 but dropped in 2005 was also revisited. The major activities of the snow survey were as follows:

- Field sampling at 131 plots along 14 slope transects and two snow courses to directly measure snow depths and SWE shortly before breakup (April 16–23).
- Repeat visits to stations on the two snow–course survey plots and selected slope transects to directly measure snowpack ablation (May 13–14 and May 22–23).
- Applying MODIS snow data products to monitor and calculate spring snow ablation rates.
- Comparing ABR's snow-course survey measurements with data from NRCS snow–course survey plots to identify long-term data sets that can be used to estimate the probable range of spring snowpack SWE.

Task 4. Evaluation and Processing of Field Data

In 2006, KP hydrologists assumed responsibility for the processing and analysis of surface hydrology data, including those data collected during snow surveys. The methodology was similar to that for previous years, except that the surface water hydrographs were generated using the manual approach rather than the mathematical approach used in 2004 and 2005.

4.1.4.4 Major Tasks/Activities for 2007

In 2007, the mine study area expanded because of the Pebble East discovery. As a result, the number of hydrologic monitoring stations increased and there were minor adjustments in the kind of data collected and the monitoring periods. Details are provided in the following task descriptions.

Task 1: Surface Hydrology Baseline Data Collection

Consistent with previous years, the 2007 hydrologic data-collection program consisted of a combination of instantaneously measured and continuously gaged stations.

Because of the Pebble East discovery, the number of hydrology stations in 2007 was increased to 39 from 32 by adding seven new CQ stations (Figure 4.1-2). Four of the new CQ-gaged stations were at locations where measurements either had not been collected before (NK100A1) or where IQ measurements had been collected only intermittently since 2004 (UT100C, UT100C1, and UT100C2). The intermittent IQ measurements at these latter three stations were collected either as part of an initial data-collection effort in 2004 (e.g., April and May 2004 at UT100C) or during the late-winter baseflow period of 2005 and 2006 (e.g., April 2006 at UT100C1 and April 2006 and February 2007 at UT100C2). The remaining three new CQ stations (UT100APC1, UT100APC2, and UT100APC3) were installed on APCS lands and were monitored by APCS field personnel.

In addition, three of the existing IQ stations (NK100B, NK119B, and UT135A) were upgraded to CQ stations. Twenty-six CQ locations were operated in 2007. Three of these continued to be managed by USGS field personnel, 20 by HDR and three by APCS. The remaining 13 stations were monitored for IQ only.

As shown in Table 4.1-2, the frequency of field measurements increased in 2007 to once per month. This change was implemented because it provided additional measurements during the winter months (i.e., ice-covered months, typically January through April and November and December) compared to previous years. This work included IQ measurements through the ice or in open channels. As much as was practical, HDR field personnel attempted to collect these data from all 33 of the Pebble Partnership-gaging stations listed in Table 4.1-2. However, the exact number and locations of the winter measurements were determined in the field according to safety considerations and the effects of icing on channel control. Winter discharge measurements followed the USGS procedures described in *Stream Discharge Measurements Under Ice Cover* (Nolan and Jacobson, 2000).

Task 2: Baseflow Stream Profiling

As in previous years, baseflow was measured in 2007 during low streamflow conditions in late winter, as near to the onset of the spring freshet as practical. Experience from field efforts in 2005 and 2006 indicate that the time period from late March to early April provides high-quality baseflow data. As shown on Figure 4.1-3, IQ measurements of baseflow were planned for 33 locations throughout the north and south forks of the Koktuli River and in Upper Talarik Creek. Many of these locations are consistent with established IQ and CQ monitoring stations, but some locations are specifically for baseflow measurements (e.g., SK100LF10 and NK100LF5).

IQ measurements were collected once during late winter (baseflow conditions). No CQ measurements were collected for this effort.

The preferred conditions preceding baseflow measurements include cold temperatures consistently below freezing to avoid surface runoff from snowmelt entering the stream. In order to avoid changing conditions, the IQ measurements were collected from all stations in each drainage (Figure 4.1-3) within as short a period as possible—typically 1 day per drainage, depending on weather.

Task 3: Fluvial Geomorphology Study

Fluvial geomorphology study was conducted in 2007 in the mine study area to characterize baseline conditions related to stream-channel form, maintenance, and stability. The initial task was to understand existing conditions and how the system's dependent variables change with a change in discharge.

Alluvial streams, such as North Fork Koktuli River, South Fork Koktuli River, and Upper Talarik Creek, adjust their channel width, depth, and slope to accommodate streamflow and sediment load; if either changes, channels respond by modifying their shape and/or slope to move the water and sediment they convey (Leopold and Wolman, 1957). For this study, hydrologic discharge and sediment load are independent variables, and channel width, depth, and slope are dependent variables.

The data collection for the fluvial geomorphology study followed standard methods that described in the literature (e.g., Kondolf and Piegay, 2003; Rosgen, 1996; Sanders, 1998; Wolman, 1954). Specific data-collection efforts in 2007 included cross-sectional and longitudinal surveys, Wolman pebble counts, and upstream, downstream, and cross-sectional photos. Additional methods such as bulk bed-load sampling were also contemplated, depending on the outcome of an evaluation of fluvial geomorphic data collected by Inter-Fluve in 2005.

In that study, Inter-Fluve collected data from 17 stream locations in the study area. These data were analyzed prior to data collection in 2007 to better plan the specifics (e.g., numbers and locations of collection sites) of the 2007 field effort. Specific analyses in the data evaluation included the following:

- Longitudinal reach and valley slope.
- Existing channel patterns.
- Hydraulic and incipient motion.
- Empirical relationships.

Data collection in 2007 was conducted between July and September. Data were collected at stations that best represented geomorphic channel conditions throughout the watershed and between major tributaries. Channel characteristics noted and documented during site visits included vegetation patterns, bank stability, and observed use of fish habitat. Field work consisted of revisiting 2005 study sites, as needed, as well as data collection at new sites.

Site selection and survey. As mentioned above, the number of sites and their locations were determined after an evaluation of the Inter-Fluve 2005 data. Sites were selected that best represented channel geometry and hydraulic conditions and that included geomorphic indicators that identified the channel-forming flow for that reach of river. At each site, three to four representative cross-sections and a longitudinal profile were surveyed and tied to a relative site-elevation datum.

Wolman pebble count. The Wolman pebble count is a sampling of a predetermined number of grains (commonly 100) from the streambed in a random manner in order to characterize the bed grain-size at a given site. At least one Wolman pebble count was made at each site.

Task 4: Snow Surveys

In 2007 the study area for snow surveys was expanded from the area immediately around the Pebble Deposit to the full extent of the North Fork Koktuli River, South Fork Koktuli River, and Upper Talarik Creek basins (Figure 4.1-6). Field surveys of snow distribution and snow ablation rates in 2007 began in mid-March and continued into May. Snow-survey plot locations for 2007 are illustrated on Figure 4.1-6. The major activities of the snow survey were as follows:

- Field sampling at several plots with high snow accumulations in 2004–2006 for reconnaissance and planning purposes (mid-March).
- Field sampling at widely spaced plots in the expanded study area (early April).
- Field sampling along slope transects and two snow–course survey plots to directly measure snow depths and SWE shortly before breakup (mid-April).
- Supplemental field sampling with depth probes and survey-level GPS equipment to better characterize snow drifts and snow distribution variability.
- Repeat visits to stations on the two snow–course survey plots and selected slope transects to directly measure snowpack ablation (late April through May).
- Refining the ablation modeling approach to incorporate data from periodic spring field surveys, analysis of MODIS satellite imagery, real-time meteorological-gage measurements (data collected by Hoefler Consulting Group for the meteorology baseline study), and stream discharge measurements (data collected by HDR and KP).
- Comparing ABR's snow-course measurements with data from NRCS snow–course survey plots and regional meteorological stations to identify long-term data sets that can be used to estimate the probable range of spring snowpack SWE.

Task 5. Evaluation and Processing of Field Data

In 2007, the processing of surface hydrology data, including those collected during snow surveys, continued as in 2006.

4.1.4.5 Major Tasks/Activities for 2008

The objectives and study area of the 2008 baseline surface hydrology program are consistent with the 2007 study plan. Details are provided in the following task descriptions.

Task 1: Surface Hydrology Baseline Data Collection

In August 2007 APCS added three new continuously gaged sites in the lower reaches of Upper Talarik Creek (UT100APC3, UT100APC2, and UT100APC1). UT100APC1 is located approximately one-quarter mile downstream of, and replaces, the former UT100A. Another new station (NH100APC1) was initiated on Alaska Peninsula Corporation land on the Newhalen River. NH100APC1 is not a continuously gaged station, but IQ is measured coincident with the collection of water-quality samples. APCS operated these four stations in 2008 using the same data-collection methods described above for previous years.

Four continuously gaged stations (SK100A, SK100B1, SK100F, and SK100G) are removed from the surface hydrology program in 2008 because the period-of-record is adequate to confidently predict discharge at these four locations (if required) using the continued data collection from other nearby continuous gages. No continuous gages are installed at these four sites in 2008. However, instantaneous measurements are collected from three of these sites along with water-quality samples. At SK100B1, instantaneous measurements with water-quality samples were collected through the May 2008 event and then are removed.

The resulting 2008 program included the following:

- Monthly collection of water-quality samples and IQ measurements at 39 stations from January through breakup.
- Monthly collection of water-quality samples and IQ measurements at 22 of the same stations from June through the remainder of 2008.
- Operation of 22 continuously gaged (discharge) stations during the ice-free months.
- Monthly IQ measurements at these gaging stations 12 months per year for the purpose of improving the reliability of the rating curves and to estimate the winter hydrograph.

Task 2: Baseflow Stream Profiling

As in previous years, baseflow was measured in 2008 during low-streamflow conditions in late winter, as near to the onset of the spring freshet as practical. Experience from field efforts in 2005, 2006, and 2007 indicate that the time period from late March to early April provides high quality baseflow data. As shown on Figure 4.1-3, IQ measurements of baseflow were performed in 11 new locations for 2008 in addition to the 33 locations measured in 2007 for a total of 44 locations throughout the north and south forks of the Koktuli River and in Upper Talarik Creek. IQ measurements were collected once during late winter (baseflow conditions). No CQ measurements were collected for this effort.

The preferred conditions preceding baseflow measurements include cold temperatures consistently below freezing to avoid surface runoff from snowmelt entering the stream. In order to avoid changing conditions, the IQ measurements were collected from all stations in each drainage within as short a period as possible—typically 1 day per drainage. Thus, data collection from the three drainages (Figure 4.1-3) required 3 to 5 days to complete, depending on weather.

Task 3: Fluvial Geomorphology Studies

Fluvial geomorphology studies were conducted in 2008 by R2 Resources Inc. in the mine study area to further characterize baseline conditions related to stream-channel form, maintenance, and stability. The objectives and study area of the 2008 baseline fluvial geomorphology program are consistent with those for 2007. Details of the 2008 work are provided in the following task descriptions.

Nine dual bulk samples were obtained from channel areas associated with surficial geology sub-units that include eroding lake deposits, glacial outwashes, landslide occurrences, and locations where sand particles appear to dominate. Six dual bulk samples from within gravels used by salmon for spawning were collected prior to spawning for use in supplementing 2007 bulk sample data. These samples were collected from nine transects, three from each of the Upper Talarik Creek, South Fork Koktuli River, and

North Fork Koktuli River. A single dual-bulk sample was obtained from each of the nine transects sampled before spawning occurred. All samples collected were analyzed to determine particle size distribution.

Task 4: Snow Surveys

Spring snow surveys continued in 2008 to complement concurrent surface hydrology studies by characterizing the distribution, SWE, and ablation rates of late-season (pre-breakup) snow across the landscape in the vicinity of the Pebble Deposit. The approach used in 2008 was the same as in 2007. Snow-survey plot locations for 2008 are illustrated on Figure 4.1-6. The major activities of the 2008 snow survey were as follows:

- Snow-distribution survey in the study area continued those conducted since 2004 in the mine study area and the 2007 survey in the extended study area. New plots were established opportunistically to collect data to support snow distribution modeling. This task also supports calibration and validation of the lidar snow depth estimates across the study area. In the extended study area, long transects (one or two per crew per day) were sampled in 2008.
- Airborne lidar measurements of the elevation at the top of the snowpack were acquired across the study area. These data provide information for estimates of drift volume and snow water equivalent in the largest snow accumulations—areas that may be unsafe to traverse and too deep to sample in the field.
- Ablation surveys were conducted biweekly for three site visits in late April and May to provide measures of snow during breakup.
- Data from statistical and physical snow-distribution and ablation modeling will add to existing models from 2004 through 2007. These efforts support predictions of snow distribution under various development scenarios.

Task 5. Evaluation and Processing of Field Data

In 2008, the processing of surface hydrology data, including those collected during snow surveys, continued as in 2007.

4.2 Transportation Corridor/Cook Inlet Study Areas

The study program for the transportation corridor/Cook Inlet study areas is based on guidelines established by the Alaska Department of Transportation and Public Facilities (ADOT&PF), the Federal Highway Administration (FHWA), and the American Association of State and Highway Transportation Officials (AASHTO). The work consists of surface water measurements only. Snow surveys are not conducted in the transportation corridor/Cook Inlet study areas.

4.2.1 Objectives of Study

Objectives of the baseline study for surface hydrology in the transportation corridor/Cook Inlet study areas are the same as for the mine study area:

- Document baseline hydrologic conditions.
- Collect data for input into studies by other disciplines.

4.2.2 Study Area/Scope

The transportation corridor/Cook Inlet study areas follow an east-southeasterly course from the deposit area, across the Newhalen River, around the southern flank of Roadhouse Mountain, along the north shore of Iliamna Lake, and through a mountain pass to Cook Inlet.

The transportation corridor study area crosses 18 streams that are of sufficient size and habitat quality to require study under the State of Alaska's Anadromous Fish Act (Alaska Statute 16.05.841). The scope of work for the surface water hydrology study, therefore, is to develop baseline hydrologic information on the streams and rivers crossed within the study area.

4.2.3 Methods/Approach

The methods/approach for collecting and analyzing data conform to the established procedures of the ADOT&PF, USGS, and FHWA. The data are collected in a manner to ensure sufficient information to evaluate the hydrologic regimes within the study areas.

Before the Pebble Project study was first implemented, data that are relevant to the transportation corridor study area had already been collected from two existing USGS continuous-record gaging stations. One station is located on the Iliamna River (at GS-3a on Figure 4.2-1) at Latitude 59°45'31" NAD 27, Longitude 153°50'41" NAD 27. This Iliamna station (USGS 15300300) has been collecting continuous data since 1996.

The second USGS station is located on Roadhouse Creek (near GS-20 and GS-20a on Figure 4.2-1), west of the Canyon Creek boundary. Roadhouse Creek is fed from small runoff streams that drain the west side of Roadhouse Mountain. It drains into Iliamna Lake near the Iliamna village townsite. Roadhouse Creek is an anadromous fish stream that meanders through the tundra and has well-vegetated banks. The Roadhouse Creek gage was first installed by the USGS in 1973. The gage recorded data for 10 years, until 1983, when the USGS disengaged the station. The USGS reinstalled the Roadhouse Creek gage (USGS No. 15300200) in May 2005 to support the surface hydrology baseline data collection for the Pebble Project studies. The gage is located at Latitude 59°45'26" NAD 27, Longitude 154°60'59" NAD 27. At the time of the USGS gage reinstallation, Roadhouse Creek was approximately 21 to 25 feet wide and 1.2 feet deep at the deepest section. A state-owned paved road passes over the creek just south of the gage. Two 10-foot-wide by 42-foot-long culverts are installed under the road embankment to allow drainage for the creek.

The existing USGS stream data and historical published weather data suggest two distinct climatic zones along the transportation corridor study area. Canyon Creek (GS-11a on Figure 4.2-1) is at the

approximate boundary between the two zones. East of the boundary, precipitation is relatively higher and stream flows are relatively larger than west of the boundary. The Iliamna River, located east of the Canyon Creek boundary, has a relatively large flow compared to surface water flows west of the boundary. Gage records from Iliamna River are used to analyze the streams east of Canyon Creek. Gage records from Roadhouse Creek (located west of the boundary) are used for streams west of Canyon Creek. These data are used to establish flow characteristics on other watersheds. Regression equations have been developed using basin characteristics for each of the two zones and will be refined using field observations.

The Iliamna River and Roadhouse Creek are operated and maintained by the USGS, and satellite data collection from the gages is processed automatically. Peak streamflow, real-time data, and historical data for these gages are available on the USGS website:

- http://waterdata.usgs.gov/nwis/dv/?site_no=15300300 for the Iliamna River site.
- http://waterdata.usgs.gov/ak/nwis/uv?site_no=15300200 for the Roadhouse Creek site.

In addition to the two USGS stations, other stations have been installed in the study areas. The locations of the stations are shown on Figure 4.2-1. Station locations have been determined based on location of the transportation corridor, land ownership status, and hydrologic and geomorphic considerations. At each location, a crest gage is established to record high water levels between monitoring events. Stream cross-sections are surveyed at apparent ordinary high water ,and photographic documentation upstream and downstream of the crest gage is also collected. Monthly instantaneous flow-velocity measurements and crest-gage readings are taken and compiled.

Computational analysis for annual high-flow and seasonal baseflow statistics for streamflow recorded by the existing USGS gaging stations on the Iliamna River and Road House Creek are used to calibrate the data collected on the selected ungaged streams in each of the two corresponding climatic zones in the study area. The statistical data are used to predict high-flow and baseflow characteristics on the ungaged streams using USGS water-resources investigations reports (Wiley and Curran, 2003; Curran et al., 2003).

4.2.4 Major Tasks and Activities

A summary of tasks and activities for surface water hydrology studies for the transportation corridor/Cook Inlet study areas is presented in Table 4.2-1. An overview of the sampling stations and the sampling conducted during the course of the study is presented in Table 4.2-2.

4.2.4.1 Major Tasks/Activities for 2004

The major tasks and activities for the transportation/Cook Inlet study areas portion of the surface water hydrology study were to compile data and document existing conditions. The work consisted primarily of researching existing information, as well as collecting preliminary field data in stream reaches within the study area.

Research sources included the following:

- Agencies: ADOT&PF; ADEC; Alaska Department of Commerce, Community and Economic Development; USGS; U.S. Army Corps of Engineers; Federal Aviation Administration; and others as necessary.
- Anecdotal information from local residents.
- Aerial photographs and other remote sensing data inspection and analysis.

Field work consisted of surface water (discharge) measurements on selected rivers and streams .A basin-characteristics file was created for each stream, and the data were stored within a GIS database.

Information collected for each basin included the following:

- Corridor station number.
- Stream name.
- Latitude and longitude.
- Location map (USGS quadrangle map designation).
- Drainage area (square miles).
- Mean channel slope (feet per mile).
- Channel length (miles).
- Surface water area of lakes and ponds (square miles).
- Total storage area (square miles).
- Precipitation data (mean annual inches) provided by National Weather Service.
- Mean basin elevation (feet above sea level).
- Forested area (square miles).
- Glaciers (square miles).
- Mean January temperature data (degrees Fahrenheit) provided by National Weather Service.
- Digital photos of the stream reach that the corridor crossed including shots looking up and downstream of the corridor.
- Title 41 classification.
- All existing surface water hydrological measurements and flood record data provided by the USGS Water Resources Branch.
- Stream classification (stable, transitional, or unstable; and sinuous, straight, braided, alluvial, or incised) within the corridor reach.
- Geomorphological data (description of sediment scour and deposition trends; stability of form over time; and bed and bank material identification).
- Estimates of expected maximum and minimum flows.

- Flow measurements collected during field programs.
- Base images:
  - Photographic copies of 2003 aerial photographs taken by others.
  - "U2" false color infrared photographs provided by the Pebble Partnership.
  - USGS topographic maps.

4.2.4.2 Major Tasks/Activities for 2005

The major tasks and activities for the transportation corridor/Cook Inlet study areas in 2005 were to compile statistical streamflow modeling data and to document existing conditions. The work consisted primarily of researching existing information, computational analysis, and collecting field data in stream reaches within the study area.

The research sources used in 2005 were the same as those used in 2004.

Field work consisted of the following:

- Surface-water discharge measurements on selected rivers and streams. (Figure 4.2-1).
- Crest-gage monitoring.
- Surveys of stream cross-sectional dimensions and elevations to be tied in to crest-gage elevation.

As in 2004, a basin-characteristics file was created for each stream being sampled within the transportation corridor study area. The data parameters measured were the same as those measured in 2004, and the data collected were uploaded into the existing GIS database.

4.2.4.3 Major Tasks/Activities for 2006

BEESC researchers did not collect new data in 2006 for the transportation corridor /Cook Inlet study areas. The only data collection task was to download and analyze the data from the two USGS stations.

Also in 2006, all baseline data on surface hydrology along the transportation corridor study area were compiled, refined and re-analyzed, and presented in the draft environmental baseline document in preparation for filing permit applications for the Pebble Project.

4.2.4.4 Major Tasks/Activities for 2007 and 2008

No new data were collected or no other work was conducted in 2007 or 2008 for the surface water hydrology study in the transportation corridor/Cook Inlet study areas.

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TABLES

Table 4.1-1
Pebble Project Environmental Baseline Studies
Study Summary for Surface Water Hydrology, Mine Study Area, 2004-2008
Consultant: HDR Alaska, Knight Piésold

2004 Data Collected or Tasks Completed	2005 Data Collected or Tasks Completed	2006 Data Collected or Tasks Completed	2007 Data Collected or Tasks Completed	2008 Data Collected or Tasks Completed
Surface Hydrology Data Collection (7 Events)	Surface Hydrology Data Collection (9 Events)	Surface Hydrology Data Collection 10 Events)	Surface Hydrology Data Collection (12 Events)	Surface Hydrology Data Collection (12 Events)
	Baseflow Measurements (1 Event)	Baseflow Measurements (1 Event)	Baseflow Measurements (1 Event)	Baseflow Measurements (1 Event)
	Upper Hyporheic Zone Monitoring			
	Flow Exchange Measurements During Low Flow			
			Fluvial Geomorphology (2 Events)	
Evaluate and Process Field Data	Evaluate and Process Field Data	Evaluate and Process Field Data	Evaluate and Process Field Data	Evaluate and Process Field Data
	Aerial Survey of Hydrography for Potential Temporary Road Corridor to Mine Site			

Table 4.1-2
Pebble Project Environmental Baseline Studies
Monitoring Station and Period-of-Record Index, Surface Water Hydrology, Mine Study Area, 2004-2008
Consultants: HDR Alaska Inc., Knight Piesold, APCS

Monitoring Station	Year	Period-of-Record By Discipline																							Station Rationale and Comments
		Surface Hydrology[1]												Surface Water Quality											
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
KC100A	2004					I	I	I	C	C	C							Q	Q	Q	Q	Q	Q			Evaluate potential interbasin transfer of water from Sourth Fork Koktuli River
	2005	I		I	C	C	C	C	C	C	C			Q		Q		Q	Q	Q	Q	Q	Q			
	2006		I	I		C	C	C	C	C	C		I		Q	Q		Q	Q	Q	Q	Q	Q		Q	
	2007		I	I	I	C	C	C	C	C	C	I	I		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	C	C	C	C	C	C	C	I	I	Q	Q	Q	Q	Q								
KR100A	2004				I		I	I	I	I	I						Q	Q	Q	Q	Q	Q	Q			Intergrates north and south forks of Koktuli River; lowers watershed site
	2005			I			I	I	I	I	I					Q			Q	Q	Q	Q	Q			
	2006			I			I	I			I		I			Q			Q	Q			Q		Q	
	2007		I	I	I	I	I	I	I	I	I	I	I		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	I	I	I	I	I	I	I	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
NH100APC1	2004																									Newhalen River
	2005																									
	2006																									
	2007								I	I	I	I	I							Q	Q	Q	Q	Q	Q	
	2008	I	I	I	I	I	I	I	I	I	I	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
NK100A	2004					I	I	I	C	C	C							Q	Q	Q	Q	Q	Q			Lower mainstem North Fork Koktuli River near South Fork Koktuli River confluence;
	2005	I		I	C	C	C	C	C	C	C			Q		Q		Q	Q	Q	Q	Q	Q			
	2006			I	C	C	C	C	C	C	C				Q	Q		Q	Q	Q	Q	Q	Q		Q	
	2007				C	C	C	C	C	C	C	I	I		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	C	C	C	C	C	C	C	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
NK100A1	2004																									Intermediate point on mainstem NK
	2005																									
	2006																									
	2007		I	I	I	C	C	C	C	C	C	I	I		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	C	C	C	C	C	C	C	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
NK100B	2004								I	I	I										Q	Q	Q			Integrates NK100A and NK100C
	2005	I		I		I	I	I	I	I	I			Q		Q		Q	Q	Q	Q	Q	Q			
	2006		I	I	I	I	I	I	I	I	I		I		Q	Q		Q	Q	Q	Q	Q	Q		Q	
	2007		I	I		C	C	C	C	C	C	I	I		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	C	C	C	C	C	C	C	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
NK100C	2004					I		I	C	C	C							Q	Q	Q	Q	Q	Q			North Fork Koktuli River "basin" integrator for headwaters
	2005	I		I		C	C	C	C	C	C			Q		Q		Q	Q	Q	Q	Q	Q			
	2006		I	I	I	C	C	C	C	C	C		I		Q	Q		Q	Q	Q	Q	Q	Q		Q	
	2007		I	I		C	C	C	C	C	C	I	I		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	C	C	C	C	C	C	C	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
NK119A	2004						I	I	C	C	C								Q	Q	Q	Q	Q			
	2005	I		I		C	C	C	C	C	C			Q		Q		Q	Q	Q	Q	Q	Q			
	2006	I	I	I		C	C	C	C	C	C		I	Q	Q	Q		Q	Q	Q	Q	Q	Q		Q	
	2007		I	I	C	C	C	C	C	C	C	I	I		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	C	C	C	C	C	C	C	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
NK119B	2004					I	I	I	I	I	I							Q	Q	Q	Q	Q	Q			Drains "back side" of deposit
	2005	I		I		I	I	I	I	I	I			Q		Q		Q	Q	Q	Q	Q	Q			
	2006		I	I																						
	2007		I	I	I	I	C	C	C	C	C	I	I				Q	Q	Q			Q	Q	Q	Q	
	2008	I	I	I	C	C	C	C	C	C	C	I	I	Q	Q	Q	Q	Q								
SK100A	2004				I		I	I	C	C	C						Q	Q	Q	Q	Q	Q	Q			Lower mainstem South Fork Koktuli River near confluence with North Fork Koktuli River
	2005	I		I	C	C	C	C	C	C	I			Q		Q		Q	Q	Q	Q	Q	Q			
	2006		I	I	I	C	C	C	C	C	C		I		Q	Q		Q	Q	Q	Q	Q	Q		Q	
	2007	I	I	I	C	C	C	C	C	C	C		I	Q	Q	Q	Q	Q	Q	Q		Q	Q	Q	Q	
	2008	I	I	I	I	I	I	I	I	I	I	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
SK100B	2004						I	I	C	C	C							Q	Q	Q	Q	Q	Q			Mainstem; located downstream of gaining reach; USGS maintains continuous gage
	2005			I	C	C	C	C	C	C	C			Q		Q		Q	Q	Q	Q	Q	Q			
	2006		I	I	C	C	C	C	C	C	C		I		Q	Q		Q	Q	Q	Q	Q	Q		Q	
	2007	I	I		C	C	C	C	C	C	C	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	C	C	C	C	C	C	C	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
SK100B1	2004																									Mainstem; located within gaining reach
	2005									I	I	C	C									Q	Q			
	2006	C	C	C	C	C	C	C	C	C	C	C	I		Q	Q		Q	Q	Q	Q	Q	Q		Q	
	2007	I	I	I	C	C	C	C	C	C	C	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	I	I								Q	Q	Q	Q	Q								
SK100B2	2004																									Mainstem; located within gaining reach
	2005					I	I	I	I	I	I							Q	Q	Q	Q	Q	Q			
	2006		I	I		I	I	I	I	I	I		I		Q			Q	Q	Q	Q	Q	Q		Q	
	2007	I	I	I	I	I	I	I	I	I	I	I	I	Q	Q			Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	I	I	I	I	I	I	I	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	

Table 4.1-2
Pebble Project Environmental Baseline Studies
Monitoring Station and Period-of-Record Index, Surface Water Hydrology, Mine Study Area, 2004-2008
Consultants: HDR Alaska Inc., Knight Piesold, APCS

Monitoring Station	Year	Period-of-Record By Discipline																							Station Rationale and Comments
		Surface Hydrology[1]												Surface Water Quality											
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
SK100C	2004						I	I	C	C	C							Q	Q	Q			Q			Mainstem; located near downstream end of losing reach; upstream of flow gain; Cominco CQ Station 16 (1993)
	2005	I		I		C	C	C	C	C	C			Q				Q	Q	Q		Q	Q			
	2006			I	I	I	C	C	C	C	C		I					Q	Q	Q	Q	Q	Q		Q	
	2007		I	I	I	C	C	C	C	C	C	I	I					Q	Q	Q		Q	Q	Q	Q	
	2008	I	I	I	I	C	C	C	C	C	C	I	I	Q	Q	Q	Q	Q								Mainstem downstream of potential MDC options; located near
SK100D	2004						I	I	I	I	I						Q	Q	Q	Q	Q	Q			Mainstem downstream of potential MDC options; located near downstream end of losing reach; upstream of flow gain; Cominco CQ Station 16 (1993)
	2005	I		I		I	I	I	I	I	I			Q		Q		Q	Q	Q	Q	Q	Q			
	2006		I	I	I		I	I	I	I	I		I						Q	Q	Q	Q	Q		Q	
	2007	I	I	I	I	I	I	I	I	I	I	I	I	Q	Q		Q	Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	I	I								Q	Q	Q	Q	Q								
SK100F	2004					I	I	I	C	C	C							Q	Q	Q	Q	Q	Q			Mainstem downstream of Frying Pan Lake (possible losing reach); same reach as Cominco CQ Station 17 (1991-1992)
	2005	I		I		C	C	C	C	C	C			Q		Q		Q	Q	Q	Q	Q	Q			
	2006	I	I	I	I	C	C	C	C	C	C		I	Q	Q	Q		Q	Q	Q	Q	Q	Q		Q	
	2007	I	I	I	I	C	C	C	C	C	C	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	I	I	I	I	I	I	I	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
SK100G	2004				I	I	I	I	C	C	C						Q	Q	Q	Q	Q	Q	Q			Upper-most main stem station; located upstream of Frying Pan Lake; same reach as Cominco Stations 6
	2005	I		I	C	C	C	C	C	C	C			Q		Q		Q	Q	Q	Q	Q	Q			
	2006	I	I	I		C	C	C	C	C	C		I	Q	Q	Q		Q	Q	Q	Q	Q	Q		Q	
	2007	I	I	I	I	C	C	C	C	C	C	I	I	Q	Q		Q	Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	I	I	I	I	I	I	I	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
SK119A	2004				I	I	I	I	C	C	C						Q	Q	Q	Q	Q	Q	Q			Tributary; flow to aquifer rechage-discharge area; Cominco Stations 18 and 20 (date unknown)
	2005	I		I	C	C	C	C	C	C	C			Q		Q		Q	Q	Q	Q	Q	Q			
	2006		I	I		C	C	C	C	C	C		I		Q	Q		Q	Q	Q	Q		Q		Q	
	2007		I		I	C	C	C	C	C	C	I	I	Q	Q		Q	Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	C	C	C	C	C	C	C	I	I	Q	Q	Q	Q	Q								
SK124A	2004																									Tributary; important data for understanding gaining reach downstream on mainstem
	2005	I		I		I	C	C	C	C	C			Q		Q		Q	Q	Q	Q	Q	Q			
	2006	I	I	I			C	C	C	C	C		I	Q	Q	Q			Q	Q	Q		Q		Q	
	2007	I	I	I		C	C	C	C	C	C	I	I	Q				Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	I	C	C	C	C	C	C	I	I	Q	Q	Q	Q	Q								
SK131A	2004				I	I	I	I	I	I	I						Q	Q	Q	Q	Q	Q	Q			Drains Koktuli Mountain
	2005	I		I		I	I	I	I	I	I			Q		Q		Q	Q	Q	Q	Q	Q			
	2006		I	I		I	I	I	I	I	I		I		Q	Q		Q	Q	Q	Q	Q	Q		Q	
	2007	I	I	I		I	I	I	I	I	I	I	I	Q	Q			Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	I	I								Q	Q	Q	Q	Q								
SK133A	2004				I	I	I	I	I	I	I						Q	Q	Q	Q	Q	Q	Q			South of deposit
	2005			I		I	I	I	I	I	I							Q	Q	Q	Q	Q	Q			
	2006		I	I		I	I	I	I	I	I		I		Q	Q		Q	Q	Q	Q	Q	Q		Q	
	2007		I	I	I	I	I	I	I	I	I	I	I		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	I	I								Q	Q	Q	Q	Q								
SK134A	2004				I	I	I	I	I	I	I						Q	Q	Q	Q	Q	Q	Q			South of deposit
	2005	I		I		I	I	I	I	I	I			Q		Q		Q	Q	Q	Q	Q	Q			
	2006	I	I	I		I	I	I	I	I	I		I	Q	Q	Q		Q	Q	Q	Q	Q	Q		Q	
	2007		I	I	I	I	I	I	I	I	I	I	I		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	I	I	I	I	I	I	I	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
SK136A	2004				I	I	I	I	I	I	I						Q	Q	Q	Q	Q	Q	Q			Drains deposit
	2005	I		I		I	I	I	I	I	I			Q		Q		Q	Q	Q	Q	Q	Q			
	2006	I	I	I		I	I	I	I	I	I			Q	Q	Q		Q	Q	Q	Q	Q	Q		Q	
	2007		I	I	I	I	I	I	I	I	I	I	I		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	I	I								Q	Q	Q	Q	Q								
SK136B	2004				I	I	I	I	I	I	I						Q	Q	Q	Q	Q	Q	Q			Drains deposit
	2005	I				I	I	I	I	I	I			Q		Q		Q	Q	Q	Q	Q	Q			
	2006		I	I		I	I	I	I	I	I		I	Q	Q	Q		Q	Q	Q	Q	Q	Q		Q	
	2007		I	I	I	I	I	I	I	I	I	I	I		Q			Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	I	I								Q	Q	Q	Q	Q								
UT100A	2004					I			I	I	I						Q	Q			Q	Q	Q			Downstream of mineralized zone; integrates all of Upper Talarik Creek; station physically moved to UT100APC1 in August 2007.
	2005	I		I		I	I	I			I			Q		Q		Q	Q	Q			Q			
	2006			I			I	I		I						Q			Q	Q	Q	Q	Q		Q	
	2007			I		I	I	I							Q	Q	Q	Q	Q	Q						
	2008																									
UT100APC1	2004																									UT100A relocated slightly downstream onto APCS lands.
	2005																									
	2006																									
	2007								I	I	I	I	I								Q	Q	Q	Q	Q	
	2008	I	I	I	C	C	C	C	C	C	C	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	

Table 4.1-2
Pebble Project Environmental Baseline Studies
Monitoring Station and Period-of-Record Index, Surface Water Hydrology, Mine Study Area, 2004-2008
Consultants: HDR Alaska Inc., Knight Piesold, APCS

Monitoring Station	Year	Period-of-Record By Discipline																						Station Rationale and Comments
		Surface Hydrology[1]												Surface Water Quality										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
UT100APC2	2004																									Monitors APCS land on Upper Talarik Creek
	2005																									
	2006																									
	2007								I	I	I	I	I								Q	Q	Q	Q	Q	
	2008	I	I	I	C	C	C	C	C	C	C	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
UT100APC3	2004																									Monitors APCS land on Upper Talarik Creek
	2005																									
	2006																									
	2007								I	I	I	I	I								Q	Q	Q	Q	Q	
	2008	I	I	I	C	C	C	C	C	C	C	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
UT100B	2004					I	I	I	C	C	C						Q	Q	Q	Q	Q	Q	Q			Lower reach of Upper Talarik Creek; downstream of tributary UT1, 190; downstream of minerealized zone; USGS maintains
	2005	I		I	C	C	C	C	C	C	C			Q		Q		Q	Q	Q	Q	Q	Q			
	2006		I	I	C	C	C	C	C	C	C		I		Q	Q		Q	Q	Q	Q	Q	Q		Q	
	2007	I	I	I	C	C	C	C	C	C	C	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	C	C	C	C	C	C	C	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
UT100C	2004				I	I											Q	Q								Intermediate point downstream of Pebble East on mainstem
	2005			I																						
	2006				I																					
	2007		I	I	I	C	C	C	C	C	C	I	I		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	C	C	C	C	C	C	C	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
UT100C1	2004																									Intermediate point downstream of Pebble East on mainstem
	2005																									
	2006				I																					
	2007		I	I	I	C	C	C	C	C	C	I	I		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	C	C	C	C	C	C	C	I	I	Q	Q	Q	Q	Q								
UT100C2	2004																									Downstream of Pebble East on mainstem; provides data to understand flow balance with Northeast Tributary (UT1, 135)
	2005																									
	2006				I																					
	2007		I			C	C	C	C	C	C	I	I		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	C	C	C	C	C	C	C	I	I	Q	Q	Q	Q	Q								
UT100D	2004				I	I	I	I	C	C	C						Q	Q	Q	Q	Q	Q	Q			Upper Talarik Creek; Cominco CQ Station 13 (1991-1993)
	2005	I		I		C	C	C	C	C	C			Q		Q		Q	Q	Q	Q	Q	Q			
	2006		I	I	I	C	C	C	C	C	C		I		Q	Q		Q	Q	Q	Q	Q	Q		Q	
	2007	I	I		I	C	C	C	C	C	C	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	C	C	C	C	C	C	C	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
UT100E	2004				I	I	I	I	C	C	C						Q	Q	Q	Q	Q	Q	Q			Upper reach of Upper Talarik Creek; downstream of potential flow gain from North Fork Koktuli River; upstream of drainage from deposit; same reach as Cominco Station 8 (date unknown)
	2005	I		I	C	C	C	C	C	C	C			Q		Q		Q	Q	Q	Q	Q	Q			
	2006	I	I	I		C	C	C	C	C	C		I	Q	Q	Q		Q	Q	Q	Q	Q	Q		Q	
	2007	I	I	I	I	C	C	C	C	C	C	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	C	C	C	C	C	C	C	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
UT119A	2004				I	I	I	I	C	C	C						Q	Q	Q	Q	Q	Q	Q			Lower reach of Upper Talarik Creek; downstream of mineralized zone
	2005	I		I	C	C	C	C	C	C	C			Q		Q		Q	Q	Q	Q	Q	Q			
	2006	I	I	I		C	C	C	C	C	C		I	Q	Q	Q		Q	Q	Q	Q	Q	Q		Q	
	2007	I	I	I	I	C	C	C	C	C	C	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	C	C	C	C	C	C	C	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
UT119B	2004				I	I	I	I	I	I	I						Q	Q	Q	Q	Q	Q	Q			Upper Talarik Creek; water quality and biological sampling
	2005	I		I		I	I	I	I	I	I			Q		Q		Q	Q	Q	Q	Q	Q			
	2006	I	I	I		I	I	I	I	I	I		I	Q	Q	Q		Q	Q	Q	Q	Q	Q		Q	
	2007	I	I	I	I	I	I	I	I	I	I	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	I	I								Q	Q	Q	Q	Q								
UT135A	2004					I	I	I	I	I	I						Q	Q	Q	Q	Q	Q	Q			Major Upper Talarik Creek tributary near confluence with mainstem of Upper Talarik Creek; winter flow contribution; Cominco CQ Station 19 (1993)
	2005	I		I		I	I	I	I	I				Q		Q		Q	Q	Q	Q	Q	Q			
	2006		I			I	I	I	I	I			I		Q	Q		Q	Q	Q	Q	Q	Q		Q	
	2007		I		I	C	C	C	C	C	C	I	I		Q			Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	I	C	C	C	C	C	C	I	I	Q	Q	Q	Q	Q								
UT138A	2004				I	I	I	I	I	I	I						Q	Q	Q	Q	Q	Q	Q			Drains "Pig Mountain"
	2005	I		I		I	I	I	I	I	I			Q		Q		Q	Q	Q	Q	Q	Q			
	2006		I	I		I	I	I	I	I	I		I		Q	Q		Q	Q	Q	Q	Q	Q		Q	
	2007	I	I		I	I	I	I	I	I	I	I	I	Q	Q		Q	Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	I	I								Q	Q	Q	Q	Q								
UT141A	2004				I	I	I	I	I	I	I						Q	Q	Q	Q	Q	Q	Q			
	2005			I		I	I	I	I	I	I					Q		Q	Q	Q	Q	Q	Q			
	2006		I	I		I	I	I	I	I	I		I		Q	Q		Q	Q	Q	Q	Q	Q		Q	
	2007	I	I	I	I	I	I	I	I	I	I	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	I	I								Q	Q	Q	Q	Q								

Table 4.1-2
Pebble Project Environmental Baseline Studies
Monitoring Station and Period-of-Record Index, Surface Water Hydrology, Mine Study Area, 2004-2008
Consultants: HDR Alaska Inc., Knight Piesold, APCS

Monitoring Station	Year	Period-of-Record By Discipline																						Station Rationale and Comments
		Surface Hydrology[1]												Surface Water Quality										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
UT146A	2004				I	I	I	I	I	I	I						Q	Q	Q	Q	Q	Q	Q			
	2005	I		I		I	I	I	I	I	I			Q		Q		Q	Q	Q	Q	Q	Q			
	2006		I			I	I	I	I	I	I		I		Q			Q	Q	Q	Q	Q	Q		Q	Drains deposit; headwaters in mineralized zone
	2007	I	I	I	I	I	I	I	I	I	I	I	I	Q	Q		Q	Q	Q	Q	Q	Q	Q	Q	Q	
	2008	I	I	I	I	I	I	I	I	I	I	I	I	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
Seeps	2004					I				I								Q				Q				
	2005			I				I	I		I					Q				Q	Q		Q			
	2006			I			I		I		I					Q			Q		Q		Q			
	2007			I		I		I		I	I					Q		Q		Q		Q	Q			
	2008			I		I		I		I	I					Q		Q		Q		Q	Q			

KEY:

C Continuous stage/discharge hydrometric data collected in streams (gaged stations with dataloggers).

I Instantaneous stream discharge measurements taken each month coincident with water-quality sampling (ungaged stations without dataloggers).

Q Surface water-quality samples collected for field and laboratory analyses.

NOTES:

1 At stations where continuous hydrometric data are collected, continuous hydrographs will be estimated throughout winter months using standard hydrometric methods. Stream gages are reinstalled each spring as early as breakup conditions allow.

Table 4.1-3
Pebble Project Environmental Baseline Studies
Study Summary for Snow Surveys, Mine Study Area, 2004-2008
Consultant: ABR, Inc.

2004 Data Collected or Tasks Completed	2005 Data Collected or Tasks Completed	2006 Data Collected or Tasks Completed	2007 Data Collected or Tasks Completed	2008 Data Collected or Tasks Completed
Mine Study Area *				
Information Gathering / Literature Search	Information Gathering / Literature Search & Review	Information Gathering / Literature Search & Review	Information Gathering / Literature Search & Review	Information Gathering / Literature Search & Review
Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan
2004 Study Plan	2005 Study Plan	2006 Study Plan	2007 Study Plan	2008 Study Plan
Snow Distribution Surveys (April)	Snow Distribution Surveys (April)	Snow Distribution Surveys (April)	Snow Distribution Surveys (April)	Snow Distribution Surveys (April)
Snow Ablation Surveys (May)	Snow Ablation Surveys (May)	Snow Ablation Surveys (May)	Snow Ablation Surveys (April and May)	Snow Ablation Surveys (April and May)
Data Entry and Analysis	Data Entry and Analysis	Data Entry and Analysis	Data Entry and Analysis	Data Entry and Analysis
Communication and Data Management	Communication and Data Management	Communication and Data Management	Communication and Data Management	Communication and Data Management
Coordination with Pebble, Agency Meetings	Coordination with Pebble, Agency Meetings, and Monthly Reporting	Coordination with Pebble, Agency Meetings, and Monthly Reporting	Coordination with Pebble, Agency Meetings, and Monthly Reporting	Coordination with Pebble, Agency Meetings, and Monthly Reporting
	2004 Progress Report	Preliminary Environmental Baseline Document	Environmental Baseline Document	Environmental Baseline Document

* In 2007, the study area was extended to include the full extent of the north and south forks of the Koktuli River and Upper Talarik Creek basins.

Table 4.1-4
Pebble Project Environmental Baseline Studies
Period-of-Record Index, Snow Surveys, Mine Study Area, 2004 - 2008
Consultant: ABR, Inc.

Transect	Stations	Year	Distribution	Ablation
1	13	2004	×	×
		2005	×	×
		2006	×	×
		2007	×	×
		2008	×	×
2	10	2004	×	×
		2005	×	×
		2006	×	×
		2007	×	×
		2008	×	×
3	5	2004	×	
		2005		
		2006		
		2007		
		2008		
4	7	2004	×	
		2005		
		2006		
		2007	×	
		2008	×	
5	7	2004	×	
		2005		
		2006	×	
		2007	×	
		2008	×	
6	9	2004	×	
		2005	×	
		2006	×	
		2007	×	
		2008	×	
8	8	2004	×	
		2005	×	
		2006	×	
		2007	×	×
		2008	×	
9	7	2004	×	
		2005		
		2006		
		2007	×	
		2008	×	
10	5	2004	×	
		2005		
		2006		
		2007		
		2008		

Table 4.1-4
Pebble Project Environmental Baseline Studies
Period-of-Record Index, Snow Surveys, Mine Study Area, 2004 - 2008
Consultant: ABR, Inc.

Transect	Stations	Year	Distribution	Ablation
11	7	2004	×	
		2005	×	
		2006	×	
		2007	×	
		2008	×	
12	8	2004	×	
		2005	×	
		2006	×	
		2007	×	
		2008	×	
13	6	2004	×	
		2005		
		2006		
		2007		
		2008		
14	9	2004	×	
		2005	×	
		2006	×	
		2007	×	×
		2008	×	
20	10	2004		
		2005	×	
		2006	×	
		2007	×	
		2008		
21	8	2004		
		2005	×	
		2006	×	
		2007	×	×
		2008	×	
22	8	2004		
		2005	×	
		2006	×	
		2007	×	
		2008	×	
23	8	2004		
		2005	×	
		2006	×	
		2007	×	
		2008	×	
24	7	2004		
		2005	×	
		2006	×	
		2007	×	
		2008	×	

Table 4.1-4
Pebble Project Environmental Baseline Studies
Period-of-Record Index, Snow Surveys, Mine Study Area, 2004 - 2008
Consultant: ABR, Inc.

Transect	Stations	Year	Distribution	Ablation
25	9	2004		
		2005	×	
		2006	×	
		2007	×	
		2008		
26	7	2004		
		2005	×	
		2006	×	
		2007	×	×
		2008		
27	7	2004		
		2005	×	×
		2006	×	×
		2007		
		2008	×	
30	10	2004		
		2005		
		2006		
		2007	×	×
		2008	×	
34	13	2004		
		2005		
		2006		
		2007	×	×
		2008	×	
38	11	2004		
		2005		
		2006		
		2007	×	×
		2008	×	
41	16	2004		
		2005		
		2006		
		2007		
		2008	×	
43	19	2004		
		2005		
		2006		
		2007		
		2008	×	
47	13	2004		
		2005		
		2006		
		2007		
		2008	×	

Table 4.1-4
Pebble Project Environmental Baseline Studies
Period-of-Record Index, Snow Surveys, Mine Study Area, 2004 - 2008
Consultant: ABR, Inc.

Transect	Stations	Year	Distribution	Ablation
49	13	2004		
		2005		
		2006		
		2007		
		2008	×	
50	8	2004		
		2005		
		2006		
		2007		
		2008	×	
51	15	2004		
		2005		
		2006		
		2007		
		2008	×	
Extensive Grid Plots	21	2004		
		2005		
		2006		
		2007	×	×
		2008		
Met Station 1	1	2004	×	
		2005	×	
		2006		
		2007	×	
		2008		
Met Station 2/4	1	2004	×	
		2005	×	
		2006		
		2007	×	
		2008		
Met Station 3	1	2004		
		2005		
		2006		
		2007	×	
		2008		

Table 4.2-1
Pebble Project Environmental Baseline Studies
Study Summary for Surface Water Hydrology, Transportation Corridor/Cook Inlet Study Areas, 2004 - 2008
Consultant: BEESC

2004 Data Collected or Tasks Completed	2005 Data Collected or Tasks Completed	2006 Data Collected or Tasks Completed	2007 Data Collected or Tasks Completed	2008 Data Collected or Tasks Completed
Information Gathering	Information Gathering			
Preparation of Scope, Schedule, Field Sampling Plan	Preparation of Scope, Schedule, Field Sampling Plan			
Field Flow Measurements	Field Flow Measurements			
Communication and Data				
Coordination with Pebble	Coordination with Pebble			
Coordination with local communities for observers	Coordination with local communities for observers			
	Data Compilation and Analysis	Data Compilation and Analysis		
Preparation of Presentation				
	Preparation of 2004 Progress Report	Preparation of Preliminary Environmental Baseline Document	Revision of Environmental Baseline Document	Revision of Environmental Baseline Document

Table 4.2-2
Pebble Project Environmental Baseline Studies
Monitoring Station, Period-of-Record Index, Surface Water Hydrology,
Transportation Corridor/Cook Inlet Study Areas, 2004 - 2006
Consultant: BEESC

Monitoring Station	Year	Period of Record by Discipline																					
		Surface Hydrology												Surface Water Quality									
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
NHRIV	2004																			Q	Q	Q	Q		
	2005														Q	Q		Q	Q	Q	Q	Q	Q		
	2006																								
GS20	2004							I	I	I	I									Q	Q	Q	Q		
	2005		I	I											Q	Q				Q	Q	Q	Q		
	2006																								
GS20A	2004							I	I	I	I									Q	Q	Q	Q		
	2005		I	I											Q	Q									
	2006																								
GS18A	2004							I		I	I									Q	Q	Q	Q		
	2005		I	I											Q	Q									
	2006																								
GS17A	2004							I	I	I	I									Q	Q	Q	Q		
	2005		I	I		I	I	I	I	I	I				Q	Q		Q	Q	Q	Q	Q	Q		
	2006																								
GS14A	2004							I	I	I	I									Q	Q	Q	Q		
	2005		I	I											Q	Q									
	2006																								
GS14B	2004							I	I	I	I									Q	Q	Q	Q		
	2005		I			I	I	I	I	I	I				Q	Q		Q	Q	Q	Q	Q	Q		
	2006																								
GS12A	2004							I	I	I	I									Q	Q	Q	Q		
	2005		I	I											Q	Q									
	2006																								
GS11A	2004							I	I	I	I									Q	Q	Q	Q		
	2005		I	I		I	I	I	I	I	I				Q	Q		Q	Q	Q	Q	Q	Q		
	2006																								
GS8A	2004							I	I	I	I									Q	Q	Q	Q		
	2005		I	I		I	I	I	I		I				Q	Q		Q	Q	Q	Q	Q	Q		
	2006																								
GS7A	2004										I												Q		
	2005																								
	2006																								
GS6A	2004							I	I	I	I									Q	Q	Q	Q		
	2005		I	I											Q	Q									
	2006																								
GS4A	2004							I	I	I	I									Q	Q	Q	Q		
	2005		I			I	I	I	I		I				Q	Q		Q	Q	Q	Q	Q	Q		
	2006																								
GS4B	2004									I	I											Q	Q		
	2005														Q	Q									
	2006																								
GS3A	2004								I	I											Q	Q	Q		
	2005		I												Q	Q		Q	Q	Q	Q	Q	Q		
	2006																								
GS23	2004							I	I	I	I									Q	Q	Q	Q		
	2005																								
	2006																								
GS22	2004							I	I	I	I														
	2005																			Q	Q	Q	Q		
	2006																								
GS21	2004								I	I	I										Q	Q	Q		
	2005		I	I		I	I	I	I	I	I				Q	Q		Q	Q	Q	Q	Q	Q		
	2006																								

KEY:

I **Instantaneous stream discharge measurements (ungaged stations without dataloggers) taken each month coincident with collecting water quality samples**

Q **Water quality samples collected for field and laboratory analyses.**

FIGURES

158°0'0"W
156°0'0"W
154°0'0"W
61°0'0"N
60°0'0"N
59°0'0"N
Nondalton
Pedro Bay
Iliamna
Koliganek
Mulchatna River
Kaskanak Creek
Iliamna Lake
Kokhanok
Ekwok
Aleknagik
Igiugig
Nushagak River
Kvichak River
Levelock
Cook Inlet
Dillingham
Clarks Point
Naknek
King Salmon

THE pebble PARTNERSHIP

Figure 4.1-1
Consolidated Study Program 2004-2008
Surface Water Hydrology
Regional Drainage

Legend

- Communities
- General Deposit Location
- Kvichak Drainage
- Nushagak Drainage
- Mine Study Area

Miles
0 10 20 30 40
Kilometers
0 10 20 30 40
N
Scale 1:1,250,000

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: RDI_HDR_Drainages_Fig4-1-1_11X17L_1of1_D01.mxd	Date: March 7,2009
Version: 1	Author: RDI- MRA

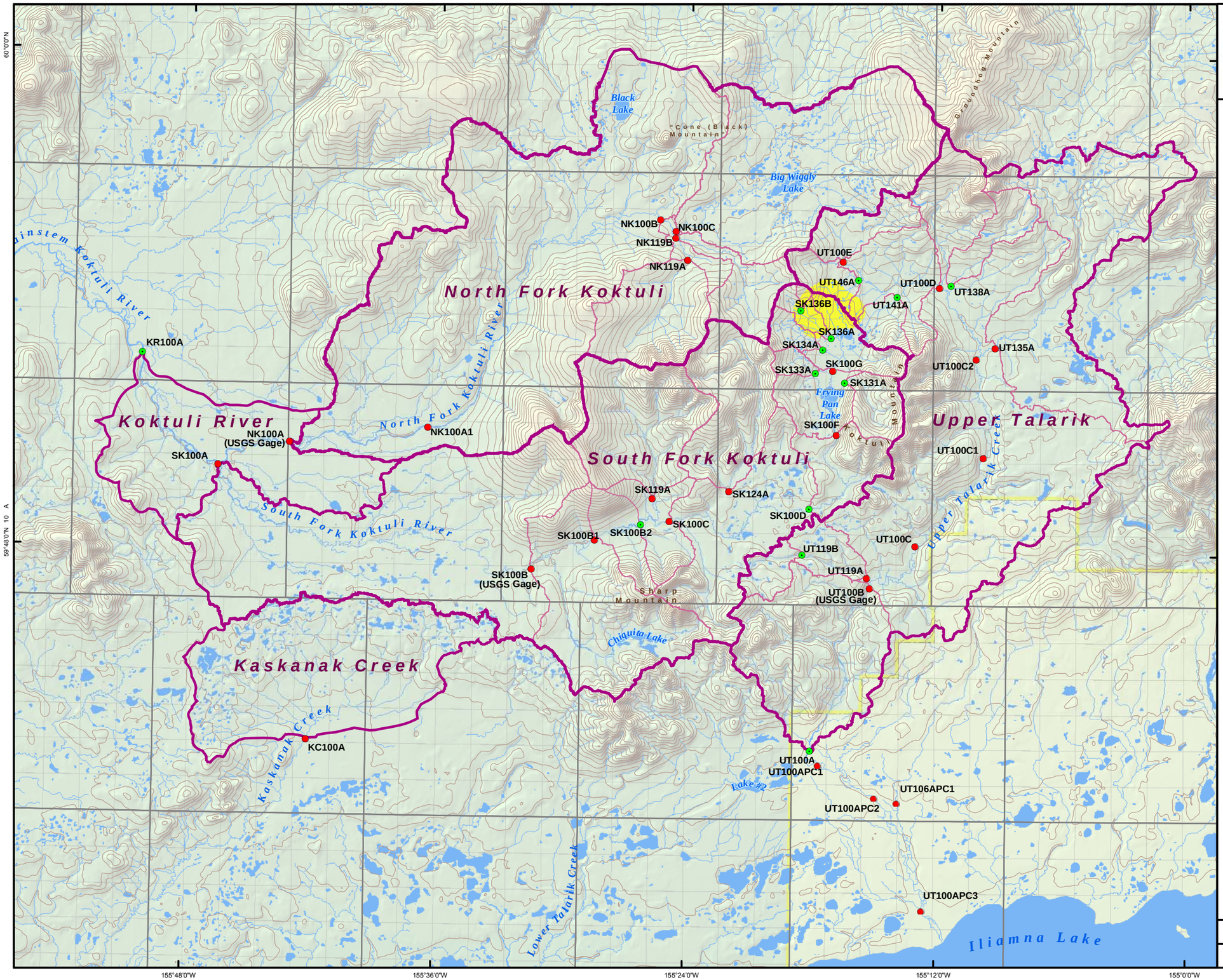

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Figure 4.1-2
Consolidated Study Program 2004-2008
Surface Water Hydrology
Monitoring Drainages and Hydrologic Stations, Mine Study Area

LEGEND

- Major Drainage Boundary
- Sub-drainage Boundary

Baseline Hydrologic Stations

- Continuous
- Instantaneous

- Stream
- Water Feature
- General Deposit Location
- Village Corporation Boundary

0 1.25 2.5 3.75 5 Miles

0 1.25 2.5 3.75 5 Kilometers

N

Scale 1:170,000

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: HDR_Fig4-2_StudyAreaDrainages.mxd,revised	Date: March 19, 2009
Version: 1, revised	Author: HDR - MC, JC; PLP-JG

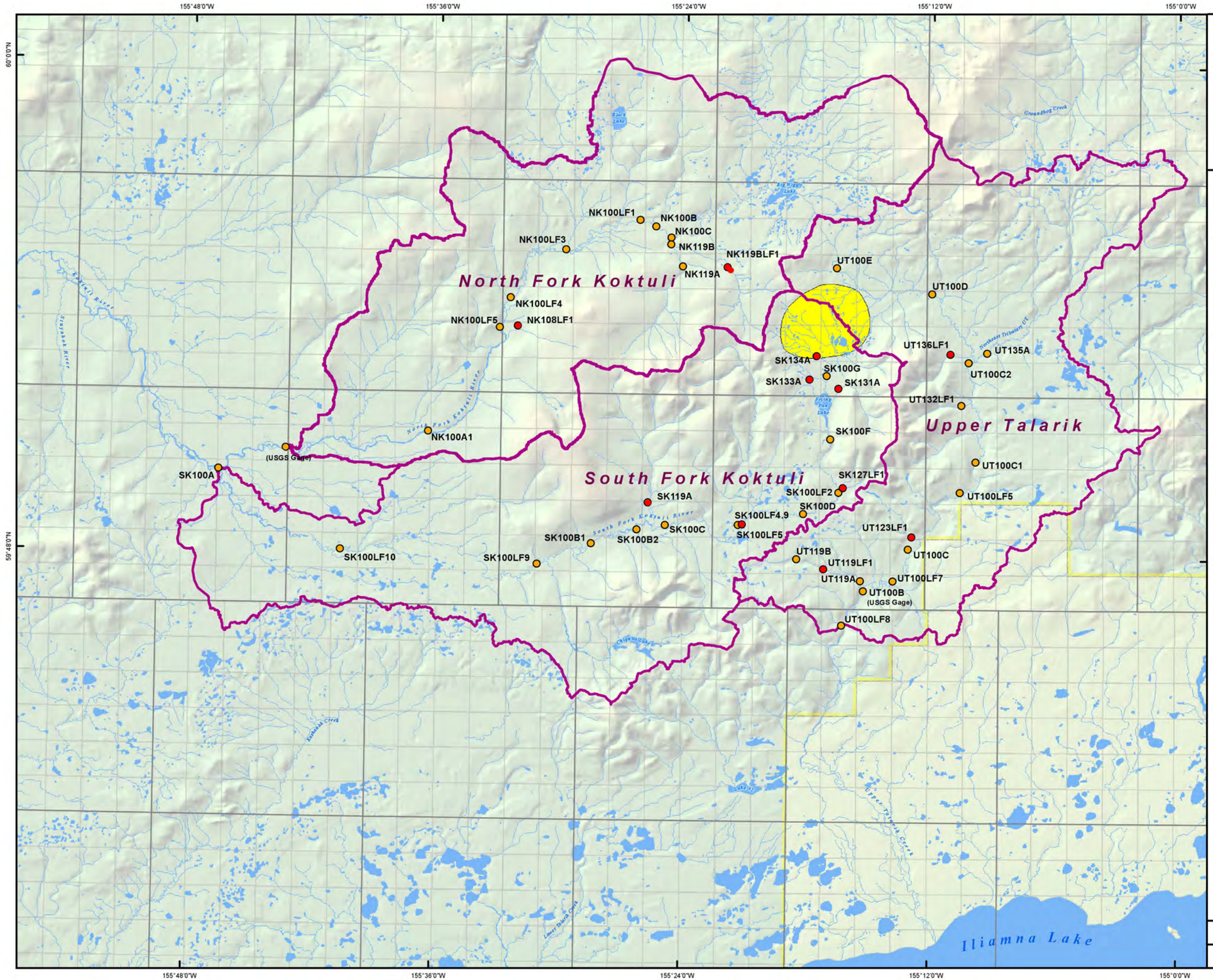

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Figure 4.1-3
Consolidated Study Program, 2004-2008
Surface Water Hydrology
Baseflow Station Locations for
2007 and 2008 Mine Study Area

Legend

- Baseflow Station 2007 and 2008
- Baseflow Station 2008 Addition
- Drainage Boundary
- Stream
- Water Feature
- General Deposit Location
- Village Corporation Boundary

0 1.25 2.5 3.75 5 Miles

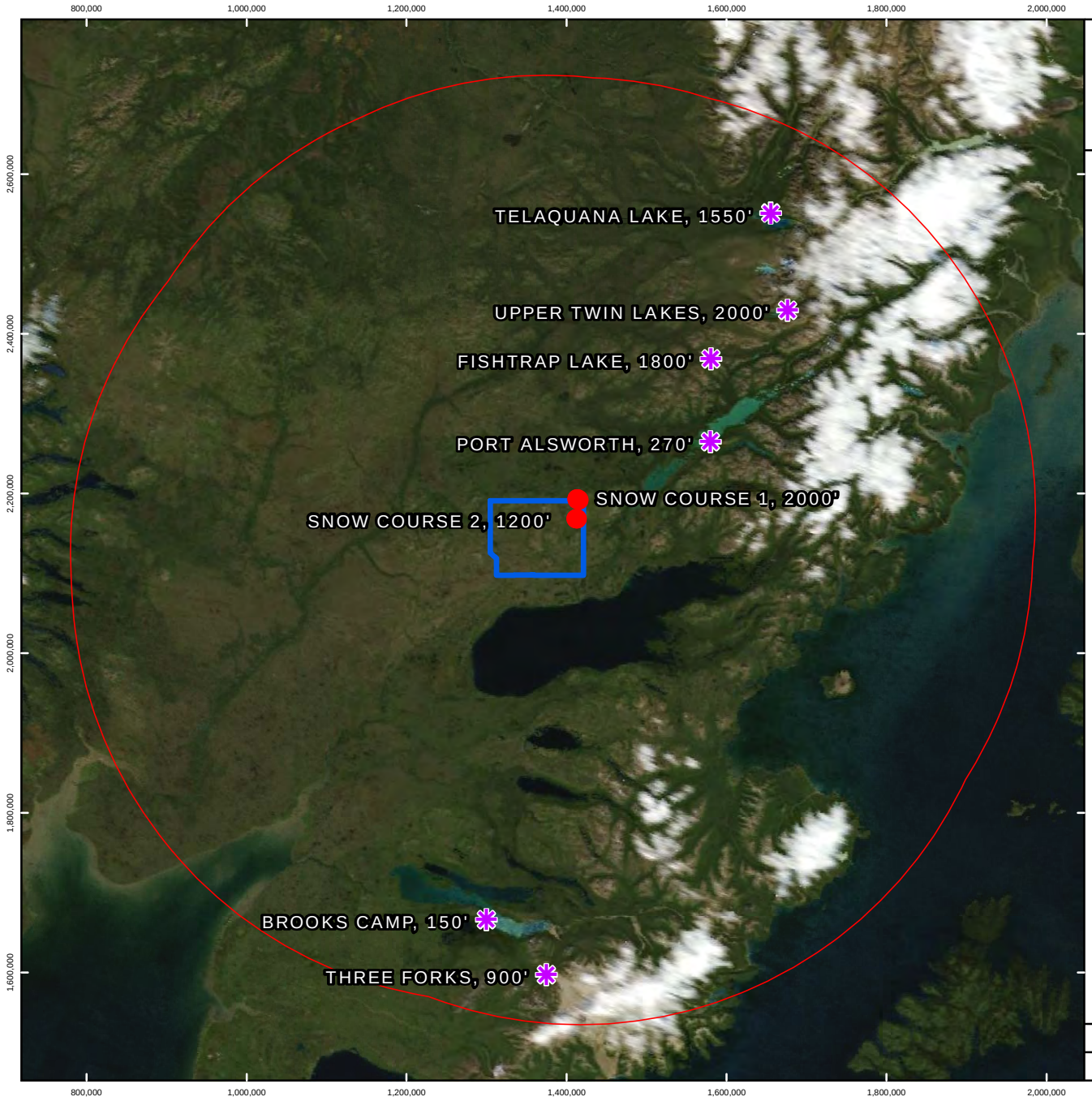
0 1.25 2.5 3.75 5 Kilometers

N

Scale 1:170,000

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: HDR_Fig4.1-2_BaseFlowStatn.mxd	Date: 20 May 2007
Version: 1	Author: HDR - MC

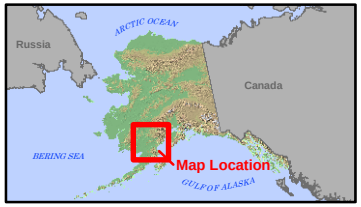


THE pebble PARTNERSHIP

Figure 4.1-4
Consolidated Study Program, 2004-2008
Snow Surveys, Regional NRCS Snow Course Locations

LEGEND

- Pebble Snow Course
- NRCS Snow Course
- Snow Distribution Model Spatial Extent
- 100-mile Buffer of Major Drainages



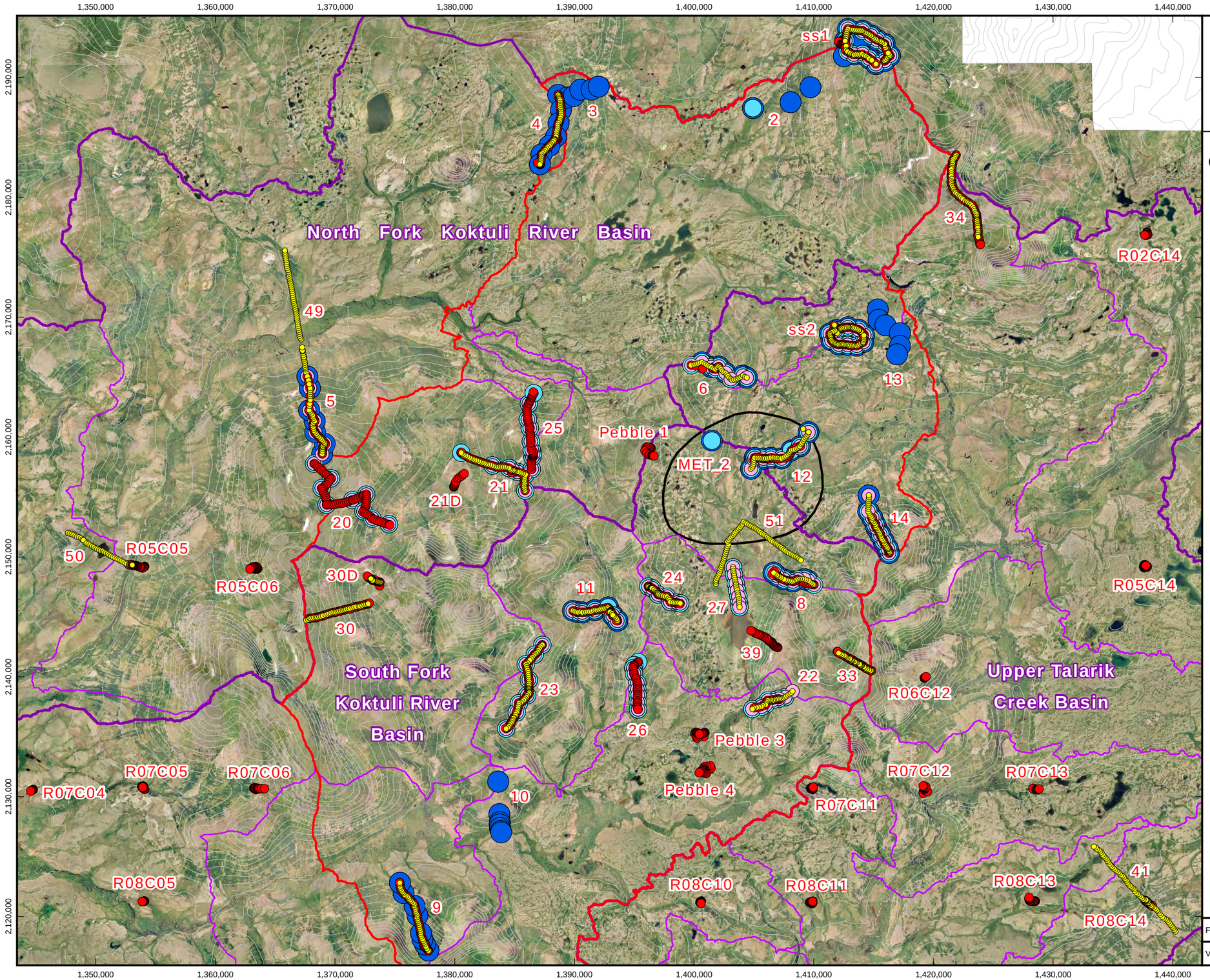
Miles
0 10 20 30 40 50
Kilometers
0 20 40 60 80

N

Scale 1:2,340,000

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: 04_SnowCoursesNRCS_StudyPlan_v03.mxd	Date: Jan. 7, 2008
Version: 3	Author: ABR-AZC



THE pebble PARTNERSHIP

Figure 4.1-5
Consolidated Study Program, 2004 - 2008
Snow Surveys Study Area and
Field Sample Plots,
Mine Study Area

Legend

- 2008 Field Survey Plot
- 2007 Field Survey Plot
- 2006 Field Survey Plot
- 2005 Field Survey Plot
- 2004 Field Survey Plot
- Mine Study Area
- Basin Boundary
- Monitored Sub-basin Boundary
- 100-foot Contour
- General Deposit Location

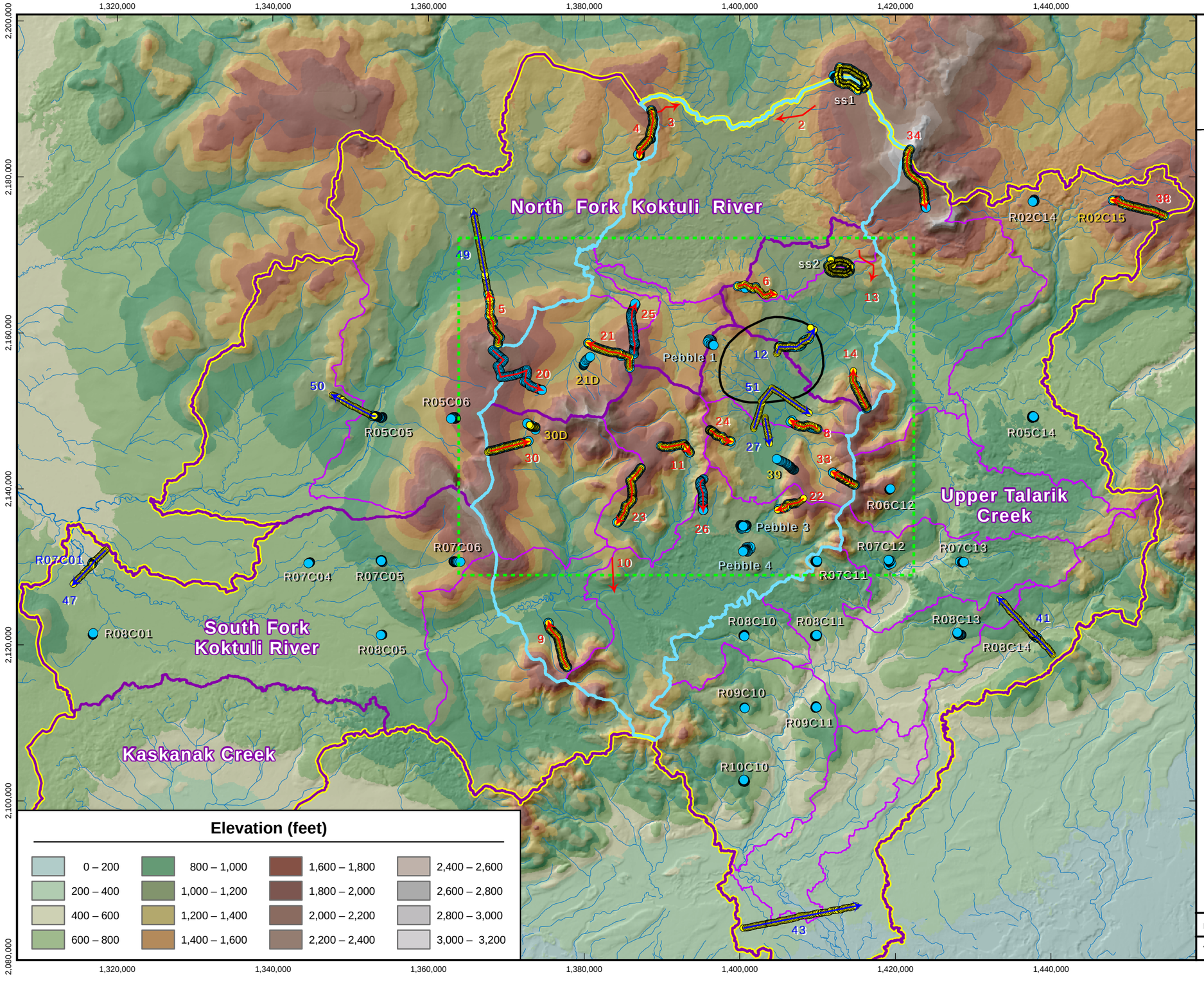
Color orthophotography based on July 2004 1:20,000 scale photography; pixel size is 1.5 feet. Imagery by Kodiak Mapping Inc., Eagle Mapping Ltd., and Resource Data, Inc.

Miles
0 0.5 1 1.5 2 2.5 3
Kilometers
0 1 2 3 4 5
Scale 1:98,000

N

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: 7-2D-03_MineSnowFieldPlots_04-08_PLP_EBD_v01.mxd	Date: Jan. 18, 2011
Version: 1	Author: ABR-AZC



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Legend

- Mountain Transect
- Valley Transect
- Snow Course
- R05C14 — Extensive Grid Transect
- 39 — Drift Transect
- Pebble 1 — Meteorological Station
- 2008 Field Survey Plot
- 2007 Field Survey Plot
- Mine Study Area
- Extended Mine Study Area
- Basin Boundary
- Monitored Sub-basin Boundary
- General Deposit Location
- Lidar Acquisition Area

Miles 0 1 2 3 4 5

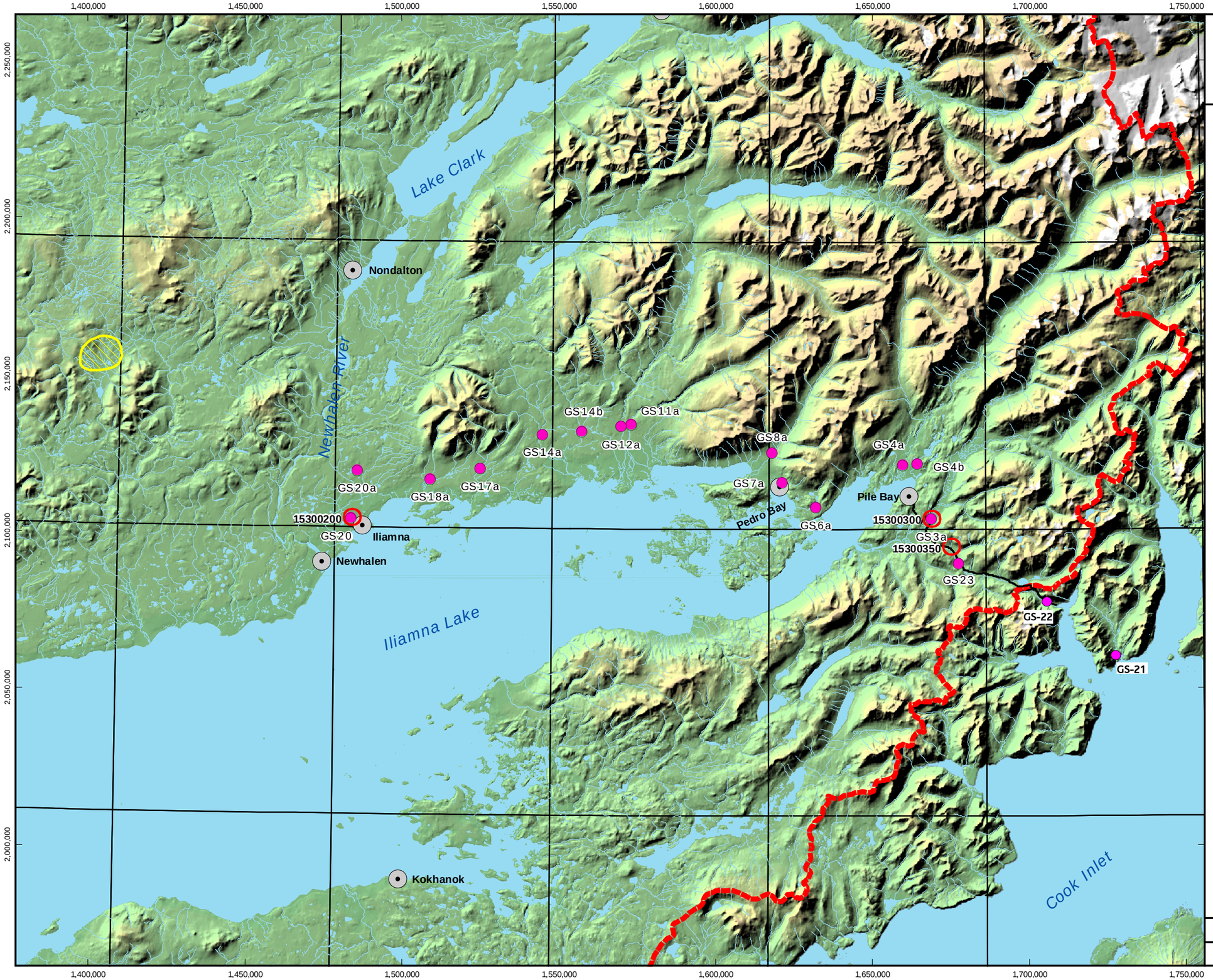
Kilometers 0 2 4 6 8

Scale 1:150,000

N

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: 7-2D-08_ExtMineSnowFldPlots04-08_PLP_EBD_v01.mxd	Date: July 23, 2010
Version: 1	Author: ABR-AZC



THE pebble PARTNERSHIP

Figure 4.2-1
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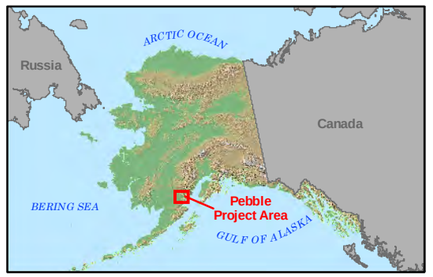
Transportation Corridor/
Cook Inlet Study Areas

Legend

- Surface Water Gage Station (USGS)
- Surface Water Gage Station (PLP)
- Towns
- Existing Roads
- General Deposit Location
- Bristol Bay/Cook Inlet Hydrologic Divide



0 4 8 12 16 Miles

0 5 10 15 20 Kilometers

N

Scale 1:363,852

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: Hydro_EBD1a_V04.mxd	Date: February 8, 2011
Version: 4	Author: BEESC-ME

PHOTOGRAPHS

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Pebble Project
Environmental Baseline Studies
2004 through 2008

CONSOLIDATED STUDY PROGRAM

5. GROUNDWATER HYDROLOGY

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ACRONYMS

ASPCS	Alaska State Plane Coordinate System
AASTM	American Society for Testing and Materials
BEESC	Bristol Environmental & Engineering Services Corporation
bgs	below ground surface
CSP	consolidated study program
EBD	*Pebble Project Environmental Baseline Document, 2004 through 2008*
HDR	HDR Alaska, Inc.
Hoefler	Hoefler Consulting Group
ID	inside diameter
KP	Knight Piésold Consulting Ltd.
NK	North Fork Koktuli River
PVC	polyvinyl chloride
SK	South Fork Koktuli River
SLR	SLR International Corp.
SRK	SRK Consulting (Canada) Inc.
3PP	Three Parameters Plus
USGS	United States Geological Survey
UT	Upper Talarik Creek
WMC	Water Management Consultants

5. GROUNDWATER HYDROLOGY

The groundwater hydrology study for the environmental baseline description for the Pebble Project has multiple components, including installing monitoring wells and piezometers, groundwater sampling, and hydraulic testing.

Several consultants have contributed to the groundwater hydrology study:

- CH2M Hill led the hydrogeology program until mid-October 2004.
- Bristol Environmental & Engineering Services Corporation (BEESC) collected the first complete round of groundwater samples in October 2004.
- SLR International Corp. (SLR) assembled and prepared field data in January 2005 and carried out the field hydrogeology program throughout 2005 and 2006.
- Water Management Consultants (WMC) provided hydrogeological advice to CH2M Hill until mid-October 2004, completed the field program at the end of the 2004 season, provided lead hydrogeological input to the groundwater program in 2005 and 2006, and is now responsible for characterizing the site hydrogeology.
- HDR Alaska, Inc. (HDR) carried out seepage and surface water monitoring from 2005 through 2008, and provides input to surface-water/groundwater interaction studies.
- Three Parameters Plus (3PP) provided input to hydrogeological studies in and around wetlands.
- Knight Piésold Consulting Ltd. (KP) provided geotechnical input and assisted with piezometer installation, testing, and monitoring from 2004 through 2008.
- SRK Consulting (Canada) Inc. (SRK) provided engineering input to the groundwater hydrology study team for water balance modeling.

Since 2005, WMC has been the prime consultant for the hydrogeology study in the mine study area. Hydrogeology studies were not conducted in the transportation corridor/Cook Inlet study areas.

5.1 Objectives of Study

The objectives of the groundwater hydrology study for the mine study area are as follows:

- To characterize the existing groundwater flow regime within the study area and define how the local groundwater regime interacts with the regional groundwater system.
- To support aquatic, fish resource, and wetlands habitat baseline studies.
- To provide data for other discipline studies.

5.2 Study Area/Scope

The mine study area is located in the headwaters of Koktuli River and Upper Talarik Creek (Figure 5-1). The mainstems of these two systems flow primarily within floodplain channels eroded into glacial deposits that form the valley infill. The valley infill is bounded by bedrock mantled with glacial overburden. Lakes and wetlands are common features in the landscape. These geologic materials and surface waters define existing groundwater levels, flow, and chemistry in the study area. Their locations and relative effect on groundwater regime, therefore, are important factors in defining the area extent of the groundwater hydrology study.

Bedrock in the study area includes Jurassic and Cretaceous sedimentary and volcanic rocks intruded by Cretaceous granodiorite to monzonite overlain by Tertiary sedimentary and volcanic rocks. Several glaciers have advanced and retreated over these base materials. The current landforms are most likely formed from the Kvichak Stade of the Wisconsin Brooks Lake Glaciation. As a result, the lower slope materials and valley infill are primarily glacial debris with some overlying alluvial deposits. The infill materials include end, lateral, and recessional moraines; ground moraine; glacio-lacustrine sediments; and outwash sands and gravels. Outwash sands and gravels typically have the highest hydraulic conductivity. Upper slopes and ridges include exposures of highly fractured bedrock, talus, rubble, and solifluction deposits. No permafrost has been detected during the site investigations.

Most of the detailed geologic investigations have been focused in the deposit area. Starting in 2007, additional drilling was performed in the Upper Talarik Creek (UT) and North Fork Koktuli River (NK) to improve characterization of the subsurface geology.

The surface exposures of highly fractured bedrock are very open and probably provide a pathway for relatively high rates of groundwater recharge. High water-returns during air-rotary drilling and low rock-quality-designation (RQD) values of core samples indicate that the hydraulic conductivity is usually high in the upper bedrock. This appears to be due to intense fracturing. The intense fracturing is up to about 50 feet thick. Piezometric data suggest that elevated hydraulic conductivity is not continuous. Below the upper bedrock, the hydraulic conductivity generally decreases with depth. However, high artesian flows from some of the deep exploration drillholes suggest that permeable faults occur within the study area. Hydraulic conductivities within these faults at these locations are exceptions to the general decrease in hydraulic conductivity with depth below the upper bedrock zone.

Refraction seismic profiles have been carried out on-site under the direction of KP personnel. These profiles provide information to assist in interpolation and extrapolation of drillhole data. These data continue to be important.

The overall scope of the groundwater hydrology study is to quantify the groundwater in the vicinity of Pebble West and Pebble East. This is being done by collecting comprehensive information on the groundwater system, including surface and subsurface geology, hydrogeologic parameters such as piezometric levels and hydraulic conductivities, locations of groundwater recharge and discharge areas, and existing groundwater quality within areas of mineralized and barren rock as well as within alluvial aquifers. The work includes developing conceptual and numerical models to characterize background conditions, to evaluate potential changes in local and regional water tables, and to estimate the

groundwater interaction with local streams, wetlands, and lakes. The results of the work provide input to the initial environmental evaluation.

5.3 Methods/Approach

The general approach used for the groundwater study evolved over time, as knowledge has been gained. In 2004, the goal was to develop an initial understanding of the hydrogeology in the area of the deposit, therefore, the general approach focused on the following:

- Collating and interpreting existing hydrology (i.e., groundwater and surface water) data collected prior to 2004.
- Determining locations and well-completion details for baseline groundwater monitoring wells.
- Installing, testing, and sampling baseline monitoring wells.
- Installing, testing, and sampling supplementary groundwater monitoring sites.
- Hydraulically testing key units.

The general approach for subsequent phases of the groundwater study expanded on this early work, including the following:

- Collating and interpreting all data collected to date.
- Testing and sampling existing baseline monitoring wells.
- Determining in detail the need and locations for additional monitoring wells.
- Installing, testing, and sampling baseline monitoring wells at new locations.
- Identifying and continued hydraulic testing of key hydrogeologic units.
- Developing a conceptual site-wide groundwater model.
- Developing a detailed understanding of the hydrology in the area of the deposit and surrounding drainages.
- Developing numerical groundwater models, as appropriate.

Details on how this approach has been implemented are described in the next sections.

5.3.1 Program Overview

The hydrogeology program is based on extensive field investigations that have included monthly measurements of up to 311 piezometric levels at 185 locations and groundwater samples collected quarterly at up to 39 clustered monitoring wells at 21 locations. The sampling conducted at piezometers and monitoring wells as of the end of 2008 is listed in Tables 5-1a through 5-1e, and summarized in Table 5-3. The piezometer and well locations are illustrated on Figure 5-2.

The field work includes drilling, installing, and developing piezometers and monitoring wells; measuring groundwater levels; sampling groundwater; and aquifer testing. The work is carried out on individual and

clustered groups of wells drilled to various depths, and one multi-zone Westbay System Activities well (the Westbay System).

KP field personnel, as part of their collection of geotechnical information for design purposes, have installed and tested 100 of these piezometers.

In addition, 71 piezometers and water-level gages have been installed in selected wetland areas (Table 5-1e, Table 5-3) to define groundwater conditions in these areas. The piezometers have been installed by SLR in cooperation with 3PP. Water levels are measured monthly in these piezometers and gages.

Additional piezometers and monitoring wells were installed to further characterize groundwater conditions in the UT and NK drainages. Starting in 2007, installations were made in the NK drainage, at the boundary between the NK and UT basins, within the UT basin, in specific areas within the South Fork Koktuli River (SK) basin.

The following sections outline basic requirements for drilling, installing, sampling, and collecting measurements from monitoring wells and piezometers, pumping wells, and the Westbay System(s).

5.3.2 Monitoring Wells and Piezometers

Piezometers and monitoring wells are used to collect information on stratigraphy, hydraulic conductivity, groundwater levels, and groundwater quality. Water-level measurements are taken in selected monitoring wells and piezometers monthly. Groundwater samples were collected from selected monitoring wells and are submitted for laboratory analyses. The analytical methods for the groundwater samples are detailed in the quality assurance project plan (Appendix G of the *Pebble Project Environmental Baseline Document, 2004 through 2008* [EBD]).

Wells are installed individually or in clusters, and each well-cluster location may include up to three wells installed at nominal depths of approximately 30 to 50 feet, 70 to 100 feet, and 150 to 200 feet. The number of wells at each site and the actual depths will vary depending on site conditions. The locations of some wells/piezometers will be determined in the field at the time of drilling.

5.3.2.1 Locating and Surveying Monitoring Wells and Piezometers

The proposed locations, drilling methods, and depths for the monitoring wells to be installed each year are determined during pre-season meetings and in the field.

Once a location has been identified and before drilling begins, SLR field-team members and drilling contractors locate the site of each well and piezometer using cadastral survey and global positioning system (GPS) coordinates and then visit the sites with WMC personnel. No intrusive action begins until SLR, the Pebble Partnership, and the drilling contractor agree that drilling rigs can be moved safely without causing harm to human health or the environment.

After each new well or piezometer is installed, a surveyor mobilizes to the site to survey Alaska State Plane Coordinate System (ASPCS) coordinates and elevations. Horizontal control is conducted to first-order accuracy (±1.0 foot), using the ASPCS, North American Datum of 1983 (NAD83). Vertical control

is conducted to third-order accuracy (±0.01 foot), using both APSC, North American Vertical Datum of 1929 (NAVD29; old) and 1988 (NAVD88, new).

Well elevations are surveyed at the top of the riser pipe and at the ground surface. All surveying data are recorded in a bound field logbook. SLR and WMC are provided with a table summarizing survey locations of all newly installed monitoring wells and piezometers.

5.3.2.2 Nomenclature for Identifying Wells and Piezometers

Wells and piezometers are identified using an alphanumeric nomenclature composed of the following components in the order shown below:

- MW, P, PW, or WL = abbreviations for monitoring well, piezometer, pumping well, or wetland piezometer, respectively. (At times, holes drilled for geotechnical or resource investigations were completed for use as monitoring wells or piezometers; they are identified by GH and I, respectively, sometimes preceded by abbreviations, such as KP or SRK, identifying the consulting firm responsible for drilling the original holes).
- Year = two digit number representing the last two digits of the year the location was drilled. (In 2004, the year-number was not fully adopted at all locations, and the year-number is not used to name wetland piezometer locations).
- Well or piezometer site number = two- or three-digit sequential number from 01 to 999. Numbers are assigned sequentially by completion and are carried over from year to year.
- Wetland piezometer = P indicating the piezometer location is in an upland position near a wetland pond, and S indicating the location is in the pond.
- Well type (if in a cluster) = single alpha character denoting general well depth, as follows:
  - SS = super shallow: less than 30 feet deep.
  - S = shallow: 30 to 50 feet deep.
  - M = intermediate: 70 to 100 feet deep.
  - D = deep: 150 to 200 feet deep.

Several examples are provided:

- MW-05-20S denotes a shallow (S) monitoring well (MW) drilled in the year 2005 (05) at the 20th well site or array (20).
- MW-06-40D denotes a deep (D) monitoring well (MW) drilled in the year 2006 (06) at the 40th well site or array (40).
- P-07-43M identifies an intermediate (M) piezometer (P) drilled in the year 2007 (07) at the 43rd well site or array (43).
- WL-P06D identifies a deep (D) piezometer installed in an upland position (P) near the sixth (06) wetland (WL) monitored for the small pools study.
- WL-S06S identifies a shallow (S) piezometer installed in the pond (S) at the sixth (06) wetland (WL) monitored for the small pools study.

5.3.2.3 Installing Monitoring Wells

Monitoring wells are installed according to requirements outlined in *Recommended Practices for Monitoring Well Design, Installation, and Decommissioning* (ADEC, 1992) and American Society for Testing and Materials (ASTM) *Method D 5092-04e1, Standard Practice for Design and Installation of Groundwater Monitoring Wells* (ASTM, 2004).

Drilling

Well borings are drilled either with an ODEX drilling system that employs a down-hole hammer and a 5- or 6-inch-inner-diameter (ID) continuous casing or with a rotary rig with HQ- or NQ-size drill-rod system. Use of the ODEX or rotary drill method depends on the relative efficiency, availability, and effectiveness of each rig, as determined in the field.

Drilling in the mine study area has revealed heaving sands. Heaving sands are controlled with water, but should this prove not to be possible, screens can be jetted into place by hooking the water hose to the top of the riser after the casing has been pulled back.

Field personnel collect cuttings from borings in order to prepare soil descriptions. Cuttings are photographed, bagged, and labeled at 5-foot intervals. The bagged samples are stored for future reference in plastic 5-gallon buckets labeled with the drillhole number, and dates and depths of samples. Visual inspection of the cuttings, together with observations of drilling activity, provides information about the characteristics of geologic materials.

Each soil boring is logged to provide a record of subsurface conditions encountered during drilling. The logs are prepared and maintained by the field supervisor overseeing the drilling activities. Observations are recorded on soil-boring logs. Boring logs are prepared in accordance with ASTM Method D 2488-00 (ASTM, 2000). Other documented observations include the following:

- Drill-rig behavior, such as rate and chatter, plugging of the return hose, and driller's observations.
- Addition of water (if any) into hole.
- Rate of water flow (if any) out of hole.

Well Design

In well-arrays (or clusters), each well in the array is installed in a separate hole, with approximately 15 to 20 feet of horizontal separation between holes. These borings are drilled to depths predetermined prior to the field visit. If the drilling equipment used requires the drive shoe to be left in the boring for a well completion, the boring is over-drilled by about 10 feet before the drive shoe was knocked off to create a rat-hole. Well-screen placement is determined after the rat-hole has been sealed during construction. Screens typically are placed across two or three depth intervals (shallow, intermediate, and/or deep) in each well array as follows:

- In shallow wells (30 to 50 feet), well screen is installed across the water table.
- In intermediate wells (70 to 100 feet), well screen is installed beneath the water table across the most permeable horizon of deep overburden.

- In deep wells (150 to 200 feet), well screen is placed beneath the water table at the fractured bedrock surface or sealed into bedrock.

Decisions on what intervals to screen are made after drilling through overburden to bedrock. At sites where previously-drilled geotechnical coring results are not available or where permeable bedrock is indicated, the drilling may extend into bedrock, if the supervising hydrogeologist finds it necessary. Well screen length varies to allow for screening and sampling of all aquifer materials in a target horizon being monitored, but is short enough to avoid crossing aquitards and joining adjacent aquifers. No screens are installed across confining units or across the bedrock/overburden interface unless an upper fractured bedrock surface is being monitored.

Well Construction

Subsurface well construction will include (from the bottom up) the following features:

- If necessary, the casing shoe is sealed at the bottom of the drillhole beneath at least 3 feet of bentonite pellets and 3 feet of transition sand before the riser pipe is placed in the casing.
- Monitoring wells are constructed of 2-inch-diameter, Schedule 40 or Schedule 80, flush-joint threaded, polyvinyl chloride (PVC) riser pipe with O-rings, extending approximately 3 feet above surface grade.
- Well screens are constructed of Schedule 40 or Schedule 80, 0.020-inch machine-slotted PVC pipe capable of retaining filter sand.
- Filter sand packs are 10-20 sieve silica sand, placed at least 2 feet above the top of the screen while pulling the casing in small increments and maintaining the filter sand below the bottom of the casing. Filter sand is not required if sands are heaving after the screen is placed.
- A 5-foot bentonite pellet plug is placed above the sand to seal the annulus above the sand. This plug does not have to be placed when heaving sands are collapsing around the riser. Instead, the casing is pulled until the heaving stops, and then the plug is installed. If placement of the bentonite plug is not feasible, grout is placed directly on top of the sand. An additional 1 foot of transition sand is placed for every 10 feet of grout to prevent the grout from penetrating the monitoring zone.
- Bentonite grout is placed above the plug through a Tremie pipe from the bottom up, with at least 30 percent solids by weight. The grout is pumped until return is observed at the surface. The casing is removed in sections, and grout is pumped until return is again observed. The bentonite grout is completed to a depth of approximately 10 feet below ground surface (bgs).
- At a depth of 10 feet bgs in each well, a bentonite/cement grout mixture (10 gallons water, 10 to 25 pounds bentonite, and 100 pounds Portland cement) is used to seal the annular space to ground surface and set the protective casing.
- Grout fallback at surface is recorded approximately 1 day after well completion.
- The length of PVC riser installed in the hole is verified with the following procedure:
  - Verify the length of each PVC pipe before it goes into the well, as follows: Lay the PVC pipe to be installed on the ground, double-check and record the lengths, and record the number of pipe sections.

  - Measure the cutoff.
  - Calculate the total length of PVC installed in the hole.
  - Measure the total depth of the well from the top of the PVC casing prior to placing any backfill and verify that the measured total length of PVC matches that placed in the well.
- Surface completion includes cementing a 5-foot, locking, steel, protective surface casing into place; placing filter sand in the annulus between the casing and the riser pipe; and attaching a 10-foot-tall reflective road marker to the steel casing. The steel casing was painted safety yellow or orange for increased visibility.

Well Development

Before they were sampled, newly constructed monitoring wells are developed to remove fines from the borehole to enhance the flow of formation water through the well, and to provide water samples with a minimal amount of suspended solids. Monitoring wells are developed after the surface seal has hardened and a minimum of 24 hours has passed after installation. Wells are developed with a high capacity, 1-inch-diameter inertial pump fitted with a surge block and operated by an electric- or gasoline-powered actuator. This method is used to maximize the sediment drawn in from the filter pack during development. A gasoline-powered suction pump may be used in some cases to polish the well.

The following parameters are monitored during development:

- Volume of water pumped.
- Quantity, color, and size of sediment removed.
- pH, temperature, specific conductance, and turbidity of water.
- Comments on well yield and results of development.

Water-level measurements are collected before and after development. All development data are recorded on a well development log.

The following technique is used for developing monitoring wells and piezometers:

1. Measure and record the water level and total depth of the well by means of a water-level indicator. Note any accumulated sediment thickness, and record all information in a logbook.
2. Lower the pump tubing with surge block to the bottom of the screen, and start the actuator. After 1 or 2 minutes, collect a water sample for filtration.
3. Filter the water sample through a 0.45-micrometer filter, and take a “before” picture of the filter.
4. Continue development until a noticeable decrease in sediment yield has been observed, to a maximum of 45 to 60 minutes.
5. Move the surge block approximately 2 feet up the screen and repeat the process.
6. Continue moving the surge block up the screen until the full screen has been developed.

7. After completing the screen surging, remove the surge block and lower the pump to the bottom of the well to remove the accumulated sediment. Then move the foot valve to about 5 feet above the top of the screen, and pump the well to polish the development.
8. The well is considered adequately developed if the water discharged by the pump is clear and includes less than 1 tablespoon of fine sand per 5 gallons of water. If more sand than this is present, repeat the process for up to 4 hours.
9. After stabilization (or 4 hours of surging and pumping), pass development water through a 0.45-micrometer filter and take an "after" picture of the filter. Measure the pH, temperature, specific conductance, and turbidity of the final developed water.
10. As a final step, lower the foot valve to the bottom of the well again to collect any sediment that accumulated during polishing of the well.

Response Testing

All groundwater monitoring wells installed in the mine study area have been response- (slug-) tested. Most of the 2004 testing was completed by CH2M Hill field personnel. WMC and SLR field personnel conducted a few 2004 and all 2005, 2006, 2007 and 2008 tests. The WMC hydrogeology team has analyzed the data to determine the apparent hydraulic conductivity near each installation. This activity will be continued with all wells installed in the future.

Response tests are completed shortly after well development and follow the standard test method in ASTM Method D 4044 (ASTM, 1996).

Before the response test is conducted, the depth to water is measured from the top of the PVC riser pipe with an electric sounder. The length that the PVC extends above the ground surface is also recorded. A down-well pressure transducer is then lowered into the well. The change in groundwater level as a function of time is monitored with the pressure transducer and field computer to demonstrate that the water level in the monitoring well has reached its static level or is responding only to regional changes in piezometric head after the transducer has been placed in the well. Water levels are measured using a well sounder before and after the response test to correlate the pressure-transducer reading to water-level elevations. The watch time for recording manual readings is synchronized with the time being recorded by the datalogger.

A slug of known volume then is rapidly lowered into the well (this slug is normally a 1-inch diameter tubing, of the same type used for well development, but that is sealed at the end). The change in water level displaced by the slug is monitored by means of the down-well pressure transducer and the datalogger as it returns to the static level. After the water level has returned to the static level, the slug is rapidly removed from the water. The water level is again monitored as it returns to the static level.

The water-level recovery data are plotted in the field to determine that enough data for analysis has been collected. If necessary, a field computer is used to plot and evaluate the data. The response test is repeated until two tests (one test is a slug-in/slug-out cycle) with enough recovery data for analysis have been completed. If the water-level recovery is slow, the recovery is monitored for up to 1 hour. Test monitoring may therefore be up to two hours (monitoring of slug insertion and slug withdrawal) per test, and only one test (slug in/slug out cycle) is conducted in this circumstance.

5.3.2.4 Installing Piezometers

Piezometers are installed to measure piezometric (i.e., water pressure) levels and aquifer response to pumping tests.

Piezometers are designed, drilled, installed, constructed, and documented in the same manner as for monitoring wells (as described above). Piezometers also are developed using procedures similar to those for monitoring wells, but for a shorter duration, because development is necessary to improve response to piezometric-level changes rather than to remove sample turbidity.

Piezometers are response tested in the same manner as for monitoring wells (as described above). While drilling geotechnical holes in the deposit area, KP field crew carried out hydraulic conductivity packer tests (also known as Lugeon tests) in both 2004 and 2005. KP crew also conducted rising and falling head tests in piezometers installed in this area. Additional packer tests were not planned in the Pebble West area for 2007, but are considered for future years.

During 2004, KP field crew also performed rising and falling head tests in GH-series piezometers installed outside of the immediate area of the Pebble West. A sounding tape was used to monitor water levels; therefore, many of the well responses could not be measured because they were too fast.

5.3.3 Pumping Wells

Pumping wells are installed to conduct tests that help define hydraulic properties of strata and related aquifers. Each site for overburden pumping tests consists of one or two pumping wells installed in proximity to one another.

These wells and related piezometers are installed using an ODEX drilling rig. Wells are pumped using an airlift method with compressors or with submersible pumps. A step test precedes the pumping test to determine the most appropriate pumping rate for the constant-rate test. The drilling contractor provides appropriate equipment to measure the pumping rate. Groundwater samples and water level measurements also may be collected by field personnel, according to the same protocols as described for monitoring wells and piezometers.

5.3.3.1 Well Design

Five-inch-ID pumping wells with 4-inch-ID screen are installed for the pumping tests. Selection of pumping-well locations and design is based on the information gained during installation of nearby piezometers. The locations and the depths are selected in the field and approved by SLR and WMC project personnel.

The pumping-well screen normally is placed in the most permeable horizon encountered during drilling. The screen slot size is selected by SLR, in consultation with WMC, from available stock based on the grain-size distribution of the screened horizon. Screen length and its placement in the borehole varies to allow for screening and sampling of the target aquifer materials and is short enough to avoid crossing aquitards and joining adjacent aquifers.

5.3.3.2 Well Installation and Construction

Wells for the pumping tests are installed using the ODEX drilling rig. During drilling, each pumping well is logged in the same manner as for the monitoring wells and piezometers, except that pumping wells are drilled with 5-inch-ID welded casing rather than the threaded casing used for monitoring wells and piezometers. After drilling to final depth, the casing shoe is knocked off. The screen and K-packer assembly is lowered into the well, and the casing is retracted to expose the screen.

5.3.3.3 Well Development

Pumping wells are developed by the drilling contractor using air-jet and airlift methods. Development continues until the return has cleaned significantly and/or optimal well yield has been achieved.

5.3.3.4 Pumping Test Procedure

The ODEX drilling contractor carried out the pumping tests under the supervision of SLR. The wells are pumped with the airlift method using compressors supplied by the drilling contractor or with a submersible electric pump. The actual pumping methods are determined in the field based on field conditions. Therefore, the drilling contractor is required to mobilize the necessary equipment to accomplish the following:

- Airlift from multiple small-diameter wells.
- Measure and record the air-lifted water pumping rate.
- Discharge the water at a suitable surface location at least 1,000 feet from the well. The discharge is to land, with infiltration occurring before the discharge can reach surface water.

Pumping tests are planned to consist of 24 hours of constant-rate pumping followed by a minimum of 24 hours of monitored recovery. The pumping tests are preceded by a step test to determine the optimal pumping rate. The wells are allowed to stabilize after the step test before starting the pumping test.

The pumping tests are conducted according to the following procedure:

1. Install a pressure transducer for monitoring background groundwater levels in a nearby piezometer or monitoring well beyond the radius of influence of the pumping test at least 2 days before the test starts.
2. Install pressure transducers in the piezometers to be used as observation wells for the pumping test as they are completed, at least 2 days before the test starts, and before drilling of the pumping well begins.
3. Install a barometric logger in a nearby piezometer simultaneously with installation of the first pressure transducer.
4. Measure the water level in the piezometers manually at regular intervals during the step test and pumping test to confirm the pressure-transducer readings and to relate the pressure-transducer data to surveyed elevations.

5. Conduct a step test in the pumping well by adjusting the submergence depth of the pipe used for injecting compressed air. Note the water-flow rate and air pressure at each step. The duration of the step test will be one to four hours.
6. Based on the results of the step test, choose a submergence depth for the pipe for the constant-rate test.
7. Monitor the recovery from the step test in the pumping well and piezometers.
8. Start the constant-rate pumping test at the chosen rate after the water levels have fully recovered.
9. Transmit the water-level data to WMC at the end of the first day.
10. Continue pumping until one of the following conditions has been observed:
    - The drawdown capacity of the transducer has been surpassed.
    - The water levels have stabilized and are unlikely to change.
    - 24 hours have passed.
11. After the pumping is terminated, monitor recovery for a minimum of 24 hours or until full recovery has occurred.

Information gathered during the pumping test is recorded on field forms and in the field logbook.

As of 2008, pumping tests have been completed at nine locations: PW-1, PW-3, PW-4, PW-5, PW-6, PW-7, PW-8, PW-9, and PW-10 (PW-2 has not been drilled). Wells PW-3, PW-4, PW-7, and PW-9 were completed in overburden, and wells PW-1, PW-5, PW-6, PW-8, and PW-10 were completed in bedrock. The wells were then developed and tested by air lifting. Several piezometers were monitored during each pumping test.

Drill circulation losses and gains for resource drilling were monitored in late 2006 and continued to be monitored by SLR field crew through 2008. In addition, in 2006 SLR personnel reviewed all existing information from 2004 through 2006.to identify drill circulation losses or gains in resource and geotechnical drilling. This information provided a qualitative assessment of the location of high permeability areas. In the coming years, this program may be continued, and as the MDC evolves, additional testing such as response to core pulling, air lift, and injection testing can be carried out. Full-scale pump tests will be considered when mobile equipment can be moved to the site.

5.3.4 Westbay System Multi-level Piezometers

In November 2006, exploration hole NDM-6349 (located in the Pebble West deposit area) was instrumented with a multi-zone well (the Westbay System, distributed by Westbay Instruments Inc. [Westbay]). It was completed with 50 packers, 50 measurement ports, and 25 pumping ports to a depth of 4,050 feet, and included surface equipment to allow field personnel to lower and raise specialized tools in the well. The installation and operational procedures for the Westbay System are detailed in the Westbay operator training manual (Schlumberger, n.d.) and are summarized below.

5.3.4.1 Drilling

The drilling begins by installing a surface casing, followed by drilling as far as possible with HQ-size coring equipment, and stepping down to complete the hole with NQ-size coring equipment, if necessary. The hole is drilled with a wireline coring rig to the final depth; HQ drill size was preferred.

5.3.4.2 Well Design

WMC personnel, with assistance from Westbay's field consultants, selects appropriate bedrock zones to monitor. The locations of packers, measurement ports, and pumping ports are selected following review of available geologic, geotechnical, and geophysical logs of the drillhole. The installation design emphasizes isolating zones that will define hydrostratigraphic conditions.

5.3.4.3 Well Construction

The installation generally includes the following.

- The casing components are laid out in order before being lowered into the hole.
- After completion of drilling, drilling fluid in the hole is replaced with clean water.
- Drill rods are removed, but N-casing (HQ rods) are left in the drillhole.
- The Westbay Model MP-38 casing components are assembled and lowered into the drillhole. Each assembled joint is pressure tested to reduce the potential for leakage.
- Water is added to the Westbay casing as it is assembled to sink the Westbay casing string into the drillhole. As the length of the Westbay casing string increases, the string is supported and the volume of water inside the MP-38 casing is adjusted to meet design strength constraints.
- Pre-inflation pressures are measured.
- Packers in the unlined portion (NQ drillhole) are inflated from the bottom up using a packer inflation tool. N-casing is removed in sections so as to minimize standing time on unstable borehole sections prior to packer inflation.
- The tension of the MP-38 casing string is adjusted during inflation to keep the casing straight, yet prevent unacceptable tensile loads from locking into the couplings.

Two pressure profiles are completed following installation. Piezometric pressures at each measurement port for each profile are measured with a down-hole probe. Pressures are measured at each port for a sufficient period of time (up to 10 minutes) to verify that transient response to activation of the measurement port is complete.

5.3.4.4 Westbay System Testing, Sampling and Pressure Profiles

At the time of the installation of the Westbay System in 2006, Westbay field consultants trained SLR personnel in the use of monitoring and testing tools to supplement the information provided in the Westbay operator's manuals supplied with the monitoring equipment. The piezometric profile in the Westbay System at NDM-6349 was measured at that time and continues to be measured monthly. Monitoring and testing of the Westbay System is performed by SLR under the direction of WMC.

The Westbay System manuals include operating procedures for the Model 2532 MOSDAX Sampler Probe, which describe step-by-step instructions for typical monitoring and testing tasks such as pressure-profile measurements, groundwater sample collection, and operation of the Model 0706 Hydraulic Pumping Port. As necessary, special procedures are developed, through consultation among SLR, WMC, and Westbay, for the performance and documentation of other tasks as described below.

Testing

Screening-level testing for hydraulic conductivity (pulse tests) are completed for all 50 measurement ports in all Westbay System holes. (By 2008, only one Westbay System had been completed, although others are contemplated for the future). The tests are carried out by parking the down-hole tool at each port, allowing pressure stabilization while adjusting the water level inside the MP-38 casing, allowing flow from the monitored interval into the casing, and then measuring the pressure recovery to the flow test. Zones where the test response is constrained by the head drop across the measurement port are identified.

Zones for well testing through pumping ports (pumping tests) are selected based on pressure profiles and the screening-level hydraulic conductivity testing. When a pumping port is opened, the Westbay casing acts as a conventional monitoring well. First, the water level inside the MP-38 casing is drawn down several meters below the piezometric level in the test zone. A high-capacity Waterra pump is used to draw the water level down. The opening tool then is lowered to the opening location, and the port is opened. The water-level recovery inside the MP-38 casing is monitored until it is stable or for 20 minutes. The probe then is removed from the hole, reconfigured, and redeployed for closing. The port then is closed, and the next test starts. A suitable record of the testing is created according to the agreed test procedure. The record includes a paper record for each test, pl

Sampling

Groundwater samples are collected from the Westbay System from measurement ports installed within relatively permeable zones. A preliminary sampling round is conducted, limited to documenting field parameters (conductivity and pH) as follows:

1. The sample bottle is rinsed with deionized water as a decontamination step.
2. The sampling equipment is deployed and operated as described in the system operator's manual (Schlumberger, n.d.).
3. The retrieved sample is extracted, and the conductivity and pH are measured.

This preliminary sampling round provides the information required to integrate the Westbay System sampling with the remainder of the sampling program. Groundwater samples will be collected from selected measurement ports coincidently with other groundwater sampling events. Protocols for collecting samples from the Westbay System(s) are being developed by SLR following installation and initial testing.

Pressure Profiles

Piezometric pressure profiles are measured in the Westbay System at regular intervals as follows:

- Monthly Profiles – A piezometric-pressure profile is completed at the end of the initial testing and monthly, to coincide with water-level monitoring of piezometers and monitoring wells. The Westbay equipment used for this purpose is deployed and operated as described in the system operator's manual (Schlumberger, n.d.).
- Continuous Profile – Continuous datalogging for 1 or more months at selected ports is planned to provide several weeks of data that can be analyzed for barometric and earth-tide effects, allowing further assessment of the interconnectivity of the monitoring zones and transmissivity. If any drilling is occurring nearby, hydraulic responses can be used for later scoping of a pumping test.

5.3.5 Collecting Water Level Measurements

Groundwater levels are measured immediately following well installation and during well development and testing throughout all phases of the field program. In general, each monitoring well and piezometer has been monitored monthly in 2005, 2006, 2007 and 2008, and this program is ongoing. Selected monitoring wells and piezometers are equipped with dedicated transducers and dataloggers that record the water level each hour.

During the monthly field visits, water levels in wells and piezometers are measured with an electric sounder. Water levels are documented in water-level measurement logs. For the water-level survey, all water levels are measured within the shortest time practical. The following protocol is employed while collecting water-level data:

- An electric sounder is used to measure water levels and total depths in all wells and groundwater piezometers.
- Electric sounders are kept clean and are maintained in accordance with manufacturer's instructions. Before the sounder is used on wells that are sampled for water quality, the probe is rinsed with deionized water.
- The reference point for water-level measurements is the access port on those installations that have submersible pumps or the high point of the PVC casing on those installations that do not have submersible pumps.

5.3.6 Collecting Water Samples

Sampling of groundwater has been ongoing since 2004 and continued through 2008. Groundwater samples were collected in September and October 2004; and in March, May, August, and November of 2005, 2006, 2007, and 2008.

As described in detail in consolidated study program (CSP) 6 (Water Quality), prior to collecting groundwater samples, the groundwater monitoring wells are purged and sampled with dedicated submersible pumps. Three-quarter-inch-diameter polyethylene (or equivalent) tubing is permanently installed between the pump and the well cap at each well. Samples are collected using non-dedicated

3/8-inch-diameter polyethylene tubing temporarily connected to the permanently-installed tubing at the well cap, and draining into the sample container.

For each sample, new non-dedicated tubing was used between the well cap and the sample container. The non-dedicated tubing allows the use of in-line filters, as needed for specific analyses. All required field measurements are collected as described in CSP 6. Purge water is disposed of on site.

The test parameters are described in CSP 6. The number of samples and sample types, as well as container types, holding times, and preservatives for each year of study, are described in the quality assurance project plan for each year.

In addition, groundwater samples have been collected from 28 clustered wells at 15 locations for age-dating. The samples were analyzed for tritium, an element used to estimate groundwater age. The tritium concentrations found indicated that all but one of the samples had probably recharged since 1972. The data from one sample (MW-5D, Table 5-1a) indicates groundwater at depth in this location may have recharged prior to 1952. Additional sampling is proposed to provide further data to assess groundwater travel times, and tritium and "daughter" products will be analyzed to improve the age-dating of the groundwater.

5.3.7 Other Data Collection Programs

5.3.7.1 Seeps and Surface Water

Because surface water-groundwater interaction is a significant concern, a survey has been initiated to determine which portions of the streams are "losing" (flow to ground) and which are "gaining" (flow from ground). This survey includes installing seepage meters and mini-piezometers. The seepage meters measure the seepage directly and were installed once to test the feasibility of using seepage meters in this terrain. The mini-piezometers have been used to measure vertical head differences between the stream stage and the underlying materials.

Some seep flows were measured during 2004, but the most comprehensive flow monitoring (conducted by HDR field personnel) started in 2005 and continued in 2006, 2007 and 2008 (as described in CSP 6, Water Quality, Section 6.1).

HDR field personnel completed relatively detailed streamflow surveys during low-flow (or baseflow) periods to determine which stream reaches were gaining and which were losing. These surveys were conducted in NK, SK, and UT from 2004 through 2008 (as described in CSP 4, Surface Water Hydrology, Section 4.1).

5.3.7.2 Resource Drilling

Information from the resource drilling program includes lithologic and structural data that form part of the background for producing a conceptual groundwater model for the study area. In addition, other indicators of ground permeability and groundwater flow include observed losses and gains of drilling—circulation fluid and evidence on the drill cores of limonite staining and calcite precipitates.

5.3.8 Calculations and Models

Based on published geologic reports and the data collected as part of the groundwater hydrology study, conceptual geologic and hydrogeologic models have been prepared. Based on these conceptual models, a site-wide monthly water balance has been developed. This water balance uses Iliamna precipitation and temperature data, adjusted for elevation, and includes interaction of surface and groundwater using a linear reservoir method. The model has been calibrated to instantaneous- and continuous-discharge measurements taken in creeks and rivers in the study area. To date, insufficient data are available to include the natural variability in precipitation and snowpack across the study area. The next phase of model development will include these variations as the data become available.

A site-wide numerical groundwater model has been prepared based on the conceptual groundwater model and the available groundwater information (e.g., groundwater levels, hydraulic conductivities, seep locations, baseflow measurements, etc.). The model includes two layers to represent the bedrock and one layer to represent the overburden. Although the model calibration is reasonable, an improvement is planned to allow modeling of multiple aquifers within the overburden where they are known to be present. In addition, the existing model boundaries will be expanded to cover a greater area.

5.4 Major Tasks/Activities

Several major tasks and activities, beginning in 2004 and continuing through 2008, have been or are being conducted for the groundwater hydrology study. They are summarized in Table 5-2. The complete inventory of monitoring sites and the period of record for each (including the number and timing of water quality and water level sampling events) are summarized in Tables 5-1a through 5-1e, according to watershed catchment area.

Details for each year, including the specific methodology employed for each task as it was introduced, are provided in the following sections.

5.4.1 Tasks and Activities for 2004

The main tasks and activities for 2004 were to develop an initial understanding of the baseline hydrogeology in the study area by conducting a review of the existing data, and to identify the locations for and installing a preliminary network of monitoring wells and piezometers. The work consisted of five tasks.

5.4.1.1 Task 1—Data Review

This activity consisted of reviewing previous baseline studies, geologic reports, and other data. These reports and databases were available from Cominco, the Pebble Partnership, U.S. Geological Survey (USGS), Alaska Department of Fish and Game, U.S. Fish and Wildlife Service, Alaska Department of Natural Resources, and the National Oceanic and Atmospheric Administration. The review included evaluating basin and sub-basin drainage areas and channel lengths, relief, annual precipitation, typical flow regimes, and stream characteristics. This geologic, meteorologic, and hydrologic information was used to prepare a preliminary conceptual model of the study area and to optimize the layout of baseline monitoring wells and piezometer networks.

5.4.1.2 Task 2—Determine Monitoring Requirements

The priorities for identifying appropriate monitoring sites are: 1) site-wide characterization, and 2) detailed characterization of the area around the deposit. Therefore, the number and location of investigations and monitoring depended on the groundwater regime and areas of interest. An additional consideration when identifying baseline locations was the possibility of ongoing sampling after the baseline period ended.

A primary objective in 2004 was to install monitoring wells as early as possible in the field program cycle. It was understood that locations of some wells could be modified as new data became available and the overall understanding of the system developed. The proposed number and locations of monitoring installations in 2004 are shown in Figure 5-3. Actual number and locations of the groundwater monitoring installations were adjusted as appropriate during the field season.

5.4.1.3 Task 3—Field Program

The field program consisted of multiple components, including monitoring well installation, groundwater sampling, seep and spring sampling, stream seepage evaluation, piezometer installation, and hydraulic testing. The following paragraphs describe each of these components in more detail.

Background Monitoring Well Installation

Eight baseline monitoring wells were planned around the deposit area. Expected depths of the wells ranged from 30 to 200 feet. These wells were to be used primarily to help characterize groundwater geochemistry in the immediate area around the deposit and surrounding drainages.

Monitoring wells were installed in the field with a helicopter-supported field program. Qualified drillers and hydrogeologists were responsible for locating, designing, installing, and sampling the wells, so that the necessary quality would be maintained. Geology and drilling data were used to make decisions in the field regarding exact well designs. It was planned to install the shallow wells with an ODEX heli-portable drill rig, because this drilling technique eliminates the problems associated with the use of drilling mud and minimizes potential site disturbance. This rig also has the advantage of using a casing for well installation, so that the screen can be completed in the appropriate geologic horizon.

It was also planned to install deeper piezometers with a heli-portable rotary drill rig. These piezometers were constructed of either 1-inch or 2-inch-diameter PVC casing depending whether NQ, HQ, or PQ rod or rotary casing was used in drilling.

Each monitoring well was developed, response-tested, and completed with a dedicated submersible sampling pump. Dedicated pumps eliminate cross-contamination problems that can result when one pump is used in multiple wells.

Supplementary Groundwater Sampling Sites

In addition to the well monitoring sites, supplementary groundwater levels and chemistry data were collected from piezometers installed in mineral exploration and geotechnical holes (e.g., KP-P3D, M, and S [SRK-5D, M and S].

Stream Seepage Investigation

It was planned to collect piezometer measurements coincident with groundwater sampling. The results of the sampling would help with interpreting high flow periods during spring runoff and fall storms, and baseflow periods during the summer and winter. It was planned to collect samples of the stream and groundwater seepages when the seepage meter installation was attempted. The specific number and locations for monitoring were determined in the field.

Piezometer Installation and Hydraulic Testing

In 2004, it was planned to install 15 piezometers and conduct two pumping tests in the deposit and surrounding areas for the purpose of hydraulic testing and for defining regional gradients. These piezometers were installed in exploration or geotechnical drillholes where possible and were constructed of 1-inch- or 2-inch-diameter PVC casing, depending on drill rod size. Slug testing and injection testing in the completed piezometers provided information from the completion zone. It was also planned to install some supplementary piezometers in holes drilled with the ODEX heli-portable rig.

Pumping tests were conducted in alluvium in and around the deposit area. Each test site included a pumping well and multiple piezometers for monitoring water levels. Three piezometer nests (three holes each) were proposed. The data from these in situ tests were intended to help define baseline conditions.

The pumping test at each site started with a step test to determine the most appropriate pumping rate for a constant rate test. The constant rate test generally lasted about 24 hours. The flow rate of the pumping well was recorded regularly. The water levels in the pumping well and observation wells were recorded frequently either with transducers or with manual sounding tapes. Barometric pressure was monitored during the test so that the necessary corrections could be applied to the water level measurements. The recovery of water levels was also recorded after the pump was turned off.

Groundwater Sampling

Four events for sampling baseline monitoring wells were planned to coincide with high groundwater levels in the spring and early fall, and low groundwater levels in summer and winter and to coincide with the parallel sampling program for surface waters (only two were conducted in September and October, see Tables 5-1a through 5-1e). Water levels were measured in monitoring wells and piezometers during the same sampling event, concurrent with surface water sampling (see CSP 4, Surface Water Hydrology, Section 4.1).

5.4.1.4 Task 4—Modeling of Groundwater Flow and Surface Water/Groundwater Interaction

The detailed objectives and scope of modeling for the groundwater system are being progressively refined. Initially, a conceptual model was developed with field data in a simple form to help define the most important hydrogeologic issues at the site and to help guide the field program. It was understood that the model would be refined progressively as additional field data became available.

5.4.1.5 Task 5—Ongoing Monitoring

It was recognized that surface water and groundwater monitoring would continue beyond the project baseline period. Therefore, the 2004 monitoring program was evaluated after the field season to identify any needed changes to monitoring locations, frequency, or parameters, or any potential data gaps that were identified.

5.4.2 Tasks and Activities for 2005

The tasks and activities for 2005 built on the preliminary work initiated in 2004. They included expanding the network of monitoring locations, implementing studies that would generate data required for modeling purposes, ongoing field work, and interactions with other project team members.

5.4.2.1 Task 1—Field Work

The WMC hydrogeology team was responsible for overseeing the hydrogeology field work in 2005, with field support provided by SLR and HDR field personnel. The WMC team assisted Pebble Partnership project managers with selecting the drilling contractor, sited the drillholes, provided input to SLR field personnel for the field protocols, and analyzed the data. SLR field personnel developed field protocols together with the WMC team, procured the necessary equipment, and carried out the field work. HDR conducted the field work related to seep and spring surveys, stream-seepage measurements, the hyporheic zone study, and the low-flow streamflow profiles. WMC collaborated with HDR to develop the scopes of work for these tasks and continues to be involved in their execution.

The field program consisted of installing monitoring wells and piezometers, developing installed wells/piezometers, slug testing, cross-hole aquifer testing, groundwater sampling, seep and spring sampling, stream-seepage evaluation, and piezometer installation and hydraulic testing. The following paragraphs describe each of these components in more detail.

Background Monitoring Well Installation

Thirty background monitoring wells were installed in 2004 (see Tables 5-1a to 5-1d). Several of these were not sampled, including a cluster of three wells at MW-2, which could not be sampled because of excessive silting.

In 2005, it was planned to add six additional baseline monitoring wells in the mine study area. Similar to 2004, expected installation depths ranged from 30 to 200 feet. The locations of these wells were decided in consultation with KP engineers during March and April, 2005. These additional wells were intended to be used primarily as background sampling locations, to help characterize groundwater geochemistry down-gradient of the deposit and adjacent drainages. Planned and existing drilling locations in 2005 are presented in Figure 5-4.

As in 2004, an ODEX rig was used for installing these wells. The wells were constructed of 2-inch-diameter PVC casing. Each monitoring well was developed, response tested, and completed with a dedicated submersible sampling pump.

In some locations, the overburden was deeper than 200 feet. At these locations, installing monitoring wells with proper seals was not always possible, but collecting data on the geology was considered worthwhile. An alternate drilling method was used to penetrate all the way to bedrock and collect data on the overburden geology. The drilling methods included PQ coring or triconing, with split-spoon sampling.

Piezometer Installation and Hydraulic Testing

In 2004, 19 piezometer locations were identified and drilled in and around the deposit area, and six of these were completed as monitoring wells. An additional 34 piezometers were installed downstream; see Tables 5-1a to 5-1d). In 2005, it was proposed to install between 25 and 30 piezometers in the deposit area and surrounding drainages for the purpose of hydraulic testing and for defining regional gradients. These piezometers were for both the groundwater and geotechnical programs. Most of these piezometers were planned to be dual completion (i.e., with monitoring zones at two different depths). They were to be constructed of 2-inch-diameter PVC casing. Slug testing in the completed piezometer would also be done to provide hydraulic conductivity data for the completion zone.

As in 2004, pumping tests were conducted in the alluvium in an areas south of the deposit. Each test site included a pumping well and multiple piezometers for monitoring water levels. It was anticipated that a total of eight piezometers divided among four new clusters would be required for these pumping tests. The pumping tests were conducted according to the same methodology employed in 2004.

Groundwater Sampling

The methods and protocols used for groundwater-quality sampling are described in CSP 6, Water Quality. In addition to taking samples for water quality, water levels were measured in monitoring wells and piezometers twelve times during the year, concurrent with surface-water sampling (also described in CSP 6).

Tracer Testing

Tracer testing has been considered as a method to define groundwater flow directions, rates, and resident times under natural gradient conditions. However, tracer testing under natural gradient conditions is time consuming, can be difficult to complete, and may not provide definitive information. As necessary, single well dilution tests can also be carried out in monitoring wells to provide discrete velocity measurements. These tests were proposed for 2005 but have not been included in the groundwater study to date.

Isotope Analysis

Isotope analysis can be employed as an alternative to tracer testing. The isotope method is a natural tracer method that can be used to characterize sources of recharge, geochemical processes within groundwater systems, and travel times from recharge areas to discharge. It is more likely to provide the necessary information at the Pebble Project site than is the tracer method. It is described as follows:

Natural isotopes of chlorine, sulfur, carbon, hydrogen, and oxygen are measured in water samples taken from multiple recharge and discharge areas. Comparing isotope concentrations between areas can potentially distinguish where recharge water is discharging. These data can then be used to help model groundwater recharge and/or discharge at a particular location.

Isotope analysis is also used to develop an understanding of geochemical processes within a system. This understanding forms a basis for postulating natural attenuation reactions that might mitigate the potential effects of a mine facility on groundwater quality.

As well, the isotope tritium is used for age-dating groundwater; a technique described above that helps to determine how long groundwater has been resident in the groundwater system. These data are used to improve estimates of travel times from recharge areas to discharge areas. This was done in 2005.

A program of isotope analysis for surface water and groundwater was included in the study plan for 2005.

Groundwater Supply Investigation

The question of groundwater supply feasibility had been raised from time to time prior to 2005; therefore, a groundwater supply investigation was proposed for the 2005 field season. The requirement for and timing of such an investigation was to be decided in consultation with the Pebble Partnership. This work, however, was not completed in 2005.

Baseflow Streamflow Profiles

A series of baseflow streamflow profiles were proposed to support the hydrogeology study. Profile measurements are important because it is assumed that all streamflow during baseflow conditions is due to groundwater discharge. As such, streamflow profiles are very useful for identifying areas where groundwater discharge to streams is pronounced and therefore where groundwater effects on streams are most likely to occur. The baseflow profiles consisted of 10-15 streamflow measurements along the NK, SK, UT and associated tributaries. The measurements were collected during periods of low flow following spring runoff in June or early July 2005 (see CSP 4, Surface Water Hydrology).

Stream Seepage Investigation

Because surface water/groundwater interaction is significant in this area, a survey was proposed in 2005 to determine which portions of the streams are “losing” and which are “gaining.” The evaluation would allow interpretation of high-flow periods during spring runoff and fall storms, and baseflow periods during the summer and winter. It was proposed to complete the survey by installing seepage meters and mini-piezometers during one field session. Seepage meters would be used to measure seepage directly, and samples of seepage and nearby surface water could be collected at the same time. This was proposed as a preliminary initiative to allow the WMC hydrogeology team to test the feasibility of using seepage meters in this terrain. The mini-piezometers would be installed as permanent installations and used to measure vertical head differences between the nearby stream stage and the underlying materials. As with seepage samples, it was proposed to collect surface-water samples at the same time that piezometer water levels were taken.

It was proposed to conduct this study at four stations in 2005, but the work was not completed and has not been done to date.

Seep and Spring Sampling

This field program started with a review of the available database of springs surveyed to date and a comprehensive mapping of their locations. The active springs were mapped in January during a field visit to sample surface water. The springs were mapped again in March, and samples were collected and flows were measured. A comprehensive mapping of springs was also completed in June. WMC field personnel revisited the springs mapped during June and selected the springs that would be included in the ongoing monitoring program.

This program provides additional data for the baseline characterization. It consists of sampling and surveying the identified priority springs as part of the baseline study. Flow rates in the priority springs were recorded again in August and October, and water quality samples were collected in October. Each visit to a spring also included documenting field descriptions of the spring, taking several pictures, and measuring field parameters (see CSP 6, Water Quality, for the full list of field parameters; pH, specific conductance, temperature are the three parameters of geochemical interest to the groundwater baseline study).

5.4.2.2 Task 2—Input to Tasks by Others

A number of tasks being completed as part of other baseline studies are interrelated with the hydrogeology baseline study. These tasks and their association with the hydrogeology study are discussed in the following paragraphs.

Streamflow Data Collection

The streamflow data are highly relevant to the hydrogeological characterization because these data contribute significantly to understanding the interaction between surface water and groundwater. HDR field crew visit their full complement of streamflow monitoring stations to collect data, and selected data (as defined in consultation with WMC hydrogeologists) are provided to WMC for review.

Meteorological Data Collection

The following meteorological data are relevant to the hydrogeological study:

- Total precipitation.
- Evaporation.
- Wind speed and direction.
- Temperature.
- Barometric pressure.

The data most relevant to the hydrogeological analysis are total precipitation and evaporation. The meteorological study team, the Hoefler Consulting Group (Hoefler), visits each station according to their study program (see CSP 2), collects the data according to protocols that have been discussed with the other team members, and provides the data to WMC hydrogeologists for review.

Site-wide Water Balance

The WMC hydrogeology team understands that a site-wide water balance is being calculated by other team members. Input from the hydrogeological study, such as findings from the baseline characterization and groundwater recharge assessment work, was provided for the water balance calculation, as required. This input included requirements for data processing, choice of catchment areas, and choice of water balance model calibration points.

Site-wide Mass Balance

The WMC hydrogeology team also understands that a site-wide mass balance is being calculated by SRK Engineers. WMC personnel provided hydrogeological characterization data (e.g. groundwater flow rates, groundwater chemistry, and attenuation capacity of aquifer solids) as required for the mass balance calculation.

5.4.2.3 Task 3—Data Review and Analysis

The review and analysis of hydrogeology data included the following subtasks:

- Quality assurance/quality control (QA/QC) for all data-collection activities.
- Reviewing drillhole logs to select monitoring zones and to interpret the overall geologic environment as it relates to the most important hydrogeologic issues at the site.
- Interpreting three-dimensional groundwater-flow directions from water-level data collected from piezometers.
- Analyzing slug tests (single well).
- Analyzing pumping tests (multiple wells).
- Interpreting groundwater and surface-water chemistry data to help with the interpretation of groundwater/surface water interactions.

5.4.2.4 Task 4—Groundwater Recharge Analysis

The results from the surface-water field program, the groundwater field program, and the site-wide water balance study are being used to develop a groundwater recharge analysis. Surface water and groundwater flow data are incorporated into an integrated model that accounts for precipitation, runoff, evapotranspiration, sublimation, spring runoff, groundwater recharge, groundwater discharge, and interbasin transfer of groundwater. This important step provides a rational connection between precipitation, surface water, and groundwater components of the hydrologic system, and so helps clarify the interaction between surface water and groundwater.

In 2005, the analysis began by collecting data on the following components:

- Precipitation.
- Runoff and streamflow.
- Evapotranspiration.

- Sublimation.
- Groundwater recharge.
- Groundwater discharge.
- Groundwater pumping from the dewatering system.
- Changes in groundwater storage.

Over time, iterations between the groundwater recharge analysis and the groundwater model will be required to develop a consistent interpretation.

The detailed objectives and scope of numerical modeling for the groundwater system is being progressively refined. In any case, a three-dimensional numerical groundwater model has been developed for assessing groundwater flow rates, flow directions, and travel times. The USGS code MODFLOW is being used for assessing flow rates and the particle-tracking code MODFPATH is being used for assessing flow directions and travel times. This model was developed in the summer of 2005 in a very simple form to help define the most important hydrogeologic issues at the site and to help guide the field program. The model has been subsequently refined as field data became available. The model is being developed at the site scale to incorporate the controlling hydrologic boundaries, and smaller submodels can be extracted as required to examine site-specific components at a larger scale. Conservative parameters have been used in the model to compensate for any uncertainties in hydrologic or hydrogeologic conditions.

5.4.3 Tasks and Activities for 2006

The tasks and activities completed in 2006 for the groundwater hydrology study were similar to those completed in 2005. They can be divided into nine tasks.

5.4.3.1 Task 1—Field Work

The field work for 2006 included the following:

- Monthly groundwater level monitoring at 181 wells at 123 locations (Figures 5-5 and 5-6, Tables 5-1a to 5-1d).
- Quarterly groundwater sampling from 34 wells at 16 locations (an additional 4 wells were sampled once in 2006; Figure 5-5, Tables 5-1a to 5-1d).
- Drilling and installing 26 additional piezometers and monitoring wells during June and July, 2006 (Figure 5-6)
- Drilling and installing 42 piezometers and water gages at wetland locations specified by 3PP personnel.

In addition, the Westbay System was installed to provide design information and background water-quality data for deep environments. Installation was in drillhole NDM-6349 to a depth of 4050 feet. The hole was drilled by a Pebble Partnership contractor. Installation was completed by the drilling contractor with field supervision by SLR field personnel, and with assistance from KP engineers. WMC hydrogeologists selected component locations. Further description of the field installation is provided in

Section 5.3.4, above. This installation was also intended to serve as a multi-level piezometer for a deep aquifer test.

SLR field personnel conducted the groundwater field work, with oversight provided by the WMC hydrogeology team. The scope of work is similar to the field work conducted in 2005.

5.4.3.2 Task 2—Input to Tasks by Others

Some studies under the direct supervision of other consultants are useful to the hydrogeology study and other studies use the findings of the hydrogeology study. The WMC hydrogeology team provided input to these studies, which included the following:

- Streamflow monitoring.
- Meteorological data collection.
- Water balance calculations.
- Site-wide mass balance calculations.
- Bench-scale attenuation testing of aquifer materials.
- Baseflow streamflow measurements.
- Reconnaissance surveys of seeps.
- Ongoing sampling and flow measurement of 24 priority seeps.
- Installation of the Westbay System in the deep bedrock drillhole at NDM-6349.

This input took the form of occasional telephone calls, memoranda, and/or meetings. The work is described in greater detail in Section 5.4.2.

5.4.3.3 Task 3—Data Review and Analysis

This task involves detailed review and analysis of data relevant to the hydrogeological study. These data include the following:

- Geologic characterization.
- Groundwater piezometric distributions.
- Well and piezometer test analyses.
- Meteorological correlations.
- Surface water flow correlations.
- Groundwater quality characterization.
- Groundwater, surface water, and seep water quality correlations.
- Developing hydrogeologic cross-sections.
- Time series and snapshots of piezometric elevations.
- Interpreting groundwater quality.

- Interpreting the relationship between groundwater, surface water, and seeps.

This work is similar to that done in 2005.

5.4.3.4 Task 4—Groundwater Recharge Analysis

The groundwater recharge analysis incorporates surface water and groundwater flow data into an integrated model that accounts for precipitation, runoff, evapotranspiration, sublimation, spring runoff, groundwater recharge, groundwater discharge, and interbasin transfer of groundwater. The analysis was initiated in 2005, and is described in Section 5.4.2. During 2006, the analysis was updated with the latest available streamflow and precipitation data to improve estimates of groundwater/surface water interactions.

5.4.3.5 Task 7—Groundwater Supply Assessment

Groundwater supply is not currently being considered; therefore, no activities were planned for the groundwater supply assessment during 2006. The proposed work is described in Section 5.4.2.

5.4.3.6 Task 8—Meetings

Meetings with the Pebble Partnership, regulators, and other consultants involved in the project were attended as necessary.

5.4.3.7 Task 9—Reporting

Formal reporting during 2006 consisted of preparing a draft environmental baseline document.

5.4.4 Tasks and Activities for 2007

The tasks and activities for 2007 built on the work completed in the previous 3 years.

5.4.4.1 Task 1—Field Work

The WMC hydrogeology team guided the hydrogeology field programs by providing support to the various consultants involved, including SLR, HDR and KP. This guidance included developing specifications for the work in consultation with Pebble Partnership project managers and the consultants. It also included ongoing input during the field programs themselves and two site visits by WMC personnel.

The field program was expanded to address the new development associated with the Pebble East discovery. The subsurface investigations for Pebble East represents about 80 percent of all subsurface investigations for the Pebble Project. Monitoring activity increased by about 25 percent as a result. The planned field programs for 2007 are described below.

Drilling for Monitoring Wells and Piezometers

As in the past, SLR field personnel conducted the hydrogeology field work, with oversight by WMC hydrogeologists. WMC hydrogeologists provided recommendations to the Pebble Partnership managers

for selecting the drilling contractor, sited the drillholes, provided input to SLR field personnel for the field protocols, and analyzed the data. SLR field personnel were responsible for developing field protocols together with WMC hydrogeologists, procuring the necessary equipment, and carrying out the field work.

The wells installed were located primarily to define stratigraphy, to test hydraulic conductivity, and to measure piezometric levels, with selected wells also used for collecting groundwater samples. Planned installations for 2007 were as follows:

- In the NK catchment.
- Near the divide of the NK and UT catchments.
- In SK drainages proximate to the deposit.

Similar to previous years, expected installation depths ranged from 30 to 200 feet. Thirty-eight wells were planned (42 boreholes, all completed as piezometers were eventually drilled), and their locations were selected in consultation with KP. The wells were drilled using the ODEX drilling technique. Planned locations of the ODEX holes (hydrogeology holes) are illustrated on Figure 5-7. Some locations are not shown on the figure because they were determined in the field at the time of drilling; these locations are shown on Figure 5-8 (for 2008).

In locations where the overburden is deeper than 200 feet, monitoring wells with proper seals could not be properly installed, but data on the geology was collected. Further details on the methodology employed are provided in Section 5.4.2.

Geotechnical Site Investigation

Subsurface exploration was carried out under the direction of KP. The primary purpose of this drilling was for geotechnical purposes, but as the location of drillholes was in the general vicinity of the deposit and adjacent watersheds, they could also provide important information for understanding the groundwater flow system in these areas. As a general practice, KP field personnel install piezometers in all of the holes that they drill for geotechnical purposes. KP engineers selected 46 locations for drilling in the 2007 program (37 were eventually drilled and completed as piezometers). The proposed holes are the geotechnical holes depicted on Figure 5-7.

KP engineers specified seismic refraction to assist with interpolation of drillhole data in the areas proximate to the deposit.

Deep-bedrock Well Testing and Sampling

Pressure profiles were carried out at the same time as piezometric pressures were measured in the existing deep-bedrock drillhole and NDM-6349. A screening-level pulse-testing program was carried out each the installation. Well development activities were carried out on selected monitoring zones. Pressure profiles were carried out monthly at the same time as piezometric measurements were made. It was planned to conduct pulse and response testing on up to 40 zones, and to collect approximately 20 groundwater samples. Air-lift pumping tests also were planned adjacent to the Westbay System to give preliminary estimates of the hydraulic properties of the deep bedrock prior to a long-term pumping test. All of these

planned events could not be completed in 2007, and some are still pending. SLR field personnel carried out the activities. WMC personnel visited the site during testing to provide direct support, as required.

Wetland Piezometer Installations

The groundwater hydrology program in 2007 included installing additional wetland piezometers and gages. The locations were specified by 3PP personnel, and the piezometers were installed by SLR field personnel, with oversight by WMC hydrogeologists.

Specialized Groundwater Testing and Sampling

Specialized groundwater sampling and testing was proposed in 2007. The work included isotope analysis and age-dating, as described in greater detail in Section 5.4.2.

In addition, SLR field personnel proposed carrying out single well dilution tests in 10 monitoring wells to provide discrete velocity measurements for comparison and correlation with velocity values obtained from age-dating or calculated using gradient, hydraulic conductivity, and estimated porosity values.

Both of these activities were proposed but not completed in 2007.

Drilling Circulation-fluid Monitoring

A program is in place to document and quantify losses and gains of drilling circulation-fluid in the resource drilling program. This program is focused on identifying zones of elevated permeability, then relating these zones to lithology or structures and identifying targets for future investigations.

Glacial Geomorphology Mapping

Thomas D. Hamilton, Ph.D., carried out geomorphological mapping of the study area with the assistance of SLR field crew. Interactions with the WMC hydrogeology team included meetings in Vancouver, BC and a site visit during the field mapping. The mapping effort resulted in a surficial materials map and an interpretation of the glacial history of the study area. The data are used to interpolate and extrapolate surface and drillhole data.

Groundwater Sampling

The methods and protocols to be used for groundwater-quality sampling are described in CSP 6 (Water Quality) and in the field sampling plan for groundwater studies (Appendix F in the EBD). In addition to the water-quality sampling, water levels were measured in monitoring wells and in piezometers monthly during the year, concurrent with stream water-quality sampling (also described in CSP 6, Water Quality).

The goal of the groundwater-quality sampling is to quantify the water chemistry under seasonal hydrologic conditions at key locations in the study area. Four seasonal sampling events (March, May, August, and October) were conducted for groundwater monitoring wells. Sampling events were timed to include high groundwater levels in the spring and early fall, and low groundwater levels in summer and late winter.

SLR field personnel continued these activities in 2007. New data points were added with the 2007 drilling program.

5.4.4.2 Task 2—Input to Tasks by Others

Some tasks under the direct supervision of other consultants had an impact on the hydrogeology study and WMC provides input to these tasks. In 2007, this input took the form of occasional telephone calls, memos, and/or meetings. The work included interacting with the consultants to ensure that their data collection met not only their own purposes, but also the needs of the groundwater hydrology program. The tasks supervised by others with relevance to the hydrogeology study are discussed below.

Seep Sampling

The seep sampling and flow-measurement program were reviewed in early 2007. As a result of that review, HDR field personnel surveyed additional areas and added data-collection points to provide additional coverage related to Pebble East. Existing data-collection points continued to be monitored.

Streamflow Data Collection

HDR field personnel also continued to provide WMC hydrogeologists with relevant streamflow data. This included continuous and spot measurements of streamflows in specific locations, as well as low-flow streamflow profiles along NK, SK, and UT. Locations relevant to the hydrogeology study were determined in consultation with the WMC hydrogeology team.

Meteorological Data Collection

Hoefler continued to collect meteorological data in 2007 (for details, see CSP 2; the work is summarized in Section 5.4.2).

The data most relevant to the hydrogeological analysis are total precipitation and evaporation, and these data are provided as they are collected to the WMC hydrogeology team for review.

Operations Water Balance

The WMC hydrogeology team continued to provide the findings from their hydrogeological characterization work, including the groundwater recharge assessment, to the KP team members responsible for calculating a water balance. This input included requirements for data processing, choice of catchment areas, and choice of water-balance model calibration points.

Site-wide Mass Balance

The WMC hydrogeology team continued to provide select hydrogeological characterization data (e.g., groundwater flow rates, groundwater chemistry, and the attenuation capacity of the aquifer solids) to SRK engineers for input into the site-wide mass balance.

Bench-scale Attenuation Testing

SRK engineers organized the attenuation testing. SLR field personnel were responsible for collecting representative aquifer materials.

5.4.4.3 Task 3—Data Review and Analysis

This task in 2007 involved detailed review and analysis of data relevant to the hydrogeological study. The work was conducted throughout the year so that field programs could be adapted to meet up-to-date results as data were analyzed and interpreted.

Data review and analysis included a number of steps, which have been consistently followed since 2005. The results are being used as follows:

- Update hydrogeologic cross-sections, piezometric time series, and snapshots of piezometric elevations.
- Estimate hydraulic conductivity, storativity, and site meteorological conditions.
- Interpret the relationships between groundwater, surface water, and seeps.

This information is important for refining the conceptual groundwater model.

5.4.4.4 Task 4—Site-wide Water Balance

This task was an evolution of the Groundwater Recharge Analysis task initiated in 2005 and continued in 2006. During 2007, the model was updated with the latest available data on snowpack (sublimation, ablation rates), climate (evapotranspiration, precipitation), streamflow measurements (including spring runoff), groundwater levels and flow data, and groundwater recharge, discharge and interbasin transfer. As in the past, the water balance model was updated monthly, and the output was made available to support ongoing estimates of groundwater/surface water interactions. The analysis was also useful in groundwater calculations. Some iterations between this analysis and the groundwater models were done to develop a consistent interpretation (i.e., the result of the analysis and of the models were fed into each other until mutually consistent results were produced).

5.4.4.5 Task 5—Site-wide Groundwater Model

During 2006, the WMC hydrogeology team developed the three-dimensional, transient, numerical groundwater model for assessing groundwater flow rates, flow directions, and travel times. This model was originally developed in the summer of 2005 in a very simple form to help define the most important hydrogeologic issues at the site and to help guide the field program. The inputs to the site-wide groundwater model were based on a hydrogeologic interpretation of the site and estimates of groundwater recharge (for details on the inputs and the model's relevance, refer to Section 5.4.2). The model was subsequently calibrated to groundwater flow estimates from the site-wide water balance calculations, and from streamflow and groundwater elevation measurements from the field.

During 2007, the inputs to the site-wide groundwater model were refined, as follows:

- The overburden was represented with multiple layers.

- Multiple zones of hydraulic conductivity were assigned to each overburden layer.
- Zones of high hydraulic conductivity were added for faults that were identified.
- The groundwater recharge rates were adjusted, as required, depending on the results from the site-wide water balance.

Following refinement of the inputs, the model was recalibrated to the new estimates of groundwater flow from the updated site-wide water-balance model and to the latest measurements of low-flow streamflow and groundwater elevation. The model also was calibrated to the results of aquifer tests that have been conducted on-site. The detailed objectives and scope of numerical modeling for the groundwater system is being progressively refined.

5.4.5 Tasks and Activities for 2008

The objectives and scope of work for the 2008 groundwater hydrology study in the mine study area are the same as those described for 2005, 2006, and 2007, with exceptions noted below.

- Drilling at 37 additional locations was performed in 2008 as part of the hydrogeology program, with most locations having two piezometers installed.
- Pumping testing was conducted at two of the newly installed piezometer locations.
- Geotechnical drilling was continued in 2008 at 142 locations.
- Groundwater sampling continued during 2008. Thirty-nine groundwater wells were sampled quarterly for cations, anions and nutrients in 2008 to document seasonal variation. The details of the sampling parameters are provided in CSP 6, Groundwater Quality.
- Monthly groundwater level measurements were taken in 2008 at 287 locations (220 from hydrogeology and geotechnical programs, and 67 from the small pools study).
- Packer testing to estimate hydraulic conductivity continued in 2008 as described in the 2008 field sampling plan (Appendix F of the EBD).
- Additional seeps and surface water quality sampling results were included in the groundwater hydrology program in 2008, as described in CSP 6, Water Quality, and CSP 4, Surface Water Hydrology.
- Groundwater quality characterization continued as more data became available in 2008. These data were correlated to surface water and seepage water quality as well as to climate and hydrologic variations.

General Considerations:

- Meteorological data continued to be reviewed and verified to ensure data collection met the needs of the groundwater hydrology program.
- The groundwater hydrology program will provide information to other programs, including the operations water balance and the site-wide mass balance.
- The conceptual geologic and groundwater hydrology model preparation described in the 2007 field sampling plan (Appendix F of the EBD*)* was continued in 2008. Additional resource drilling

from 2007 and 2008 provided additional lithologic and structural information that gives the background for producing a conceptual groundwater model for the study area.

5.5 References

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American Society for Testing and Materials (ASTM). 2004. Method D 5092-04e1, Standard Practice for Design and Installation of Groundwater Monitoring Wells.

Schlumberger Water Services (Schlumberger). n.d. Westbay System Operator Training Manual, Pressure Profile, Sampling, Purging.

TABLES

Table 5-1a
Pebble Project Environmental Baseline Studies
Monitoring Sites and Period-of-Record Index, Groundwater Hydrology, Mine Study Area, 2004 - 2008
Wells and Piezometers Upstream of Frying Pan Lake in South Fork Koktuli Watershed
Consultant: Water Management Consultants

Monitoring Site	Year	Period of Record by Task																						Notes
		Sampling												Water Levels										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
GH04-06	2004																									
	2005																	●	●	●	●	●	●	●	●	Monument noted as damaged in August
	2006													●	●	●		●	●	●	●	●	●	●	●	Jacked in July
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH04-26	2004																						●			
	2005													●	●	●	●	●	●	●	●	●	●	●	●	
	2006													●	●	●		●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●						Last measurement notes 'dry/caved'
	2008																									
GH04-27	2004																						●			
	2005													●		●	●	●	●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH04-46	2004																						●			
	2005													●	●	●	●	●	●	●	●	●	●	●	●	
	2006													●		●	●	●	●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH04-47	2004																						●			
	2005													●	●	●	●	●	●	●	●	●	●	●	●	Monument Damaged in July
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007														●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH04-48	2004																						●			
	2005													●	●	●	●	●	●	●	●	●	●	●	●	Frost Jacking damage in May, 0.95 ft PVC cut off in July
	2006													●	●	●			●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH05-53	2004																									
	2005																							●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008														●	●	●	●	●	●	●	●	●	●	●	
GH05-54	2004																									
	2005																							●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●						last measurement in July
	2008																									
GH05-55	2004																									
	2005																							●	●	
	2006													●	●	●		●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●						last measurement in July
	2008																									
GH05-56	2004																									
	2005																							●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●						last measurement in July
	2008																									

Table 5-1a
Pebble Project Environmental Baseline Studies
Monitoring Sites and Period-of-Record Index, Groundwater Hydrology, Mine Study Area, 2004 - 2008
Wells and Piezometers Upstream of Frying Pan Lake in South Fork Koktuli Watershed
Consultant: Water Management Consultants

Monitoring Site	Year	Period of Record by Task																						Notes
		Sampling												Water Levels										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
GH05-58	2004																									
	2005																							●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH05-59	2004																									
	2005																							●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH05-60	2004																									
	2005																							●	●	constantly frozen or flowing
	2006													●	●	●		●	●	●	●	●	●	●	●	
	2007																				●	●	●	●	●	Flowing--plugged with stopper in March
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH05-61	2004																									
	2005																							●	●	
	2006													●	●	●		●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	Frozen/flowing between Oct 06-Apr 07
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH05-63	2004																									
	2005																							●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	Often frozen until ~ April of each year
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH06-70D	2004																									
	2005																									
	2006																									
	2007																				●	●	●	●	●	frozen or flowing
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH06-70S	2004																									
	2005																									
	2006																									
	2007																				●	●	●	●	●	frozen or flowing
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH06-71A	2004																									
	2005																									
	2006																									
	2007																				●	●	●	●	●	plugged as of September
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH06-72	2004																									
	2005																									
	2006																									
	2007																				●	●	●	●	●	plugged as of September
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH06-74	2004																									
	2005																									
	2006																									
	2007																				●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	

Table 5-1a
Pebble Project Environmental Baseline Studies
Monitoring Sites and Period-of-Record Index, Groundwater Hydrology, Mine Study Area, 2004 - 2008
Wells and Piezometers Upstream of Frying Pan Lake in South Fork Koktuli Watershed
Consultant: Water Management Consultants

Monitoring Site	Year	Period of Record by Task																						Notes
		Sampling												Water Levels										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
GH06-80	2004																									
	2005																									
	2006																									
	2007																				●	●	●	●	●	
	20008													●	●	●	●	●	●	●	●	●	●	●	●	
GH07-91	2004																									
	2005																									
	2006																									
	2007																									deep snow - wanded, but could not
	20008																									locate
GH07-92D	2004																									
	2005																									
	2006																									
	2007																								●	deep snow - wanded, but could not
	20008													●				●	●	●	●	●	●	●	●	locate
GH07-92S	2004																									
	2005																									
	2006																									
	2007																								●	deep snow - wanded, but could not
	20008													●				●	●	●	●	●	●	●	●	locate
GH07-93	2004																									
	2005																									
	2006																									
	2007																								●	
	20008													●	●			●	●	●	●	●	●	●	●	could not locate due to deep snow
GH07-94	2004																									
	2005																									
	2006																									
	2007																								●	
	20008													●	●	●	●	●	●	●	●	●	●	●	●	
GH07-104	2004																									
	2005																									
	2006																									
	2007																								●	
	20008													●	●	●	●	●	●	●	●	●	●	●	●	
GH07-105	2004																									
	2005																									
	2006																									
	2007																								●	frozen
	20008													●	●	●	●	●	●	●	●	●	●	●	●	
GH07-106	2004																									
	2005																									
	2006																									
	2007																								●	plugged
	20008													●	●	●	●	●	●	●	●	●	●	●	●	
I-125	2004																									
	2005													●	●	●	●	●	●	●	●	●	●	●	●	Monument damaged in August
	2006													●	●	●	●	●	●	●	●	●	●	●	●	Frozen for most of the year
	2007													●	●	●	●	●	●	●	●	●	●	●	●	Frozen for most of the year
	2008													●	●	●	●	●	●	●	●	●	●	●	●	Frozen for most of the year

Table 5-1a
Pebble Project Environmental Baseline Studies
Monitoring Sites and Period-of-Record Index, Groundwater Hydrology, Mine Study Area, 2004 - 2008
Wells and Piezometers Upstream of Frying Pan Lake in South Fork Koktuli Watershed
Consultant: Water Management Consultants

Monitoring Site	Year	Period of Record by Task																						Notes
		Sampling												Water Levels										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
I-172	2004																									
	2005													●	●	●	●	●	●	●	●	●	●	●	●	Strong sulfur smell
	2006													●	●	●		●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
I-192	2004																									
	2005																	●	●	●	●	●	●	●	●	Flowing, extension in place as of July
	2006													●	●	●		●	●	●	●	●	●	●	●	Plugged/Frozen
	2007													●	●	●	●	●	●	●	●	●	●	●	●	Standpipe plugged to prevent artesian flow
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
I-201	2004																									
	2005													●	●	●	●	●	●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
KP-P3D/ SRK-5D	2004									●	●												●			
	2005			●		●			●					●	●	●	●	●	●	●	●	●	●	●	●	Well has shallow water. Winter sampling was scheduled, but samples were not obtained
	2006					●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	Standpipe plugged to prevent artesian flow
	2007			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2008			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
KP-P3M/ SRK-5M	2004									●	●												●			
	2005			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2006			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2007			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2008			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
KP-P3S /SRK-5S	2004									●	●												●			
	2005			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2006			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2007			●		●			●			●		●	●	●	●	●		●	●	●	●	●	●	
	2008			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
KP-P4	2004																						●			
	2005			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2006			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2007			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2008			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
M-110	2004																									
	2005													●	●	●	●	●	●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
M-12	2004																									
	2005													●	●	●	●	●	●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
M-21	2004																									
	2005																	●	●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	

Table 5-1a
Pebble Project Environmental Baseline Studies
Monitoring Sites and Period-of-Record Index, Groundwater Hydrology, Mine Study Area, 2004 - 2008
Wells and Piezometers Upstream of Frying Pan Lake in South Fork Koktuli Watershed
Consultant: Water Management Consultants

Monitoring Site	Year	Period of Record by Task																						Notes
		Sampling												Water Levels										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
M-62	2004																									
	2005													●	●	●	●	●	●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
MW-5D	2004									●	●												●			
	2005			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2006			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2007			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2008			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
MW-5M	2004									●	●												●			
	2005			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2006			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2007			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2008			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
MW-5S	2004									●	●												●			
	2005			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2006			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2007			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2008			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
MW-05-12D	2004																									
	2005								●			●							●	●	●	●	●	●	●	
	2006			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2007			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2008			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
MW-05-12S	2004																									
	2005								●			●							●	●	●	●	●	●	●	
	2006			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2007			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2008			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
P-2D	2004																						●			
	2005													●	●	●	●	●	●	●	●	●	●	●	●	August - new datum w/cap = 0.1 ft
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-2M	2004																						●			
	2005													●	●	●	●	●	●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-3	2004																						●			
	2005													●	●	●	●	●	●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-4AD	2004										●												●			
	2005			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2006			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2007			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	

Table 5-1a
Pebble Project Environmental Baseline Studies
Monitoring Sites and Period-of-Record Index, Groundwater Hydrology, Mine Study Area, 2004 - 2008
Wells and Piezometers Upstream of Frying Pan Lake in South Fork Koktuli Watershed
Consultant: Water Management Consultants

Monitoring Site	Year	Period of Record by Task																						Notes
		Sampling												Water Levels										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
P-4AS	2004																						●			
	2005											●		●	●	●	●	●	●	●	●	●	●	●	●	
	2006			●		●			●		●			●	●	●	●	●	●	●	●	●	●	●	●	
	2007			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2008			●		●			●		●			●	●	●	●	●	●	●	●	●	●	●	●	
P-4MID	2004																						●			
	2005													●	●	●	●	●								Piezometer damaged in April 2005, casing
	2006																									at surface needs repair
	2007																									
	2008																									
P-6D	2004																						●			
	2005													●	●	●	●	●	●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-6M	2004																						●			
	2005													●	●	●	●	●	●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-6S	2004																						●			
	2005													●	●	●	●	●	●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-07D	2004																									
	2005																		●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-07S	2004																									
	2005																		●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-08	2004																									
	2005																		●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-09D	2004																									
	2005																		●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-09S	2004																									
	2005																		●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-20D	2004																									
	2005																				●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	Standpipe plugged to prevent artesian flow
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	

Table 5-1a
Pebble Project Environmental Baseline Studies
Monitoring Sites and Period-of-Record Index, Groundwater Hydrology, Mine Study Area, 2004 - 2008
Wells and Piezometers Upstream of Frying Pan Lake in South Fork Koktuli Watershed
Consultant: Water Management Consultants

Monitoring Site	Year	Period of Record by Task																						Notes
		Sampling												Water Levels										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
P-05-20S	2004																									
	2005																				●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-21D	2004																									
	2005																				●	●	●	●	●	Standpipe plugged to prevent artesian flow
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-21M	2004																									
	2005																				●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	Standpipe plugged to prevent artesian flow
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-21S	2004																									
	2005																				●	●	●	●	●	Often frozen
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-29D	2004																									
	2005																					●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-29D2	2004																									
	2005																					●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-29M	2004																									
	2005																					●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-29S	2004																									
	2005																					●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-36D	2004																									
	2005																					●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-36M	2004																									
	2005																					●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-36S	2004																									
	2005																					●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
PQ-4	2004																									
	2005											●										●	●	●	●	
	2006			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2007			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2008			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	

Table 5-1a
Pebble Project Environmental Baseline Studies
Monitoring Sites and Period-of-Record Index, Groundwater Hydrology, Mine Study Area, 2004 - 2008
Wells and Piezometers Upstream of Frying Pan Lake in South Fork Koktuli Watershed
Consultant: Water Management Consultants

Monitoring Site	Year	Period of Record by Task																						Notes
		Sampling												Water Levels										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
PQ-8	2004																									
	2005																	●	●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	flowing/frozen
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
PQ-9	2004																									
	2005																	●	●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
SRK-1A	2004																									
	2005													●		●	●	●	●	●	●	●	●	●	●	
	2006													●	●	●		●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	Frozen or flowing

KEY:

GH = Geotechnical Drillhole
MW = Monitoring Well
P = Piezometer
I = Resource drill hole used as Piezometer
KP = Resource drillhole installed as piezometer by Knight Piesold
SRK = Resource drillhole installed as piezometer by SRK International

Table 5-1b
Pebble Project Environmental Baseline Studies
Monitoring Sites and Period-of-Record Index, Groundwater Hydrology, Mine Study Area, 2004 - 2008
Wells and Piezometers Downstream of Frying Pan Lake in South Fork Koktuli River Watershed
Consultant: Water Management Consultants

Monitoring Site	Year	Period of Record by Task																						Notes
		Sampling												Water Levels										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
GH04-03	2004																						●			
	2005													●	●	●	●	●	●	●	●	●	●	●	●	Monument damaged as of August
	2006													●	●	●		●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH04-04	2004																									
	2005													●	●	●	●	●	●	●	●	●	●	●	●	Monument damaged as of August
	2006													●	●	●	●	●	●	●	●	●	●	●		
	2007													●	●	●	●	●	●	●						
	2008																									
GH04-05	2004																						●			
	2005													●	●	●	●	●	●	●	●	●	●	●	●	Monument damaged as of August
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH04-10	2004																									
	2005													●	●	●	●	●	●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●						
	2008																									
GH04-11	2004																						●			
	2005													●	●	●	●	●	●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●						
	2008																									Dry
GH04-12A	2004																						●			
	2005													●	●	●	●	●	●	●	●	●	●	●	●	Monument damaged as of August
	2006													●	●	●		●	●	●	●	●	●	●		
	2007														●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH04-14	2004																						●			
	2005													●				●	●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH04-16	2004																						●			
	2005													●	●	●	●	●	●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	Caved as of August 06 - remove from list?
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH04-17	2004																						●			
	2005													●	●	●	●	●	●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH04-18	2004																						●			
	2005													●	●	●	●	●	●	●	●	●	●	●	●	Monument at angle
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
GH04-19	2004																						●			
	2005													●	●	●	●	●	●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●		●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH04-20	2004																						●			
	2005													●	●	●	●	●	●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●		●	●	●	almost always flowing/frozen
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH04-22	2004																						●			
	2005																	●	●	●	●	●	●	●	●	Monument damaged as of June
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	

Table 5-1b
Pebble Project Environmental Baseline Studies
Monitoring Sites and Period-of-Record Index, Groundwater Hydrology, Mine Study Area, 2004 - 2008
Wells and Piezometers Downstream of Frying Pan Lake in South Fork Koktuli River Watershed
Consultant: Water Management Consultants

Monitoring Site	Year	Period of Record by Task																						Notes
		Sampling												Water Levels										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
GH04-28	2004																						●			
	2005													●	●	●	●	●	●	●	●	●	●	●	●	Monument damaged as of August
	2006													●	●	●		●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH04-29A	2004																						●			
	2005															●		●	●	●	●	●	●	●	●	
	2006													●	●	●		●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●						
	2008																									
GH04-30	2004																						●			
	2005													●	●	●	●	●	●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH04-31	2004																						●			
	2005																	●	●	●	●	●	●	●	●	
	2006													●	●	●		●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●						
	2008																									
GH04-32	2004																						●			
	2005													●	●	●	●	●	●	●	●	●	●	●	●	Monument damaged as of August
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●						
	2008																									
GH04-33	2004																						●			
	2005													●	●	●	●	●	●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH04-35	2004																						●			
	2005													●	●	●	●	●	●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH04-37	2004																						●			
	2005													●	●	●	●	●	●	●	●	●	●	●	●	Monument damaged as of September
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH04-38	2004																						●			
	2005														●	●	●	●	●	●	●	●	●	●	●	Monument damaged as of August
	2006													●	●	●		●	●	●	●	●	●	●		
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH04-39	2004																									
	2005															●		●	●	●	●	●	●	●	●	
	2006													●	●	●		●	●	●	●	●	●	●		
	2007													●	●	●	●	●	●	●						
	2008																									
GH04-41	2004																						●			
	2005													●	●	●	●	●	●	●	●	●	●	●	●	Monument damaged as of August
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	Frozen
GH04-42	2004																						●			
	2005													●	●	●	●	●	●	●	●	●	●	●	●	
	2006													●	●	●		●	●	●	●	●	●	●	●	Dry year round
	2007													●	●	●	●	●	●	●						
	2008																									
GH04-43	2004																						●			
	2005													●	●	●	●	●	●	●	●	●	●	●	●	Monument damaged as of July
	2006													●	●	●		●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	

Table 5-1b
Pebble Project Environmental Baseline Studies
Monitoring Sites and Period-of-Record Index, Groundwater Hydrology, Mine Study Area, 2004 - 2008
Wells and Piezometers Downstream of Frying Pan Lake in South Fork Koktuli River Watershed
Consultant: Water Management Consultants

Monitoring Site	Year	Period of Record by Task																						Notes
		Sampling												Water Levels										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
GH04-44	2004																						●			
	2005													●	●	●	●	●	●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●						dry/frozen
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH04-45A	2004																									
	2005													●	●	●	●	●	●	●	●	●	●	●	●	
	2006													●	●			●	●	●	●	●	●	●	●	typically dry
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH05-51	2004																									
	2005																							●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●						
	2008																									
GH05-52	2004																									
	2005																							●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●						Standing water
	2008																									
GH06-75	2004																									
	2005																									
	2006																									
	2007																				●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH06-76	2004																									
	2005																									
	2006																									
	2007																				●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH06-77	2004																									
	2005																									
	2006																									
	2007																				●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
MW-1D	2004									●	●															
	2005			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2006			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2007			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2008			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
MW-1M	2004									●	●															
	2005			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2006			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2007			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2008			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
MW-1S	2004									●	●															
	2005			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2006			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2007			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2008			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
MW-2D	2004									●	●												●			
	2005			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2006			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2007			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2008			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
MW-05-2M	2004																						●			Well was scheduled to be sampled, but excessive silt prevents sampling
	2005											●		●	●	●	●	●	●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	

Table 5-1b
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Monitoring Sites and Period-of-Record Index, Groundwater Hydrology, Mine Study Area, 2004 - 2008
Wells and Piezometers Downstream of Frying Pan Lake in South Fork Koktuli River Watershed
Consultant: Water Management Consultants

Monitoring Site	Year	Period of Record by Task																						Notes
		Sampling												Water Levels										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
MW-2S	2004																						•			Well was scheduled to be sampled, but excessive drawdown (due to silt) prevents sampling
	2005											•		•	•	•	•	•	•	•	•	•	•	•	•	
	2006													•	•	•	•	•	•	•	•	•	•	•	•	
	2007													•	•	•	•	•	•	•	•	•	•	•	•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	
MW-05-2SR	2004																									Well was scheduled to be sampled, but excessive silt prevents sampling
	2005																					•	•	•	•	
	2006													•	•	•	•	•	•	•	•	•	•	•	•	
	2007													•	•	•	•	•	•	•	•	•	•	•	•	Dry/frozen all 2007 dates
	2008													•	•	•	•	•	•	•	•	•	•	•	•	
MW-3D	2004																						•			
	2005			•		•			•					•	•	•	•	•	•	•	•	•	•	•	•	
	2006			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
	2007			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
	2008			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
MW-11D	2004										•												•			
	2005			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
	2006			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
	2007			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
	2008			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
MW-11M	2004										•												•			
	2005			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
	2006			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
	2007			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
	2008			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
MW-11S	2004										•												•			
	2005			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
	2006			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
	2007			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
	2008			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
MW-05-11SS[1]	2004																									
	2005											•										•	•	•	•	
	2006					•			•			•		•	•	•		•	•	•	•	•	•	•	•	Well has shallow water: winter sampling was scheduled, but sample was not obtained
	2007			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
	2008			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
MW-05-13D	2004																									
	2005								•			•							•	•	•	•	•	•	
	2006			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
	2007			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
	2008			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
MW-05-13S	2004																									
	2005								•			•							•	•	•	•	•	•	
	2006			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
	2007			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
	2008			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
MW-05-14D	2004																									
	2005											•								•	•	•	•	•	•	
	2006			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
	2007			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
	2008			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
MW-05-14S	2004																									
	2005											•								•	•	•	•	•	•	
	2006			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
	2007			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
	2008			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
P-05-10D	2004																									
	2005																			•	•	•	•	•	•	
	2006													•	•	•	•	•	•	•	•	•	•	•	•	
	2007													•	•	•	•	•	•	•	•	•	•	•	•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	

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Monitoring Sites and Period-of-Record Index, Groundwater Hydrology, Mine Study Area, 2004 - 2008
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Consultant: Water Management Consultants

Monitoring Site	Year	Period of Record by Task																						Notes
		Sampling												Water Levels										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
P-05-10S	2004																									
	2005																			●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-11D	2004																									
	2005																				●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-11M	2004																									
	2005																				●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-11S	2004																									
	2005																				●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-12	2004																									
	2005																			●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-13	2004																									
	2005																			●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-14D	2004																									
	2005																			●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-14S	2004																									
	2005																			●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-15D	2004																									
	2005																			●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	Frozen/dry all 2007
P-05-15S	2004																									
	2005																			●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-16D	2004																									
	2005																			●	●	●	●	●	●	
	2006													●	●	●		●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008														●	●	●	●	●	●	●	●	●	●	●	
P-05-16M	2004																									
	2005																			●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008														●	●	●	●	●	●	●	●	●	●	●	
P-05-16S	2004																									
	2005																			●	●	●	●	●	●	
	2006													●	●	●		●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008														●	●	●	●	●	●	●	●	●	●	●	

Table 5-1b
Pebble Project Environmental Baseline Studies
Monitoring Sites and Period-of-Record Index, Groundwater Hydrology, Mine Study Area, 2004 - 2008
Wells and Piezometers Downstream of Frying Pan Lake in South Fork Koktuli River Watershed
Consultant: Water Management Consultants

Monitoring Site	Year	Period of Record by Task																						Notes
		Sampling												Water Levels										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
P-05-16SS	2004																									
	2005																			●	●	●	●	●	●	
	2006													●	●	●		●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008														●	●	●	●	●	●	●	●	●	●	●	
P-05-17D	2004																									
	2005																			●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-17S	2004																									
	2005																			●	●	●	●	●	●	
	2006													●	●	●		●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-18	2004																									
	2005																			●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-19D	2004																									
	2005																				●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-19S	2004																									
	2005																				●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-22D	2004																									
	2005																				●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-23	2004																									
	2005																				●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-24D	2004																									
	2005																				●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-24S	2004																									
	2005																				●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-25	2004																									
	2005																				●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-26D	2004																									
	2005																					●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-26M	2004																									
	2005																					●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	

Table 5-1b
Pebble Project Environmental Baseline Studies
Monitoring Sites and Period-of-Record Index, Groundwater Hydrology, Mine Study Area, 2004 - 2008
Wells and Piezometers Downstream of Frying Pan Lake in South Fork Koktuli River Watershed
Consultant: Water Management Consultants

Monitoring Site	Year	Period of Record by Task																						Notes
		Sampling												Water Levels										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
P-05-26S	2004																									
	2005																					●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-27D	2004																									
	2005																					●	●	●	●	
	2006													●	●				●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008															●	●	●	●	●	●	●	●	●	●	
P-05-27M	2004																									
	2005																					●	●	●	●	
	2006													●	●	●		●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008														●	●	●	●	●	●	●	●	●	●	●	
P-05-27S	2004																									
	2005																					●	●	●	●	
	2006													●	●	●			●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008														●	●	●	●	●	●	●	●	●	●	●	

KEY:

GH = Geotechnical Hole
MW = Monitoring Well
P = Piezometer
WL = Wetlands Location

NOTES:

1. Well MW-05-11SS is at the same location as MW-11 shown on Figure 5.1-2.

Table 5-1c
Pebble Project Environmental Baseline Studies
Monitoring Sites and Period-of-Record Index, Groundwater Hydrology, Mine Study Area, 2004 - 2008
Wells and Piezometers in North Fork Koktuli River Watershed
Consultant: Water Management Consultants

Monitoring Site	Year	Period of Record by Task																						Notes
		Sampling												Water Levels										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
GH04-01	2004																						•			
	2005													•	•	•	•	•	•	•	•	•	•	•	•	
	2006													•	•	•	•	•	•	•	•	•	•	•	•	
	2007													•	•	•	•	•	•	•						
	2008																									Caved in
GH04-08	2004																						•			
	2005																	•	•	•	•	•	•	•	•	
	2006													•	•	•		•	•	•	•	•	•	•	•	
	2007													•	•	•	•	•	•	•	•	•	•	•	•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	frozen/flowing
GH04-23	2004																						•			
	2005													•	•	•	•	•	•	•	•	•	•	•	•	Monument damaged as of August
	2006													•	•	•	•	•	•	•	•	•	•	•	•	
	2007													•	•	•	•	•	•	•	•	•	•	•	•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	
GH04-25	2004																									
	2005													•	•	•	•	•	•	•	•	•	•	•	•	
	2006													•	•	•	•	•	•	•	•	•	•	•	•	
	2007													•	•	•	•	•	•	•	•	•	•	•	•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	
GH05-57	2004																									
	2005																						•	•		
	2006													•	•	•	•	•	•	•	•	•	•	•	•	
	2007													•	•	•	•	•	•	•	•	•	•	•	•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	
GH06-66	2004																									
	2005																									
	2006																									
	2007																				•	•	•	•	•	wrench in monument
	2008													•	•	•	•	•	•	•	•	•	•	•	•	
GH06-67	2004																									
	2005																									
	2006																									
	2007																				•	•	•	•	•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	
GH06-68	2004																									
	2005																									
	2006																									
	2007																				•	•	•	•	•	no monument
	2008													•	•	•	•	•	•	•	•	•	•	•	•	
GH06-69	2004																									
	2005																									
	2006																									
	2007																				•	•	•	•	•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	
GH07-81	2004																									
	2005																									
	2006																									
	2007																								•	
	2008													•				•	•	•	•	•	•	•	•	Could not located due to deep snow; wanded
GH07-82D	2004																									
	2005																									
	2006																									
	2007																								•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	
GH07-82S	2004																									
	2005																									
	2006																									
	2007																								•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	

Table 5-1c
Pebble Project Environmental Baseline Studies
Monitoring Sites and Period-of-Record Index, Groundwater Hydrology, Mine Study Area, 2004 - 2008
Wells and Piezometers in North Fork Koktuli River Watershed
Consultant: Water Management Consultants

Monitoring Site	Year	Period of Record by Task																						Notes
		Sampling												Water Levels										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
GH07-83D	2004																									
	2005																									
	2006																									
	2007																								•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	frozen
GH07-83S	2004																									
	2005																									
	2006																									
	2007																								•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	frozen
GH07-84	2004																									
	2005																									
	2006																									
	2007																								•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	
GH07-85	2004																									
	2005																									
	2006																									
	2007																								•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	
GH07-86	2004																									
	2005																									
	2006																									
	2007																								•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	frozen
GH07-87D	2004																									
	2005																									
	2006																									
	2007																								•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	frozen
GH07-87S	2004																									
	2005																									
	2006																									
	2007																								•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	
GH07-88	2004																									
	2005																									
	2006																									
	2007																								•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	
GH07-89D	2004																									
	2005																									
	2006																									
	2007																								•	
	2008																	•	•	•	•	•	•	•	•	Deep snow; wanded but couldn't locate
GH07-89S	2004																									
	2005																									
	2006																									
	2007																								•	
	2008																	•	•	•	•	•	•	•	•	Deep snow; wanded but couldn't locate
GH07-90D	2004																									
	2005																									
	2006																									
	2007																									
	2008																	•	•	•	•	•	•	•	•	Deep snow; wanded but couldn't locate
GH07-90S	2004																									
	2005																									
	2006																									
	2007																									
	2008																	•	•	•	•	•	•	•	•	Deep snow; wanded but couldn't locate
GH07-95	2004																									
	2005																									
	2006																									
	2007																								•	
	2008														•	•	•	•	•	•	•	•	•	•	•	
GH07-96D	2004																									
	2005																									
	2006																									
	2007																								•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	

Table 5-1c
Pebble Project Environmental Baseline Studies
Monitoring Sites and Period-of-Record Index, Groundwater Hydrology, Mine Study Area, 2004 - 2008
Wells and Piezometers in North Fork Koktuli River Watershed
Consultant: Water Management Consultants

Monitoring Site	Year	Period of Record by Task																						Notes
		Sampling												Water Levels										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
GH07-96S	2004																									
	2005																									
	2006																									
	2007																								•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	
GH07-97D	2004																									
	2005																									
	2006																									
	2007																								•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	
GH07-97S	2004																									
	2005																									
	2006																									
	2007																								•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	
GH07-98D	2004																									
	2005																									
	2006																									
	2007																								•	
	2008													•				•	•	•	•	•	•	•	•	Deep snow; wanded but couldn't locate
GH07-98S	2004																									
	2005																									
	2006																									
	2007																								•	
	2008													•				•	•	•	•	•	•	•	•	Deep snow; wanded but couldn't locate
GH07-99	2004																									
	2005																									
	2006																									
	2007																									
	2008													•	•	•	•	•	•	•	•	•	•	•	•	
GH07-100	2004																									
	2005																									
	2006																									
	2007																								•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	
GH07-101	2004																									
	2005																									
	2006																									
	2007																								•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	
GH07-102D	2004																									
	2005																									
	2006																									
	2007																								•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	
GH07-102S	2004																									
	2005																									
	2006																									
	2007																								•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	
GH07-103D	2004																									
	2005																									
	2006																									
	2007																								•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	
GH07-103S	2004																									
	2005																									
	2006																									
	2007																								•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	dry well
MW-6D	2004									•	•												•			
	2005			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
	2006			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
	2007			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
	2008			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	

Table 5-1c
Pebble Project Environmental Baseline Studies
Monitoring Sites and Period-of-Record Index, Groundwater Hydrology, Mine Study Area, 2004 - 2008
Wells and Piezometers in North Fork Koktuli River Watershed
Consultant: Water Management Consultants

Monitoring Site	Year	Period of Record by Task																						Notes
		Sampling												Water Levels										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
MW-7D	2004									●	●												●			
	2005			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2006			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2007			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2008			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
MW-7S	2004									●	●												●			
	2005			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2006			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2007			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2008			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
MW-8D	2004									●	●												●			
	2005			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2006			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2007			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2008			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
MW-8M	2004									●	●												●			
	2005			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2006			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2007			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2008			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
MW-8S	2004									●	●												●			
	2005			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2006			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2007			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2008			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
MW-9D	2004									●	●												●			
	2005			●		●			●					●	●	●	●	●	●	●	●	●	●	●	●	Well has shallow water: winter sampling was scheduled, but samples were not obtained
	2006					●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2007			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2008			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	Standpipe plugged to prevent artesian flow
MW-10	2004										●												●			
	2005			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2006			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2007			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2008			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	

KEY:
GH = Geotechnical Hole
MW = Monitoring Well
P = Piezometer
WL = Wetlands Location

Table 5-1d
Pebble Project Environmental Baseline Studies
Monitoring Sites and Period-of-Record Index, Groundwater Hydrology, Mine Study Area, 2004 - 2008
Wells and Piezometers in Upper Talarik Creek Watershed
Consultant: Water Management Consultants

Monitoring Site	Year	Period of Record by Task																						Notes
		Sampling												Water Levels										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
GH04-02	2004																						●			
	2005														●	●	●	●	●	●	●	●	●	●	●	Monument damaged as of August
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH04-13	2004																						●			
	2005													●	●	●	●	●	●	●	●	●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH05-64	2004																									
	2005																							●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
GH06-78	2004																									
	2005																									
	2006																									
	2007																									
	2008																									no piezo
KP-P1/ SRK-2	2004																						●			
	2005			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2006			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2007			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2008			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
MW-4 (Stand 1)	2004																									Well was scheduled to be sampled, but lack of water precluded sampling
	2005													●	●	●	●	●	●	●	●	●	●	●	●	No monument
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-28D	2004																									
	2005																					●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-28S	2004																									
	2005																					●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-30D	2004																									
	2005																					●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-30S	2004																									
	2005																					●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-31D	2004																									
	2005																					●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-31S	2004																									
	2005																					●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-32D	2004																									
	2005																					●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	

Table 5-1d
Pebble Project Environmental Baseline Studies
Monitoring Sites and Period-of-Record Index, Groundwater Hydrology, Mine Study Area, 2004 - 2008
Wells and Piezometers in Upper Talarik Creek Watershed
Consultant: Water Management Consultants

Monitoring Site	Year	Period of Record by Task																							Notes
		Sampling												Water Levels											
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
P-05-33D	2004																								
	2005																					●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-34D	2004																								
	2005																					●	●	●	●	Well caved in December
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-05-35D	2004																								
	2005																					●	●	●	●	
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-06-37D	2004																								
	2005																								
	2006											●									●	●	●	●	●	
	2007			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2008			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
P-06-37M	2004																								
	2005																								
	2006											●									●	●	●	●	●	
	2007			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2008			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
P-06-37S	2004																								
	2005																								
	2006											●									●	●	●	●	●	
	2007			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2008			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
P-06-38D	2004																								
	2005																								
	2006											●									●	●	●	●	●	
	2007			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	
	2008			●		●			●			●		●	●	●	●	●	●	●	●	●	●	●	●	Standpipe plugged to prevent artesian flow
P-06-38M	2004																								
	2005																								
	2006																					●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-06-39D	2004																								
	2005																								
	2006																					●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-06-39S	2004																								
	2005																								
	2006																					●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
P-06-40D	2004																								
	2005																								
	2006																					●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	Standpipe plugged to prevent artesian flow
P-06-40M	2004																								
	2005																								
	2006																					●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	Plugged, casing flush with ground

Table 5-1d
Pebble Project Environmental Baseline Studies
Monitoring Sites and Period-of-Record Index, Groundwater Hydrology, Mine Study Area, 2004 - 2008
Wells and Piezometers in Upper Talarik Creek Watershed
Consultant: Water Management Consultants

Monitoring Site	Year	Period of Record by Task																							Notes
		Sampling												Water Levels											
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
P-06-40S	2004																									
	2005																									
	2006																				•	•	•	•	•	typically frozen
	2007													•	•	•	•	•	•	•	•	•	•	•	•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	
P-06-41D	2004																									
	2005																									
	2006													•	•	•	•	•	•	•	•	•	•	•	•	
	2007													•	•	•	•	•	•	•	•	•	•	•	•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	
P-06-41M	2004																									
	2005																									
	2006																				•	•	•	•	•	typically frozen
	2007													•	•	•	•	•	•	•	•	•	•	•	•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	
P-06-41S	2004																									
	2005																									
	2006																				•	•	•	•	•	
	2007													•	•	•	•	•	•	•	•	•	•	•	•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	
P-07-44D	2004																									
	2005																									
	2006																									
	2007																								•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	dry
P-07-44S	2004																									
	2005																									
	2006																									
	2007																								•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	dry
P-07-45D	2004																									
	2005																									
	2006																									
	2007																								•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	
P-07-46D	2004																									
	2005																									
	2006																									
	2007																								•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	
P-07-47D	2004																									
	2005																									
	2006																									
	2007																								•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	Monument needs to be fixed
SRK-2A	2004																						•			
	2005													•	•	•	•	•	•	•	•	•	•	•	•	
	2006													•	•	•	•	•	•	•	•	•	•	•	•	
	2007													•	•	•	•	•	•	•	•	•	•	•	•	
	2008													•	•	•	•	•	•	•	•	•	•	•	•	
SRK-3	2004																						•			
	2005											•		•	•	•	•	•	•	•	•	•	•	•	•	
	2006			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
	2007			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	
	2008			•		•			•			•		•	•	•	•	•	•	•	•	•	•	•	•	

KEY:

GH = Geotechnical Hole
MW = Monitoring Well
P = Piezometer
WL = Wetlands Location

Table 5-1e
Pebble Project Environmental Baseline Studies
Monitoring Sites and Period-of-Record Index, Groundwater Hydrology, Mine Study Area, 2004 - 2008
Piezometers for Wetland Study
Consultant: Water Management Consultants

Monitoring Site	Year	Period of Record by Task																						Notes
		Sampling												Water Levels										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
WL-P01D	2004																									
	2005																									
	2006													●	●	●	●			●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●		●	●	●	●	●	●	●	●	●	●	
WL-P01S	2004																									
	2005																									
	2006													●	●	●		●	●	●	●	●	●	●	●	
	2007																	●	●	●	●	●	●	●		Stake down, couldn't locate after Dec
	2008																	●	●	●	●	●	●	●	●	
WL-S01D	2004																									
	2005																									
	2006													●	●	●		●	●	●				●	●	
	2007													●	●	●	●	●							●	tends to be in deep water
	2008													●				●	●	●	●	●	●	●	●	making it inaccessible.
WL-S01G	2004																									
	2005																									
	2006													●	●	●			●	●	●	●	●	●	●	
	2007																	●	●	●	●	●	●	●	●	Staff gage often not visable (snow)
	2008																	●	●	●	●	●	●	●	●	
WL-S01S	2004																									
	2005																									
	2006													●	●	●		●	●	●				●	●	
	2007													●	●	●	●	●							●	
	2008													●	●			●	●	●	●	●	●	●	●	
WL-P02D	2004																									
	2005																									
	2006													●	●	●	●		●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
WL-P02S	2004																									
	2005																									
	2006													●	●	●			●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	often dry
	2008															●	●	●	●	●	●	●	●	●	●	
WL-S02D	2004																									
	2005																									
	2006													●	●	●	●	●	●	●	●			●	●	
	2007													●	●	●	●							●	●	often frozen
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
WL-S02G	2004																									
	2005																									
	2006															●		●	●	●	●	●	●	●	●	
	2007														●	●	●	●	●	●	●	●	●	●	●	
	2008																	●	●	●	●	●	●	●	●	
WL-S02S	2004																									
	2005																									
	2006													●	●	●	●	●	●	●		●		●	●	
	2007													●	●	●	●								●	typically frozen
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
WL-P03D	2004																									
	2005																									
	2006													●	●	●		●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●				●	●	●	●	●	●	●	●	

Table 5-1e
Pebble Project Environmental Baseline Studies
Monitoring Sites and Period-of-Record Index, Groundwater Hydrology, Mine Study Area, 2004 - 2008
Piezometers for Wetland Study
Consultant: Water Management Consultants

Monitoring Site	Year	Period of Record by Task																						Notes
		Sampling												Water Levels										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
WL-P03S	2004																									
	2005																									
	2006													●	●	●	●	●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008																	●	●	●	●	●	●	●	●	Stake down, could not locate
WL-S03D	2004																									
	2005																									
	2006													●	●	●					●	●	●	●		tilted @ 30 degree angle
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
WL-S03G	2004																									
	2005																									
	2006													●	●	●				●		●	●	●	●	
	2007													●	●	●	●		●	●	●	●	●	●	●	
	2008													●				●	●	●	●	●	●	●	●	
WL-S03S	2004																									
	2005																									
	2006													●	●	●				●	●	●	●	●	●	tilted @ 30 degrees
	2007													●	●	●	●	●	●	●	●	●	●	●	●	needs to be fixed
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
WL-P04D	2004																									
	2005																									
	2006													●	●	●		●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008																	●	●	●	●	●	●	●	●	Stake down, could not locate
WL-P04S	2004																									
	2005																									
	2006													●	●	●		●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008																	●	●	●	●	●	●	●	●	Stake down, could not locate
WL-S04D	2004																									
	2005																									
	2006													●	●	●		●								Well stand down as of June
	2007																									
	2008																									
WL-S04G	2004																									
	2005																									
	2006													●	●	●		●	●	●	●	●	●	●	●	
	2007																●	●	●	●	●	●	●	●	●	
	2008																	●	●	●	●	●	●	●	●	
WL-S04S	2004																									
	2005																									
	2006													●	●	●		●								Well stand down as of June
	2007																									
	2008																									
WL-P05D	2004																									
	2005																									
	2006													●	●	●		●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	often frozen/dry
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
WL-P05S	2004																									
	2005																									
	2006													●	●	●		●	●	●	●	●	●	●	●	often dry
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	

Table 5-1e

Pebble Project Environmental Baseline Studies

Monitoring Sites and Period-of-Record Index, Groundwater Hydrology, Mine Study Area, 2004 - 2008

Piezometers for Wetland Study

Consultant: Water Management Consultants

Monitoring Site	Year	Period of Record by Task																						Notes
		Sampling												Water Levels										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
WL-S05D	2004																									
	2005																									
	2006													●	●	●		●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●			
	2008																	●	●	●	●	●	●	●	●	in pond
WL-S05S	2004																									
	2005																									
	2006													●	●	●		●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●		●	
	2008													●				●	●	●	●	●	●	●	●	Stake down, could not locate
WL-P06D	2004																									
	2005																									
	2006													●	●	●		●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
WL-P06S	2004																									
	2005																									
	2006													●	●	●		●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	often dry
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
WL-S06D	2004																									
	2005																									
	2006													●	●	●		●	●	●	●	●	●	●		
	2007													●	●	●	●	●								out of water, jacked too tall to
	2008																	●	●	●	●	●	●	●	●	measure as of June 06
WL-S06G	2004																									
	2005																									
	2006																									Gage out of water or not visable
	2007																									
	2008																									
WL-S06S	2004																									
	2005																									
	2006													●	●	●		●	●	●	●	●	●	●		
	2007													●	●	●	●	●	●							Jacked out of water as of June
	2008																									
WL-P07D	2004																									
	2005																									
	2006													●	●	●		●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
WL-P07S	2004																									
	2005																									
	2006													●	●	●		●	●	●	●	●	●	●	●	typically dry
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
WL-S07D	2004																									
	2005																									
	2006													●	●	●				●		●		●	●	
	2007													●	●	●					●	●			●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
WL-S07G	2004																									
	2005																									
	2006													●	●	●			●	●		●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●		●	●	●	●	●	●	●	●	

Table 5-1e
Pebble Project Environmental Baseline Studies
Monitoring Sites and Period-of-Record Index, Groundwater Hydrology, Mine Study Area, 2004 - 2008
Piezometers for Wetland Study
Consultant: Water Management Consultants

Monitoring Site	Year	Period of Record by Task																						Notes
		Sampling												Water Levels										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
WL-S07S	2004																									
	2005																									
	2006													●	●	●				●				●	●	
	2007													●	●	●					●	●			●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
WL-P08D	2004																									
	2005																									
	2006													●	●	●		●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
WL-P08S	2004																									
	2005																									
	2006													●	●	●		●	●	●	●	●	●	●	●	dry/frozen
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
WL-P09D	2004																									
	2005																									
	2006													●	●	●		●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008																	●	●	●	●	●	●	●	●	
WL-P09S	2004																									
	2005																									
	2006													●	●	●		●	●	●	●	●	●	●	●	
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
WL-P10D	2004																									
	2005																									
	2006													●	●	●		●	●	●	●	●	●	●	●	dry/frozen
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
WL-P10S	2004																									
	2005																									
	2006													●	●	●		●	●	●	●	●	●	●	●	dry/frozen
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
WL-P11D	2004																									
	2005																									
	2006													●	●	●		●	●	●	●	●	●	●	●	often frozen/dry
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
WL-P11S	2004																									
	2005																									
	2006													●	●	●		●	●	●	●	●	●	●	●	often frozen/dry
	2007													●	●	●	●	●	●	●	●	●	●	●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
WL-P15D	2004																									
	2005																									
	2006																									
	2007																							●	●	
	2008																	●	●	●	●	●	●	●	●	Wanded but couldn't locate in snow
WL-P15G	2004																									
	2005																									
	2006																									
	2007																							●	●	
	2008																	●	●	●	●	●	●	●	●	Gage not visable

Table 5-1e
Pebble Project Environmental Baseline Studies
Monitoring Sites and Period-of-Record Index, Groundwater Hydrology, Mine Study Area, 2004 - 2008
Piezometers for Wetland Study
Consultant: Water Management Consultants

Monitoring Site	Year	Period of Record by Task																						Notes
		Sampling												Water Levels										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
WL-P15S	2004																									
	2005																									
	2006																									
	2007																							●	●	
	2008																	●	●	●	●	●	●	●	●	Wanded but couldn't locate in snow
WL-P16D	2004																									
	2005																									
	2006																									
	2007																							●	●	
	2008													●				●	●	●	●	●	●	●	●	Wanded but couldn't locate in snow
WL-P16G	2004																									
	2005																									
	2006																									
	2007																								●	
	2008																	●	●	●	●	●	●	●	●	Could not locate
WL-P16S	2004																									
	2005																									
	2006																									
	2007																							●	●	
	2008																	●	●	●	●	●	●	●	●	Wanded but couldn't locate in snow
WL-P17D	2004																									
	2005																									
	2006																									
	2007																							●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
WL-P17S	2004																									
	2005																									
	2006																									
	2007																							●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
WL-P18D	2004																									
	2005																									
	2006																									
	2007																							●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
WL-P18G	2004																									
	2005																									
	2006																									
	2007																							●		
	2008																	●	●	●	●	●	●	●	●	Gage not visable
WL-P18S	2004																									
	2005																									
	2006																									
	2007																							●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
WL-P19D	2004																									
	2005																									
	2006																									
	2007																							●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
WL-P19S	2004																									
	2005																									
	2006																									
	2007																							●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	

Table 5-1e
Pebble Project Environmental Baseline Studies
Monitoring Sites and Period-of-Record Index, Groundwater Hydrology, Mine Study Area, 2004 - 2008
Piezometers for Wetland Study
Consultant: Water Management Consultants

Monitoring Site	Year	Period of Record by Task																						Notes
		Sampling												Water Levels										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
WL-P20D	2004																									
	2005																									
	2006																									
	2007																							●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	Frozen
WL-P20G	2004																									
	2005																									
	2006																									
	2007																							●	●	
	2008																	●	●	●	●	●	●	●	●	Gage not visable
WL-P20S	2004																									
	2005																									
	2006																									
	2007																							●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	Frozen
WL-P21D	2004																									
	2005																									
	2006																									
	2007																							●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	Frozen
WL-P21G	2004																									
	2005																									
	2006																									
	2007																							●	●	
	2008																	●	●	●	●	●	●	●	●	Gage not visable
WL-P21S	2004																									
	2005																									
	2006																									
	2007																							●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	Frozen
WL-P22D	2004																									
	2005																									
	2006																									
	2007																							●	●	
	2008																	●	●	●	●	●	●	●	●	Wanded but couldn't locate in snow
WL-P22S	2004																									
	2005																									
	2006																									
	2007																							●	●	
	2008													●				●	●	●	●	●	●	●	●	Wanded but couldn't locate in snow
WL-P23D	2004																									
	2005																									
	2006																									
	2007																							●	●	
	2008													●				●	●	●	●	●	●	●	●	Wanded but couldn't locate in snow
WL-P23S	2004																									
	2005																									
	2006																									
	2007																							●	●	
	2008																	●	●	●	●	●	●	●	●	Wanded but couldn't locate in snow
WL-P24D	2004																									
	2005																									
	2006																									
	2007																							●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	

Table 5-1e
Pebble Project Environmental Baseline Studies
Monitoring Sites and Period-of-Record Index, Groundwater Hydrology, Mine Study Area, 2004 - 2008
Piezometers for Wetland Study
Consultant: Water Management Consultants

Monitoring Site	Year	Period of Record by Task																						Notes
		Sampling												Water Levels										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
WL-P24S	2004																									
	2005																									
	2006																									
	2007																							●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	
WL-P25D	2004																									
	2005																									
	2006																									
	2007																							●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	Frozen
WL-P25S	2004																									
	2005																									
	2006																									
	2007																							●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	Frozen
WL-P26D	2004																									
	2005																									
	2006																									
	2007																							●	●	
	2008													●				●	●	●	●	●	●	●	●	Wanded but couldn't locate in snow
WL-P26S	2004																									
	2005																									
	2006																									
	2007																							●	●	
	2008													●	●	●	●	●	●	●	●	●	●	●	●	Frozen

KEY:

GH = Geotechnical Hole
MW = Monitoring Well
P = Piezometer
WL = Wetlands Location

TABLE 5-2
Pebble Project Environmental Baseline Studies
Study Summary for Groundwater Hydrology, Mine Study Area, 2004-2008
Consultant: Water Management Consultants

2004 Data Collected or Tasks Completed	2005 Data Collected or Tasks Completed	2006 Data Collected or Tasks Completed	2007 Data Collected or Tasks Completed	2008 Data Collected or Tasks Completed
Field Work	Field Work	Field Work	Field Work	Field Work
Input to Tasks by Others	Input to Tasks by Others	Input to Tasks by Others	Input to Tasks by Others	Input to Tasks by Others
	Data Review and Analysis	Data Review and Analysis	Data Review and Analysis	Data Review and Analysis
	Groundwater Recharge Analysis	Groundwater Recharge Analysis		
		Westbay multi-level piezometer Installation	Westbay Monitoring	Westbay Monitoring
			Site-wide Groundwater Model	Site-wide Groundwater Model
			Site Water Balance	Site Water Balance
Identify Groundwater Quality Sampling Locations; Collect Samples (September/October)	Identify New Groundwater Quality Sampling Locations; Collect Quarterly Samples	Identify New Groundwater Quality Sampling Locations; Collect Quarterly Samples	Collect Quarterly Groundwater Quality Samples	Collect Quarterly Groundwater Quality Samples
Meetings	Meetings	Meetings	Meetings	Meetings
	Reporting	Reporting	Reporting	Reporting

TABLE 5-3
Summary of Monitoring Wells and Piezometers Sampled during 2007, by Drainage

		Piezometer Measurements		Groundwater Samples	
Drainage	**Sub-drainage**	**Piezometers and Monitoring Wells**	**Piezometer and Monitoring Well Sites**	**Monitoring Wells**	**Monitoring Well Sites**
South Fork Koktuli	Upstream of Frying Pan Lake	76	54	12	6
	Downstream of Frying Pan Lake	80	55	13	6
North Fork Koktuli		46	33	8	5
Upper Talarik Creek		38	21	6	4
Wetlands		71	22		
TOTAL		**311**	**185**	**39**	**21**

FIGURES

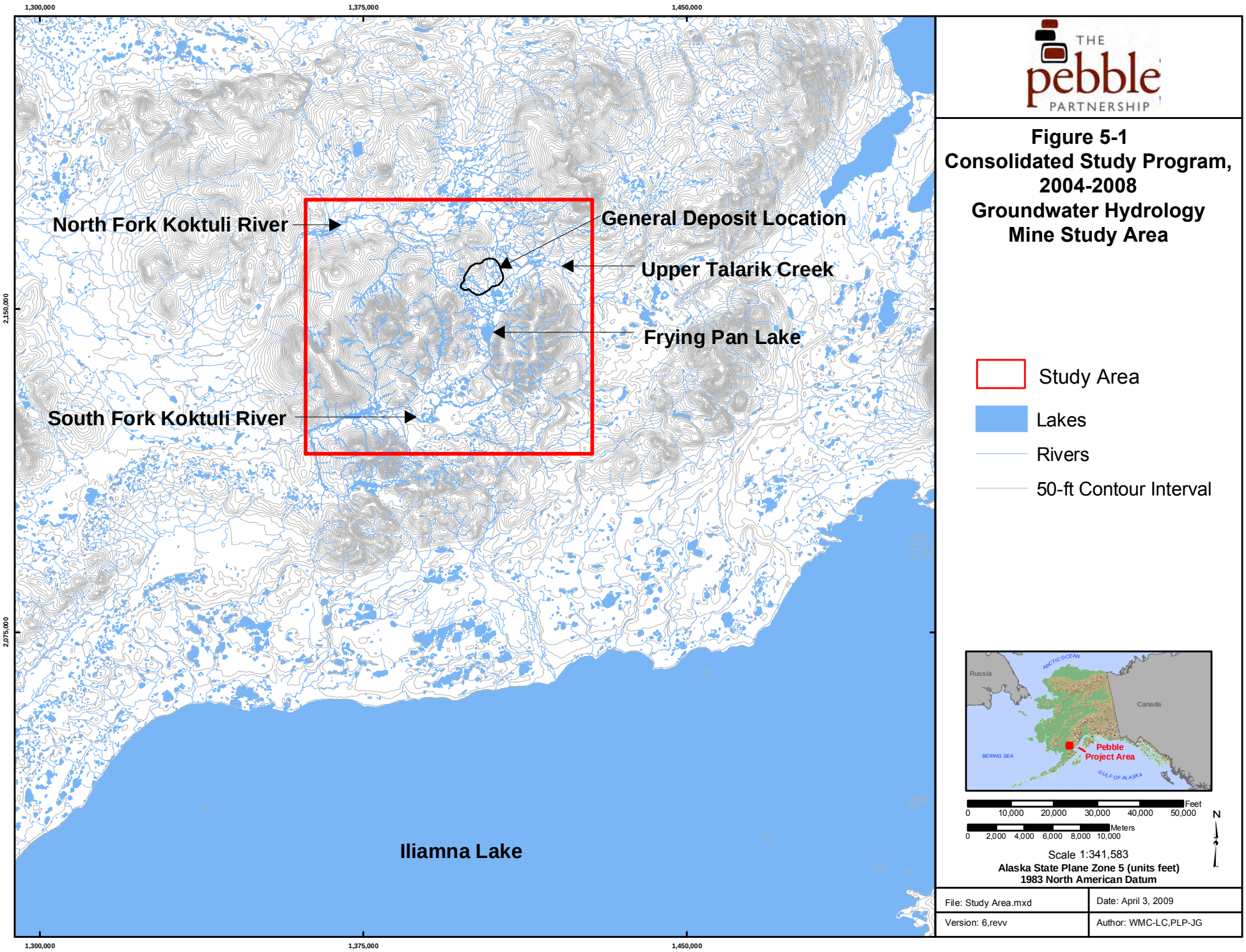
1,300,000
1,375,000
1,450,000
2,150,000
2,075,000
North Fork Koktuli River
General Deposit Location
Upper Talarik Creek
Frying Pan Lake
South Fork Koktuli River
Iliamna Lake
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Figure 5-1
Consolidated Study Program, 2004-2008
Groundwater Hydrology
Mine Study Area
Study Area
Lakes
Rivers
50-ft Contour Interval
ARCTIC OCEAN
Russia
Canada
BERING SEA
GULF OF ALASKA
Pebble Project Area
Feet
0 10,000 20,000 30,000 40,000 50,000
Meters
0 2,000 4,000 6,000 8,000 10,000
N
Scale 1:341,583
Alaska State Plane Zone 5 (units feet)
1983 North American Datum
File: Study Area.mxd
Date: April 3, 2009
Version: 6,revv
Author: WMC-LC,PLP-JG

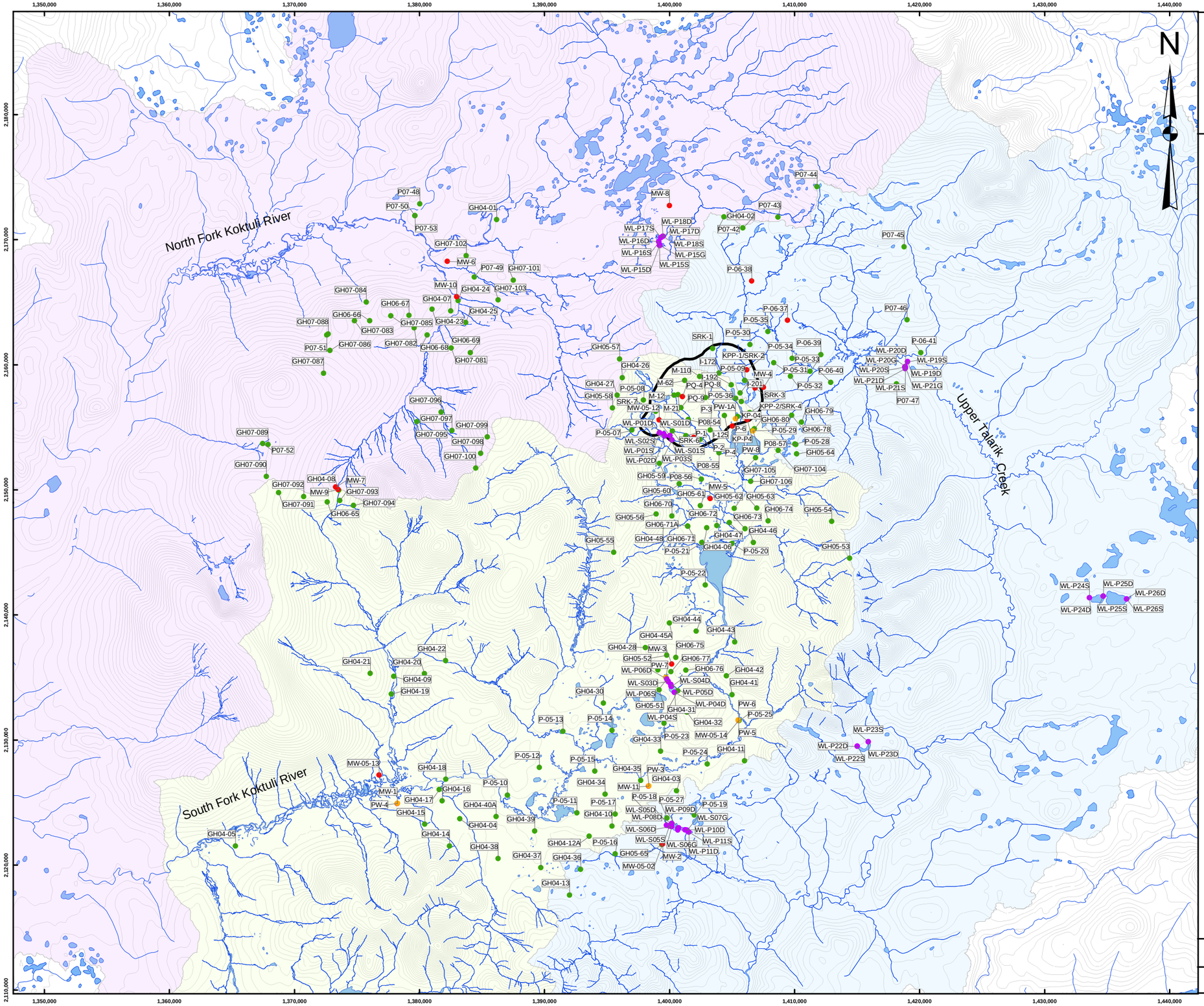


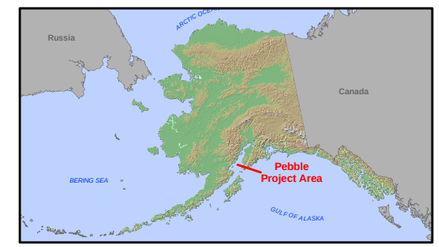
Figure 5-2
Consolidated Study Program, 2004 - 2008 Groundwater Hydrology Existing Well and Piezometer Locations (2008), Mine Study Area

Legend

- Monitoring Well (MW)
- Piezometer (P, GH, I, M)
- Pumping Well (PW)
- Wetland Piezometer (WL)
- General Deposit Location
- Lakes
- Rivers
- 50-ft Contour Interval

Watershed

- North Fork Koktuli River
- South Fork Koktuli River
- Upper Talarik Creek



Feet
0 5,000 10,000 15,000 20,000

Meters
0 1,000 2,000 3,000 4,000

Scale 1:94,231

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

Project No: 7126	Date: May 27, 2008
Version: 1	Author: WMC-LC

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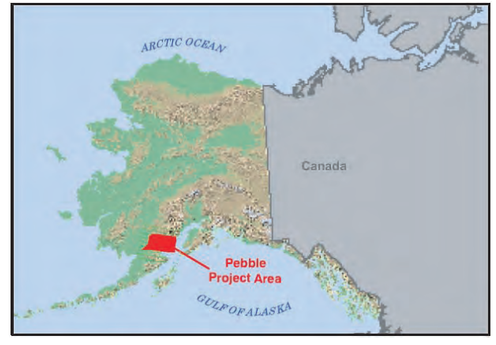
Figure 5-3
Consolidated Study Program, 2004-2008
Groundwater Hydrogeology Existing and Proposed
Monitoring Well and Piezometer Locations (2004)
Mine Study Area

Legend

- *Current NDM Mineral Claim Boundary*
- *Other Claim Boundary*
- *Proposed 2004 Geotechnical Drill Holes with Piezometers*
- P-1 *Supplementary MW or Regional Piezometer*
- PW-1 *Pumping Test Location*
- MW-1 *Baseline Monitoring Wells*

Privileged and Confidential

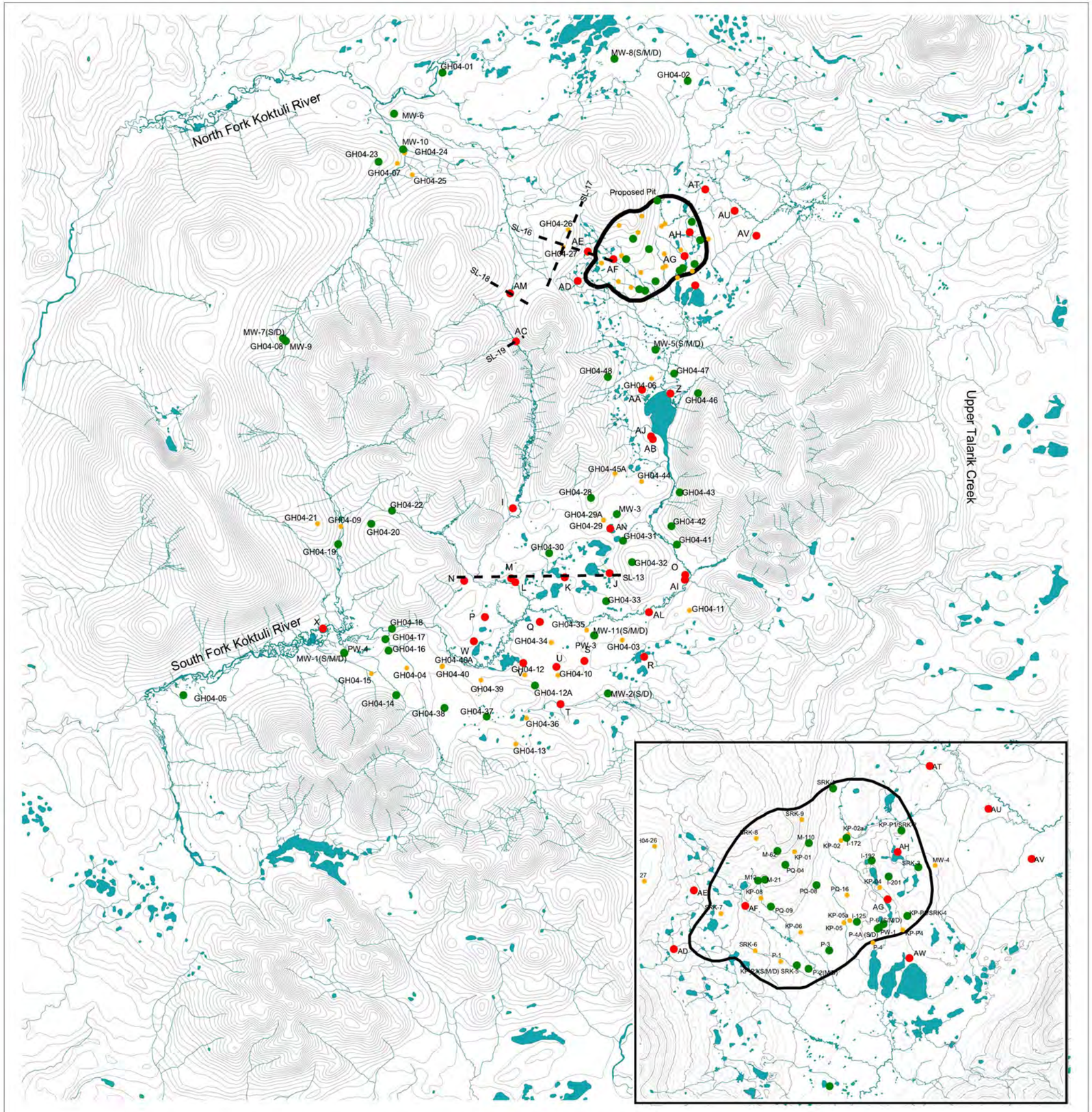


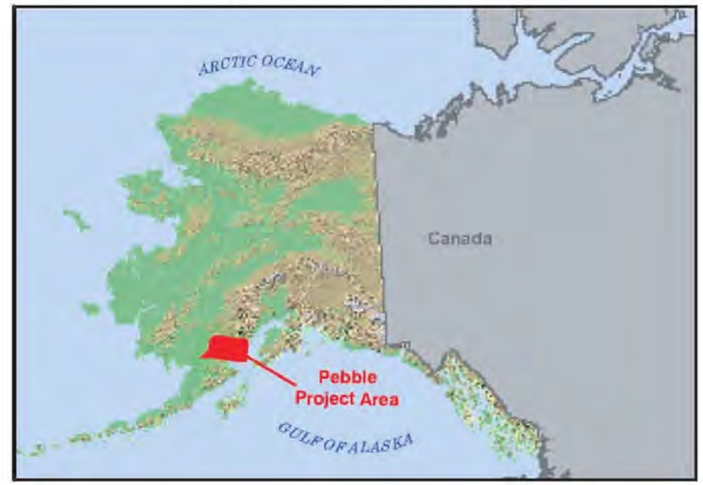
Scale 0 1 2 3 miles

Scale 1000 0 1000 2000 3000 4000 5000 m

N

File: 1	**Date: April 3, 2009**
Version: Hydro_Geo_Mon_Plan,rev	**Author: KP, PLP**





Scale 0 1 2 3 miles

Scale 1000 0 1000 2000 3000 4000 5000 m

N

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Figure 5-4
Consolidated Study Program, 2004-2008
Groundwater Hydrology Existing and Proposed Monitoring Well and Piezometer Locations (2005), Mine Study Area

LEGEND

- Existing Drill Hole
- Existing Monitoring Well
- Proposed Drill Hole
- Proposed Seismic Line

File: Figure 5.1-4.pdf	**Date: April 3, 2009**
Version: 2	**Authors: WMC-HM, PLP-JG**

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Figure 5-5
Consolidated Study Program, 2004-2008
Groundwater Hydrology Existing and Proposed Monitoring Well and Piezometer Locations (2006)
Mine Study Area

Legend

- Piezometer
- Monitoring Well
- Proposed Baseline Monitoring Well (2006)
- Proposed Piezometer (2006)
- Seep
- Sampled Seep
- Stream Gaging Location

0 4000 8000 12000 16000 20000 Feet

0 1000 2000 3000 4000 5000 Meters

N

File: SP Ch5 Figure5.1- 5 MWs and piezos	Date April 3, 2009
Version: 1 rev	Authors: WMC-HC, PLP-JG

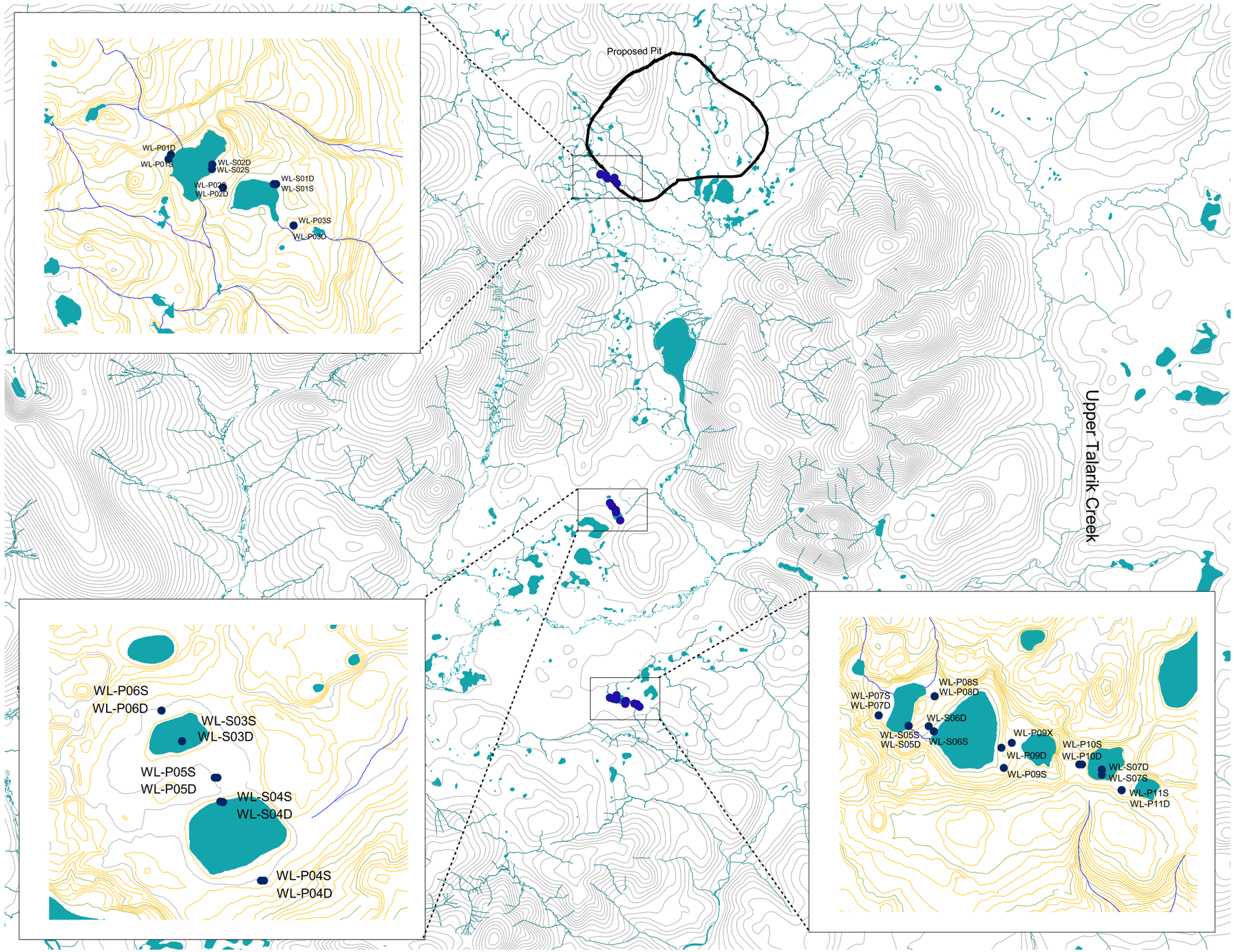

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Figure 5-6
Consolidated Study Program, 2004-2008
Groundwater Hydrology Proposed Wetlands Piezometer Locations (2006)
Mine Study Area

● Wetlands Piezometer

0 4000 8000 12000 16000 Feet

0 1000 2000 3000 4000 Meters

N

File: SP Ch5 Figure 5.1- 6	Date April 3, 2009
Version 1 rev	Authors; WMC-HM, PLP-JG

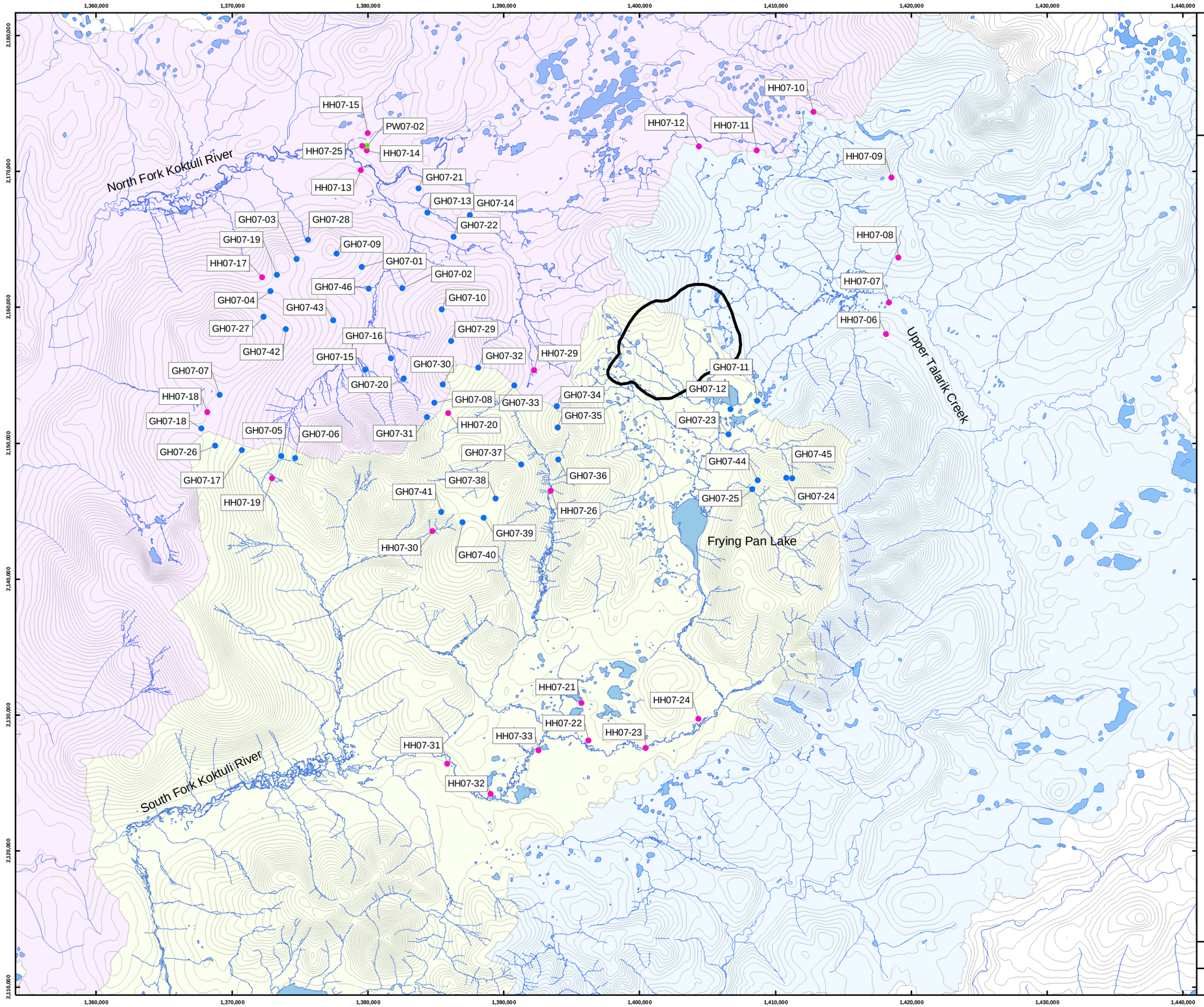

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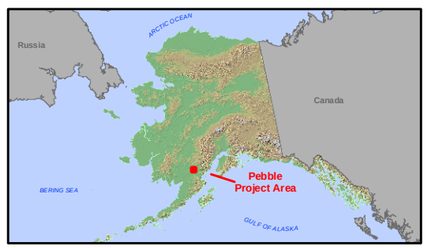
Figure 5-7
Consolidated Study Program, 2004-2008
Groundwater Hydrology Proposed Monitoring Well and Piezometer Locations (2007)
Mine Study Area

Legend

- GH07 - Geotechnical Hole
- HH07 - Hydrogeology Hole
- PW07 - Pumping Well
- Lakes
- General Deposit Location
- Rivers
- 50-ft Contour Interval

Watershed

- North Fork Koktuli River
- South Fork Koktuli River
- Upper Talarik Creek



0 4,000 8,000 12,000 16,000 Feet

0 1,000 2,000 3,000 4,000 Meters

N

Scale 1:87,189

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

Project No: 7126	Date: April 3, 2009
Version: 6, Rev.	Author: WMC-LC, PLP-JG

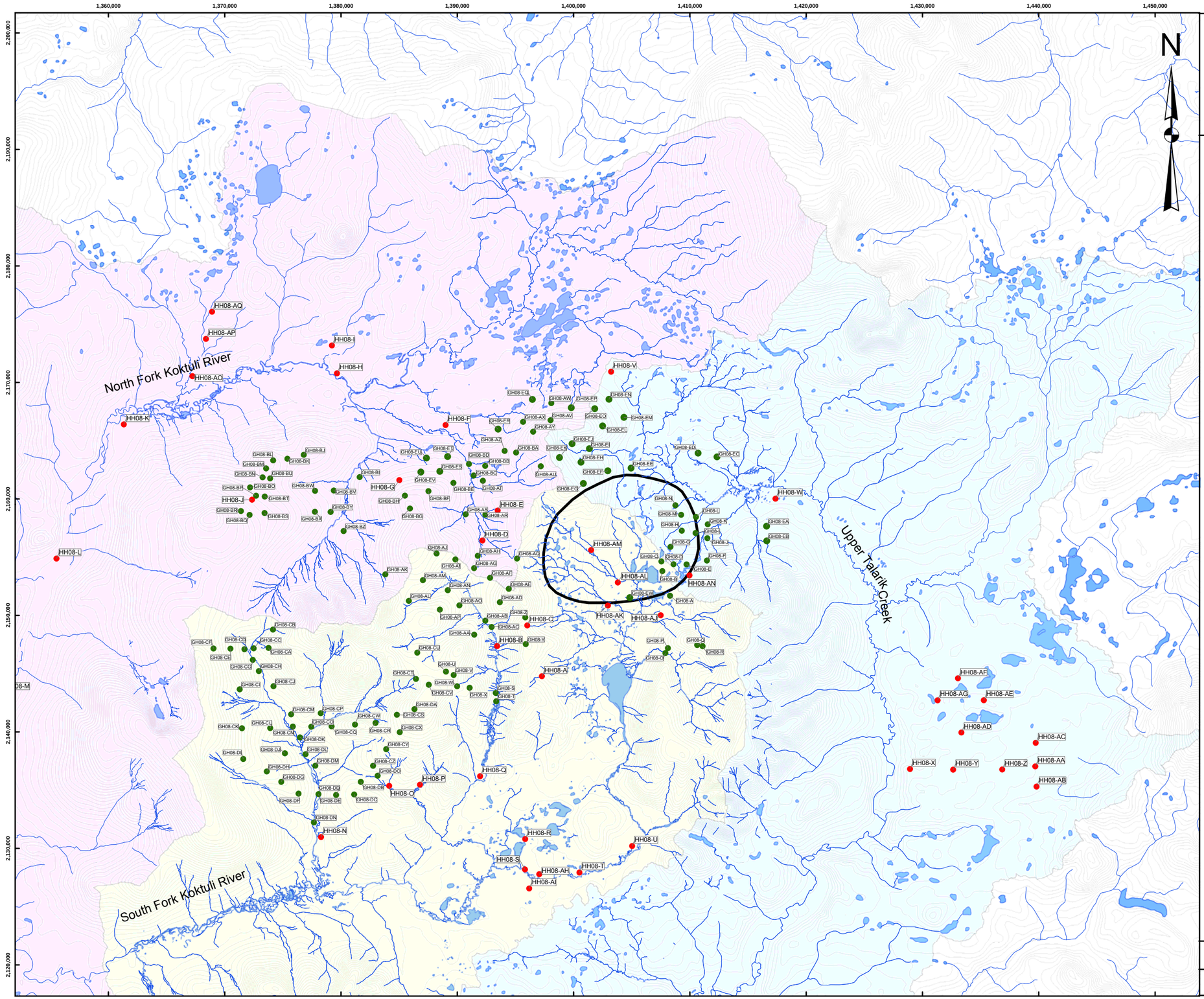


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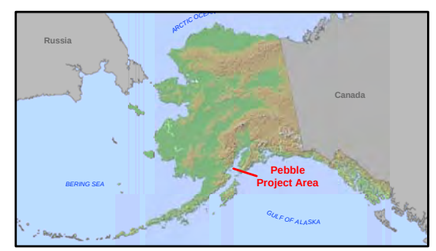
Figure 5-8
Consolidated Study Program, 2004-2008 Groundwater Hydrology Proposed Monitoring Well and Piezometer Locations (2008) Mine Study Area

Legend

- HH08 - Hydrogeology Hole
- GH08 - Geotechnical Hole
- Rivers
- General Deposit Location

Watershed

- North Fork Koktuli River
- South Fork Koktuli River
- Upper Talarik Creek
- Lakes
- 50-ft Contour Interval



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0 1,000 2,000 3,000 4,000 Meters

Scale 1:101,273

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

Project No: 7126	Date: June 23, 2008
Version: 2	Author: WMC-LC

Pebble Project
Environmental Baseline Studies
2004 through 2008

CONSOLIDATED STUDY PROGRAM

6. WATER QUALITY

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ACRONYMS AND ABBREVIATIONS

APCS	Alaska Peninsula Corporation Services LLC
BEESC	Bristol Environmental & Engineering Services Corporation
CSP	consolidated study program
DO	dissolved oxygen
EC	specific electrical conductivity
FSP	field sampling plan
GPS	global positioning system
HDR	HDR Alaska, Inc.
KC	Kaskanak Creek
KR	Koktuli River, Main Stem
MRL	method reporting limit
NK	North Fork Koktuli River
ORP	oxidation-reduction potential
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
SGS	SGS Environmental Services, Inc.
Shaw	Shaw Environmental Services, Inc.
SLR	SLR Alaska, Inc.
SK	South Fork Koktuli River
SRK	SRK Consulting (Canada) Inc.
USGS	U.S. Geological Survey
UT	Upper Talarik Creek
WMC	Water Management Consultants

6. WATER QUALITY

The water quality component of the environmental baseline description for the Pebble Project includes reconnaissance surveys, and the sampling and analysis of surface water, groundwater, and sediments. There are several consultants for the water quality study:

- HDR Alaska, Inc. (HDR) is the lead consultant for collecting surface water quality data for streams, seeps, ponds and lakes and for sediments in the mine study area. Sampling of ponds in the mine study area is conducted in coordination with SLR Alaska, Corp. (SLR).
- Water Management Consultants (WMC) is the prime consultant for collecting groundwater quality data in the mine study area, with support provided by SLR. WMC is also responsible for data compilation, evaluation, and presentation.
- Bristol Environmental & Engineering Services Corporation (BEESC) is the lead consultant responsible for collecting surface water, groundwater (from drinking water wells, only) and sediment quality data in the transportation corridor/Cook Inlet study areas. BEESC also collected groundwater data in the mine site study area in October 2004.
- Shaw Environmental Services, Inc. (Shaw) supports the program with sample handling and expediting.
- SRK Consulting (Canada) Inc. (SRK) provides geochemistry input with respect to the selection of water quality sampling locations, parameter analysis, and data evaluation.
- Alaska Peninsula Corporation Services LLC performed sample collection on portions of Upper Talarik Creek and the Newhalen River beginning in 2007.
- CH2M Hill performed surface water quality and groundwater quality sample collection in the mine study area through September of 2004.

Much of the water quality study is carried out in collaboration with the Pebble Partnership engineering design team and with consultants working on other disciplines, such as surface water hydrology, groundwater hydrology, trace elements, fish and aquatic invertebrates, and wetlands.

The work is being carried out as two programs (one for surface water, seeps, and sediments, and one for groundwater) conducted in two study areas: in the mine study area and along the transportation corridor/Cook Inlet study areas. The two programs are discussed separately herein according to study area.

6.1 Mine Study Area

6.1.1 Study Objectives

The main objectives of water quality studies in the mine study area are as follows:

- Collect baseline data to provide scientific documentation of the naturally occurring chemical constituents, their concentrations, and their variability in surface water, groundwater, and sediments.
- To provide a database of site water chemistry to support aquatic, fisheries, and other resource studies.
- To synthesize the information obtained into a baseline data set.

6.1.2 Surface Water, Seep and Sediment Quality Studies

6.1.2.1 Study Area/Scope

The area for surface water, seep and sediment quality studies in the mine study area encompasses the general deposit area and those areas drained by the north and south forks of the Koktuli River, Upper Talarik Creek, and tributaries of these water bodies. The Kaskanak Creek watershed, although located southwest of the deposit area, is also monitored to identify potential interbasin transfer from the South Fork Koktuli River into the Kaskanak Creek watershed. Figure 6.1-1 depicts the mine study area for surface water quality.

6.1.2.2 Methods/Approach

The general approach for the surface water quality study is to collect samples from streams, lakes, ponds and seeps, as well as from sediments associated with these water systems. The methods are based on procedures described in the United States Geological Survey *National Field Manual for the Collection of Water Quality Data, Techniques of Water Resources Investigations* (USGS, 2008), and have been refined and formalized over 5 years of study. They can be summarized as follows:

- Sampling and analyzing surface water and sediments from selected water systems to identify the presence of naturally occurring constituents in order to develop a signature of natural conditions.
- Analyzing the collected data to characterize the natural trends and statistical variance of the concentrations of naturally occurring constituents in each system.
- Conducting several sampling events under a range of hydrologic conditions throughout the year to understand how seasonal changes affect water quality.

More detail on the sample collection, handling and analysis protocols for water quality baseline studies at the mine site are outlined in the 2005 Final Quality Assurance Project Plan (QAPP; Appendix G of the *Pebble Project Environmental Baseline Document, 2004 through 2008)* and in the annual field sampling plans (FSPs) prepared each year for surface-water quality, hydrology, sediment, and groundwater quality studies (Appendix F of the *Pebble Environmental Baseline Document, 2004 through 2008)*. An overview

of how sampling stations are selected, sample collection, handling and analysis, and data evaluation is provided in the following sections.

Station Selection

Selecting the right sampling station is key to ensuring appropriate water quality information. Water quality sampling stations in the mine study area include streams, lakes, ponds, and seeps.

The selection of all sampling stations for water quality has been coordinated with the study teams for surface water hydrology (consolidated study program [CSP] 4), groundwater hydrology (CSP 5), trace elements (CSP 7), and fish and aquatic resources (CSP 11).The location of each station was based on its ability to contribute to the following:

- Establishing a baseline of surface water quality.
- Characterizing surface water systems for geochemical parameters.
- Documenting chemistry in water systems with potential to supply water.
- Documenting water chemistry in potential receiving waters.
- Providing data for fish habitat and other resource studies.

The stream locations for water quality monitoring through 2008 are depicted on Figure 6.1-1.

For seep sampling, the HDR study team has defined seeps as follows:

- Surface water expressions that exhibit a distinct groundwater point source and distinct flow path extending downslope approximately 30 feet or until entering a larger drainage feature.
- Large diffuse seep areas that coalesce into a distinct flow path with dry ground up-gradient.

Seeps are not characterized by the following:

- Small features that appear to be directly reabsorbed downslope.
- Small drainages with accumulating surface runoff.
- Meltwater features that coalesce below snow fields.
- Marshy areas and ponds with no distinct flow path below the feature.

The HDR and WMC study teams selected the locations for conducting seep inventories and for sampling seep water quality. Their selections are based on a variety of criteria, including quantity of flow, spatial distribution in the study area, and proximity to the deposit area.

The seep inventory areas and the location of seep monitoring stations are depicted on Figure 6.1-2.

Sample Collection and Handling

Surface water samples have been collected from streams and seeps since 2004. Since 2006, surface water samples have also been collected from lakes and ponds. Sediment samples have been collected since 2004.

Depending on the flow and depth, water quality samples at each stream, lake, and pond station are collected using an integrated, suspended wading-type sample (e.g., DH-48 or DH-81 sampler), when possible. Grab samples may be taken, if necessary.

Because water flow changes throughout the year, stream water samples are collected monthly to provide a record of how water chemistry changes with changing flow. This allows the study team to characterize surface water chemistry throughout the year and under different hydrologic conditions. For example, samples taken during breakup and during high precipitation events represent conditions associated with high-flow periods. Conversely, samples taken in late winter and late fall represent minimum flow conditions, which are important for assessing the effects of groundwater discharge on water quality.

Pond and lake samples are typically taken once per year during a summer sampling event.

Seep samples are taken periodically throughout the year, to document the quality and flow of water discharging from select seeps in the study area. This type of sampling is done on ephemeral flows, low flows, or seeps that are specific to the deposit area. These data are useful for investigating the geochemistry of these seeps, for assessing interactions of groundwater with surface water, and for interpreting the groundwater regime.

Sediment sampling is an important component of the environmental baseline study because the data provide information on the long-term deposition or storage of metals in stream, lake, pond and seep substrates. Sediment samples from streams, lakes, ponds, and seeps are collected primarily during the summer months. Samples are collected with an Ekman dredge or by grab sampling, at the same time that water quality samples are taken from the associated water bodies.

Surface water at each monitoring station is field-tested during each sample collection event for select parameters. Field-testing parameters include dissolved oxygen (DO), specific electrical conductivity (EC), pH, temperature, turbidity, and oxidation-reduction potential (ORP) (see Table 6.1-1). Instruments and kits for measuring field parameters are serviced before each event. Every morning of each sampling event, instruments are checked with calibration solutions to ensure accuracy. Visual observations of color, odor, or other noteworthy visible indicators are also made.

Both filtered and unfiltered samples are collected. Filtering is done in the field or samples are iced and filtered within 12 hours of collection.

Shaw packs the samples with gel ice and ships them from Iliamna to the appropriate primary or quality assurance (QA) laboratory. Shaw also is responsible for filling out and maintaining electronic chain-of-custody documentation. Primary and duplicate surface water samples (except surface water samples to be analyzed for mercury) are shipped to SGS Environmental Services, Inc. (SGS) in Anchorage, Alaska. Primary surface water samples for mercury analysis are shipped to North Creek Analytical Inc., part of

the TestAmerica Co. group of companies. Quality assurance samples for all parameters are shipped to Columbia Analytical Services in Kelso, Washington.

Water quality samples are measured for the parameters listed in Table 6.1-2. The information in the table includes references for the analytical test methods, the method reporting limit (MRL), and the precision and accuracy criteria for each parameter. Metals analyses are conducted on total (unfiltered) and dissolved (filtered) samples. Samples from select monitoring stations are occasionally analyzed for organic constituents. These constituents include, but are not limited to, pesticides, volatile compounds, and semi-volatile compounds.

Sediments are submitted to the contract laboratories for analysis for the parameters listed in Table 6.1-3.

Quality Control / Quality Assurance

Samples are collected at each monitoring station according to appropriate quality assurance/quality control (QA/QC) procedures, including taking separate samples for QA/QC purposes (i.e., duplicates, samples, double-blind samples, etc.). Discrete “blind” duplicate samples also are taken and sent to an independent, external laboratory for chemical analysis to compare against the contract-laboratory analysis. All laboratories also participate in their own in-house laboratory QA/QC programs.

The Pebble Partnership appointed an Analytical QA/QC Manager to be responsible for quality management for all analytical programs. The Analytical QA/QC Manager’s role is to ensure consultant work plans, field procedures, laboratory analyses, and deliverables meet technical and quality requirements stipulated by regulatory agencies and the Pebble Partnership. The role included regular, well-defined QA/QC review of program plans and design, program execution, agency coordination and compliance, and program deliverables. The primary outcomes are to ensure analytical data quality is consistent among consultants, met specified data quality objectives (including MRLs), and is legally defensible. At a minimum, the QA/QC tasks include the following:

- Evaluation of laboratory QA/QC programs.
- QA/QC review of sampling and analysis plans.
- Design and execution of double blind studies.
- On-site QA/QC evaluation of field sampling activities.
- Analytical data review/validation.
- Quality Assurance Reports.

Data Evaluation

Data evaluation includes the QA/QC review described above, as well as tabulating the water chemistry data, preparing summary statistics, comparing results to water chemistry criteria, plotting key parameters, monitoring the spatial distribution of key parameters, and assessing the relationship between flow and water chemistry, where appropriate.

The data for water quality are used as input data for the site baseline water balance and water chemistry loading models. The evaluation includes comparing and contrasting catchments. All field and analytical

parameters are included in the evaluations. In addition, field measurements and observations (such as turbidity, color, and odor) are considered.

6.1.2.3 Major Tasks/Activities

The tasks and activities for the surface water quality study near the mine site are conducted in conjunction with the surface water hydrology and aquatic resources studies. The field work for surface water hydrology and water quality studies is conducted at the same time, and the surface water data collected are used for estimating water balances and to correlate water quality with flow conditions. Data for seeps also are used to assess groundwater/surface water interactions.

A summary of the data collected and tasks completed for the surface water quality study for each year, from 2004 through 2008, is provided in Table 6.1-4. The information in Table 6.1-5 lists all surface water quality sampling stations and the record of sampling for each from 2004 through 2008.

Tasks and Activities for 2004

The main tasks and activities for 2004 included the following:

- Compiling and reviewing existing water chemistry data from previous studies in the study area to evaluate suitability and to determine whether the data could be used to supplement the data collected under the current study.
- Field studies for collecting water chemistry data for surface water and seeps, and for collecting sediment quality data.
- Reviewing data as part of the analytical QA/QC program and incorporating them into the project database (CSP 19).
- Evaluating the water and sediment quality data.

The field studies are discussed in additional detail in the following sections.

Sample Site Selection. WMC and HDR, in collaboration with CH2M Hill and USGS personnel, identified 35 surface water stations (all associated with streams) and 34 seep stations (18 stations associated with springs and seeps, and 16 stations associated with streams).

Field Studies-Surface Water Sampling. HDR field personnel conducted seven surface water quality monitoring events from April to October 2004. Samples were collected at 30 of the 35 planned surface water monitoring stations, as listed in the period-of-record index for 2004 (Table 6.1-5).

Surface water at each monitoring station was field-tested for DO, EC, pH, temperature, turbidity, and ORP. Discrete samples were taken at each monitoring station. Flow and depth integrated samples were collected with a DH-48 sampler when possible. Both filtered and unfiltered samples were collected. Appropriate QA/QC procedures were used, including the collection of QA/QC samples.

All samples were sent to an independent external laboratory for chemical analysis. Laboratory analysis of surface water samples was conducted for the parameters in Table 6.1-2. Samples from select monitoring

stations for two sampling events were analyzed for organic constituents, including pesticides, volatile compounds, and semi-volatile compounds.

Field Studies-Seep Sampling. The seep sampling program in 2004 focused on seeps or springs in the vicinity of the mineralized area. The analytical data from collected seep samples were used to help interpret apparently anomalous (elevated) values in areas of mineralization, and for calibrating rock testing results being collected as part of the geochemistry study (CSP 7). CH2M Hill field personnel planned to collect samples in a single sampling event from 18 springs and seeps, and from 16 permanently installed stations for monitoring stream seepage. Sample collection and handling procedures in the latter would be the same as for groundwater. Eleven of the planned 34 seep locations identified at that time were eventually sampled.

Field personnel also planned to conduct a reconnaissance survey in May and September 2004 to identify new seeps and to measure water chemistry and flow.

Field Studies-Sediment Sampling. Sediments were collected at 23 stations in June, July, and September. SK100G and UT100B were resampled in August.

Sample Analysis and Data Evaluation. All water quality samples from streams and seeps were submitted for laboratory analysis for the parameters listed in Table 6.1-2. Sediment samples were analyzed for the parameters listed in Table 6.1-3. The primary laboratory was SGS in Anchorage, Alaska, and the QA laboratory was Columbia Analytical Services, Inc., in Kelso, Washington. Other laboratories are used periodically for specialized tests. All laboratory analyses were conducted under an in-house laboratory QA/QC program. Chemical data received from the analytical laboratory was validated by the Analytical QA/QC Manager.

Tasks and Activities for 2005

The main tasks for 2005 were similar to those for 2004, with some minor changes and additions as described in the following paragraphs.

Sample Site Selection. The criteria and procedures used in 2005 for selecting sampling sites for water chemistry were the same as those used in 2004.

Field Studies-Surface Water Sampling. Eight surface water monitoring events were planned from January to October 2006. Samples were collected at the same 30 surface water monitoring stations sampled during the 2004 field season and as recorded in Table 6.1-5, with the following exceptions:

- Samples were not collected from UT100C.
- SK124A was added to provide flow and water quality data from a major tributary of the South Fork Koktuli River.
- SK100B1 and SK100B2 were added to provide flow and water quality data for upwelling or gaining reaches (or “springs”) on the South Fork Koktuli River.

In total, 32 stations were sampled.

As in 2004, surface water at each monitoring station was field-tested for the parameters listed in Table 6.1-1. The DH-48 depth-integrated sampler used in 2004 was replaced with the DH-81 sampler, based on technical advice from USGS personnel on the potential for metal contamination with the DH-48. Discrete depth-integrated samples were collected with the DH-81 sampler when possible. Otherwise grab surface samples were taken. All samples were sent to the contracted independent laboratory for chemical analyses. Laboratory samples were analyzed for the same analytes as in 2004 (listed in Table 6.1-2).

Samples to be analyzed for organic constituents were also collected from select monitoring stations during the two sampling events in August and October 2005. Organic analytes included pesticides, volatile compounds, and semi-volatile compounds.

A detailed description of sampling procedures for surface water and sediment in the mine study area was presented in the 2005 FSP (Appendix F of the *Pebble Environmental Baseline Document, 2004 through 2008*).

Field Studies-Seep Sampling. After reviewing the database of seeps surveyed in 2004, a comprehensive reconnaissance survey of seeps was planned in 2005 with input from WMC hydrologists. Aerial inventories were conducted in January, March, and May, June and July 2005 to identify and map a more representative number of seeps for measuring water chemistry and flow. It was planned to review the results of the survey to identify approximately 20 sites for sampling in July 2005 and up to 40 sites for sampling in August and October 2005. Following the June and July reconnaissance efforts, 24 seeps were selected for discharge and water quality measurements (based on discussions with WMC hydrologists, most of the seeps sampled in 2004 by CH2M Hill and in March 2005 by HDR were not included in this list). All identified seep sites were measured for field parameters (Table 6.1-1) and flow, as well for the water chemistry analytes listed in Table 6.1-2.

Seep sampling, sample analyses and data evaluation procedures were the same as for 2004, except that portable weirs (60° and 90°, V-notch) were developed to measure discharge in large seeps. Direct catch into a calibrated container was used in the smaller seeps.

Field Studies-Sediment Sampling. It was planned to collect sediment in July 2005 from six lake locations, selected based on geographic representation (see Figure 6.1-1, for the location of these lakes):

- Frying Pan Lake
- Big Wiggly Lake.
- Two new lake sites in the southern portion of the mine study area (Chiquita and Lake No. 2, were proposed) and co-located with newly proposed fish-monitoring sites.
- Two lake sites considered prime moose pond habitat (Black Lake and Mud Lake [near Lily Lake] were proposed) and co-located with aquatic-vegetation sampling sites.

Lake sediment samples were collected from a boat in locations that were most likely to have sediment deposition. Sediment was collected using dredge or core-sampling techniques.

Sediment samples were also taken at a subset of the stream and seep locations where water-quality samples were collected in 2005. Sediment was collected at 17 stream stations and from seven seep stations. Every sample station was not sampled during all events because either high-flow conditions

prevented collection of a sediment sample, or the amount of sediment available was insufficient to make a sample. Stream sediment samples were taken in June, July and/or September. Seep sediments were collected in July (seven samples) and October (five samples). Sediment samples were analyzed for the analytes listed in Table 6.1-3.

Data Evaluation. The water chemistry results were subjected to the QA/QC review described in the QAPP (Appendix G of the *Pebble Environmental Baseline Document, 2004 through 2008)*, and compiled and evaluated the same way as in 2004: tabulating the data, summarizing statistics of water-chemistry data and comparing results to water-chemistry criteria, preparing plots of key analytical parameters, presenting the spatial distribution of key analytical parameters, and evaluating flow and quality relationships, where appropriate.

Tasks and Activities for 2006

In 2006, the surface water, seep, and sediment quality program for the mine study area was updated based on project design changes and an evaluation of the results from 2005 studies. One station (NK119B) was dropped from the program in June. The number of annual sampling events increased to include the months of November and December to further characterize winter conditions.

Field Studies-Surface Water Sampling. All stream stations sampled in 2005, with the exception of NK119B, were resampled in 2006. In total, 31 stations were sampled as shown in Table 6.1-5:

- Seventeen stations for baseline monitoring:
  - North Fork Koktuli—four locations (NK100A, NK100B, NK100C, and NK119A) were selected to monitor water quality because these sites are co-located with fish-tissue and macroinvertebrate monitoring sites.
  - South Fork Koktuli—seven locations (SK100A, SK100B, SK100B1, SK100C, SK100D, SK119A, and SK124A) were selected, several of which are co-located with fish-tissue and macroinvertebrate monitoring sites.
  - Upper Talarik—six locations (UT100B, UT100D, UT100E, UT119A, UT119B, and UT141A) were selected, several of which are co-located with fish-tissue and macroinvertebrate monitoring sites.
- Station SK100B2 (installed in 2005 with SK124A and SK100B1) to expand the existing 2-year baseline database for the South Fork Koktuli River.
- The remaining 13 stations to continue adding to the existing baseline database begun in 2004. These were not originally included in the 2006 study plan, but were added during the field season.

Water quality samples were taken from all seven lakes that were sampled for sediments in 2005. Frying Pan Lake was sampled once in July at the inlets, outlet, and deepest part of the lake for water to track potential chemical/hydrologic flows in and out of the lake. The other six lakes were sampled once in August, by wading into each lake and collecting a grab sample to assess baseline chemical characteristics.

All surface water and seep quality samples were analyzed for the same parameters as in 2005. In addition and starting in May 2006, the analytical laboratory included orthophosphate and separate analyses for

nitrate and nitrite. No samples were collected in 2006 for the analysis of organic constituents (i.e., volatile organic compounds, semivolatile organic compounds, and pesticides).

Field Studies-Seep Sampling. Based on the seep reconnaissance survey in 2005, WMC selected 24 priority seeps throughout the study area. They were sampled by HDR in 2005 and resampled again in 2006. They were sampled for water quality and flow in March (winter low-flow event), May (spring breakup event), July or August (summer low-flow event), and October (fall precipitation event). Other seep activities included the following:

- Measuring total and ferrous iron using a field-portable Hach colorimeter 890 to provide an estimate of redox conditions.
- A seep reconnaissance survey to identify seeps that were persistent and flowing when groundwater levels were low prior to spring breakup in May 2006.
- An expanded seep reconnaissance survey of areas not surveyed in 2005. The work was conducted in June and October 2006 for the mineralized area (i.e., near the Pebble West deposit), South Fork Koktuli River springs area (near SK100B1 and SK100B2), and MDC NK1.190/Option G.
- Other seep activities for June included the following:
  - A one-time sampling protocol for seep precipitates, established with input from SRK.
  - Analyzing samples of precipitates to determine their elemental and mineralogical composition.
  - Measuring field parameters in seeps in the mineralized area to identify low-pH and high-conductivity seeps.
  - A reconnaissance survey of seeps near old Cominco well sites to identify whether the wells or boreholes have created unnatural seeps.
  - Identifying additional seeps to sample in the mineralized area and South Fork Koktuli River springs area.

Field Studies-Sediment Sampling. Sediment samples were collected from 13 stream locations in June 2006 for total sulfur, acid volatile sulfide, and simultaneously extractable metals analyses. Sampling locations were selected by Mark Stelljes of SLR from sites where sediment was sampled in 2004 and 2005. The 2006 sediment sample locations were as follows:

- North Fork Koktuli River—NK100A, NK100B, NK100C.
- South Fork Koktuli River—SK100A, SK100B, SK100C, SK119A.
- Upper Talarik Creek—UT100B, UT100D, UT100E, UT119A, UT119B, UT141A.

Sediment was also collected from Frying Pan Lake in July and from several ponds in August. No other sediment samples were collected.

Field Studies-Small Pools Sampling. This program was initiated in 2006 to characterize conditions of small pools and ponds. It was designed and implemented in conjunction with the trace elements baseline

study (CSP 7), in which field personnel collect vegetation samples in and near these small pools and ponds.

Samples are collected from two types of ponds in the mine study area: 1) perched and 2) groundwater-fed. Because these ponds types have different sources of water, they may contain different naturally occurring constituents. Perched ponds dry up seasonally, and the water largely represents precipitation in the form of snowmelt or rain. Groundwater-fed ponds are perennial water bodies and reflect primarily groundwater quality (although these ponds also get seasonal water from snowmelt and rainfall). The effect of beaver activity in both groundwater-fed and perched ponds is an additional variable to be considered. The organic content of the water and sediments is expected to be much higher in these ponds than in ponds without beaver activity because of the presence of decaying wood matter and beaver waste. In addition, diminished flow may affect parameters such as dissolved oxygen.

The results of the pond water-quality sampling are being used in the small pools study, which is part of the wetlands study (CSP 10).

The sampling locations were selected based on geographic representation and potential source waters (i.e., perched or groundwater-fed). In 2006, water quality and sediment samples were collected in select ponds at four stations each in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek drainages.

Tasks and Activities for 2007

Tasks and activities for 2007 were similar to those conducted in previous years, with adjustments to address project design changes and data gaps identified by evaluating study results to date. The main tasks and activities were as follows:

- Sample and analyze stream and seep surface water from each major drainage area to characterize the natural conditions in various seasons and under various flow regimes.
- Sample and analyze naturally occurring constituents in lake and pond surface water to characterize range and variability.

In addition to sampling surface water bodies, sediment samples were also collected to support the trace elements study (CSP 7). Samples were analyzed in the field and by the analytical laboratory for the list of parameters given in Tables 6.1-1, 6.1-2, and 6.1-3. As indicated in Table 6.1-2, dissolved organic carbon was added to list of parameters for surface water quality.

Sample Stations and Sample Frequency. The number of stream samples for surface water quality monitoring was increased in 2007. The three new sites were added in the lower reaches of Upper Talarik Creek (UT100APC1, UT100APC2, and UT100APC3). They are being managed by Alaska Peninsula Corporation Services LLC (APCS) field personnel. APCS personnel also added one site (NH100APC1) on Alaska Peninsula Corporation land on the Newhalen River. As a result of the Pebble East discovery, one station (UT100C) that had not been sampled since 2004 and a second station (NK119B) that was not sampled in 2006, were reintroduced. Three new stream stations (NK100A1, UT100C1 and UT100C2) were added to the water quality study.

Therefore, samples were collected at 39 stream stations located on the North Fork Koktuli River, South Fork Koktuli River, mainstem of the Koktuli River, Upper Talarik Creek, and Kaskanak Creek, as identified on Figure 6.1-1 and listed in Table 6.1-5.

HDR and WMC personnel continued the program to inventory the location and relative size of seeps (the seep reconnaissance surveys) within the mine study area in 2007. Surveys were conducted by flying over the study area in a helicopter and documenting seeps with a global positioning system (GPS) unit. Figure 6.1-2 depicts seeps that have been inventoried in the past and areas that were proposed for inventory in 2007.

Field Studies-Stream Sampling. The rationale and sampling locations for stream sampling are described above. Thirty-nine stations were sampled, including all stations sampled in 2006 and the new stations installed in 2007. Stream sampling events occurred monthly from January to December. All stations were sampled during each event, except for stations NK100A1, UT100C, UT100C1 and UT100C2, which were not sampled in January, and UT100APC1, UT100APC2, and UT100APC3, which were not sampled until August.

Field Studies-Lake Sampling. In July and August 2007, HDR field personnel sampled the six lakes first identified for sampling in 2005 (Table 6.1-5). Water quality grab samples and field parameter measurements were collected at Black Lake, Big Wiggly Lake, Frying Pan Lake, Chiquita Lake, Mud Lake, and Lake No. 2. SLR sampled sediments and vegetation at the same locations at the same time.

Field Studies-Seep Sampling. HDR personnel continued to sample the 44 seep stations set up in previous years, and planned to sample up to 56 additional seeps in 2007, depending on the results of reconnaissance surveys. Seeps were sampled for flow and water quality in March, May, July, September, October, and November. At every seep location, personnel measured flow using direct catch or portable weirs, measured field parameters using portable instrumentation and kits, and collected water quality samples to be sent to SGS and ACZ for analysis.

Field Studies-Sediment Sampling. Stream sediments were collected in June 2007 at 14 selected stream water-sampling sites (Table 6.1-5). Sediments were also collected from select ponds in September 2007, as described below.

Field Studies-Small Ponds Sampling. The same twelve ponds selected in 2006 for sampling, were resampled in 2007. Samples were taken of water and sediment, in conjunction with SLR's vegetation sampling. The ponds are identified in Table 7.1-6 in CSP 7 (Trace Elements) and their locations are depicted on Figure 7.1-5 in CSP 7.

Data Evaluation. All samples were reviewed according to the QA/QC protocols developed by the Analytical QA/QC Manager, and as described elsewhere in this CSP.

Data analysis and presentation included the following:

- Tabulating and summarizing water-chemistry data and statistics.
- Preparing plots of key analytical parameters, identifying anomalies, and comparing results to water quality criteria.

- Presenting the temporal and spatial distribution of key analytical parameters.
- Evaluating season, flow, and water quality relationships where appropriate.

The data were also provided as baseline input for the water balance and water chemistry loading models.

Tasks and Activities for 2008

Tasks and activities for 2008 were similar to those conducted in previous years, with adjustments to address project design changes and data gaps identified by evaluating study results to date. The main tasks and activities were to sample and analyze stream and seep surface water from each major drainage area to characterize the natural conditions in various seasons and under various flow regimes.

Sample Stations and Sample Frequency. The number of stream samples for surface water quality monitoring was decreased in 2008. Sites NK119B and UT100A were entirely removed from the sampling program in 2008. Following sampling through May of 2008, the 14 stations KC100A, SK100C, SK100D, SK124A, SK131A, SK133A, SK136A, SK136B, UT100C1, UT100C2, UT119B, UT135A, UT138A and UT141A were removed from the sampling program because it was determined that a sufficient number of samples characterizing these sites had been collected over the previous 4 years of study.

Two new sites were added to tributaries of South Fork Koktuli (SK116A and SK117A) managed by HDR, and one new site was added to Upper Talarik Creek tributary UT106APC1 managed by APCS field personnel.

Therefore, samples were collected over the year at 40 stream stations located on the North Fork Koktuli River, South Fork Koktuli River, mainstem of the Koktuli River, Upper Talarik Creek, and Kaskanak Creek, as identified on Figure 6.1-1 and listed in Table 6.1-5.

HDR and WMC personnel continued the program to inventory the location and relative size of seeps (the seep reconnaissance surveys) within the mine study area in 2008. Surveys were conducted by flying over the study area in a helicopter and documenting seeps with a GPS unit. Figure 6.1-2 depicts seeps that have been inventoried in the past and areas that were proposed for inventory in 2008.

Field Studies-Stream Sampling. The rationale and sampling locations for stream sampling are described above. Forty stations were sampled, including all stations sampled in 2007, except NK119B and UT100A and the three new stations installed in 2008. Stream sampling events occurred monthly from January through December. All stations were sampled during each event, except for stations KC100A, KR100A, SK100C, SK124A, and UT106APC1 in January; SK100C, SK124A, SK134A, and UT106APCS1 in February; SK100C, SK124A, and UT106APCS1 in March; and SK124A and UT106APCS1 in April. Sampling for the new stations SK117A and SK119A did not begin until September.

Field Studies-Lake Sampling. No lake samples were collected in 2008.

Field Studies-Seep Sampling. HDR personnel continued to sample 28 of the seep stations set up in previous years. No additional stations were started. Seeps were sampled for flow and water quality in May, July, September, and November. At every seep location, personnel measured flow using direct catch or portable weirs, measured field parameters using portable instrumentation and kits, and collected water-quality samples to be sent to SGS and ACZ for analysis.

Field Studies-Sediment Sampling. Stream sediments were collected in June 2007 at 14 selected stream water sampling sites (Table 6.1-5). Sediments were also collected from select ponds in September 2007, as described below.

Field Studies-Small Ponds Sampling. No Small pond samples were collected in 2008.

Data Evaluation. All samples were reviewed according to the QA/QC protocols developed by the Analytical QA/QC Manager, and as described elsewhere in this CSP.

Data analysis and presentation included the following:

- Tabulating and summarizing water chemistry data and statistics.
- Preparing plots of key analytical parameters, identifying anomalies, and comparing results to water-quality criteria.
- Presenting the temporal and spatial distribution of key analytical parameters.
- Evaluating season, flow, and water-quality relationships where appropriate.

The data were also provided as baseline input for the water-balance and water-chemistry loading models.

6.1.3 Groundwater Quality Studies

6.1.3.1 Study Area/Scope

The area for groundwater quality studies in the vicinity of the mine study area encompass the area around the headwaters of Koktuli River and Upper Talarik Creek. The study area is illustrated on Figure 5.1-1 in CSP 5.

The scope of the groundwater quality study for the mine study area is to define the baseline chemical characteristics of groundwater. This characterization is being used to help define the groundwater flow system (as introduced in the groundwater hydrology discussion in CSP 5).

6.1.3.2 Methods/Approach

Monitoring wells and piezometers are being sampled both up-gradient and down-gradient of the deposit area. Sampling events are timed to coincide with varying seasonal hydrologic conditions at key locations in the study area. Samples are collected four times during the year: in March (late winter before break-up), May (spring after break-up), August (summer), and October (fall). This frequency is standard for baseline studies for other projects in Alaska.

Samples are collected at the monitoring wells and piezometers shown on Figure 6.1-3. Groundwater quality samples are collected concurrently with the groundwater flow studies described in CSP 5. Procedures for field measurements, sample handling and data management are the same as for surface water quality with the following exceptions:

- Groundwater samples to be analyzed for dissolved metals are filtered in-line during sample collection in the field because of the potential for oxygen-depleted groundwater to become oxygenated.
- Field parameters are measured in a flow-through cell.

Details of the groundwater sampling protocols are provided in the 2007 FSP for groundwater studies (Appendix F in the *Pebble Project Environmental Baseline Document, 2004 through 2008)*. SLR field crew collect the groundwater samples and submit them to the laboratory for analysis. All samples are analyzed for a wide range of cations and anions. The parameters were selected to accomplish the following:

- Identify baseline water quality conditions.
- Provide general information on groundwater quality that can help with the site-wide water balance.

The parameters to be analyzed for in the laboratory are the same as those listed for surface water in Table 6.1-2, except groundwater samples are not analyzed for organic carbon.

The data derived from groundwater and seep water analyses (as described, above) are compiled, evaluated, and presented according to the same methods as described for surface water, above. The evaluation is done to support concurrent and future studies.

6.1.3.3 Major Tasks/Activities

The main tasks and activities for the groundwater quality baseline study were to identify locations for and collect samples from groundwater monitoring wells and seeps. Details are provided in CSP 5 and summarized in Table 5.1-2.

Tasks and Activities for 2004

The main tasks and activities for the groundwater study in 2004 were to identify suitable locations for groundwater sampling, and to conduct a field program for collecting and submitting samples for analytical testing.

It was planned to sample once during the field season year: in September or October 2004. Baseline groundwater samples were collected by BEESC field personnel from 24 monitoring wells, as detailed in Tables 5.1-1a through 5.1-1e in CSP 5. In addition to collecting the discrete samples for water chemistry analysis, field staff also measured water levels and field parameters in the monitoring wells (Table 6.1-1).

In addition, several non-baseline samples were collected from supplementary monitoring wells, flowing drillholes, and selected piezometers to help delineate the groundwater regime.

Tasks and Activities for 2005

The main tasks and activities for groundwater quality sampling in 2005 were similar to those in 2004, with some minor additions, as described below.

Four seasonal sampling events (March, May, August, and October) were conducted for groundwater quality monitoring. The samples were collected from all monitoring wells installed in 2004 plus all wells installed in 2005 (as they became available). Thirty six wells were sampled.

Groundwater samples from the wells were obtained according to the same methods as described above. Measurements for field parameters were made at all locations at the time of sampling (Table 6.1-1).

All samples were analyzed for the same range of cations and anions described in Table 6.1-2. Samples were also analyzed for pesticides, polychlorinated biphenyls, and volatile and semi-volatile organic compounds.

Tasks and Activities for 2006

The sampling points for the groundwater quality study that were sampled in 2005 continued to be sampled in 2006. Two groundwater sampling locations were added in the deposit during the 2006 field program. The new locations are depicted as Proposed Baseline Monitoring Wells on Figure 5.1-5, CSP 5.

The field program started in early June. Field measurements of water quality were made at each station at the same time samples were collected for laboratory analysis. Samples were collected from 38 monitoring wells. Some wells scheduled for sampling could not be sampled because of siltation, low water levels, or frozen winter conditions.

Tasks and Activities for 2007

The main activities for 2007 were to collect quarterly samples from each groundwater sampling well, conduct field measurements of water quality during each sampling event, submit the samples for analysis, and compile and analyze the data.

SLR collected groundwater samples from 38 monitoring wells, as detailed in Tables 5.1-1a through 5.1-1e (CSP 5). Field parameters were measured each time groundwater samples were collected. Samples were submitted to the laboratories for analysis. Analytes for field measurements and laboratory analysis were the same as in previous years.

WMC compiled and interpreted the groundwater quality data. The data were plotted quarterly as the results became available. These plots included the following:

- Box and whisker plots to compare all water quality analyses.
- Time-series plots to examine temporal trends.
- Piper plots to characterize the water type and potential relationships between water sample locations.
- Stiff diagrams to examine the spatial distribution of overall water quality.
- Bubble plots to examine the spatial distribution of individual parameters.

In addition, the concentrations of analytes in the groundwater were evaluated to identify anomalies when compared with water-quality criteria.

The groundwater quality data were updated as more data became available over the year.

Tasks and Activities for 2008

The following activities were performed to support the groundwater quality program in 2008:

- Quarterly groundwater samples were collected by SLR from 36 wells throughout 2008.
- WMC continued with the compilation, interpretation, and reporting of groundwater data as detailed for 2007.

6.2 Transportation Corridor/Cook Inlet Study Areas

Water quality baseline studies in the vicinity of the transportation corridor/Cook Inlet study areas include reconnaissance surveys, collecting and analyzing surface water, groundwater and stream sediment samples, and data evaluation.

6.2.1 Study Objectives

The following are objectives of the baseline water quality study for these study areas:

- Collect data for the characterization of water resources, including surface water from streams and tundra ponds, and groundwater wells used for drinking water.
- Synthesize the information obtained into a baseline data set for use by other disciplines.

The work is described separately according to studies for surface water and those for groundwater.

6.2.2 Surface Water and Sediment Quality Studies

6.2.2.1 Study Area/Scope

The overall study area for surface water and sediment quality studies for the transportation corridor/Cook Inlet study areas is generally located between the Newhalen River and Cook Inlet.

The scope of work is to collect periodic water quality and sediment samples over time to establish the baseline conditions in the study area. The results compiled to date are being used to support the preparation of an environmental baseline document for the Pebble Project.

6.2.2.2 Methods/Approach

The methods and approach for surface water and sediment quality studies in the transportation corridor/Cook Inlet study areas are generally the same as those employed in the mine study area, as described in Section 6.1.2.2. In brief, the work involves reconnaissance surveys to identify appropriate sampling locations, periodic field visits over the year to collect samples and conduct field measurements of water quality, submitting collected samples for laboratory analysis, and data evaluation.

Surface water samples are collected from representative stream crossings once per month (usually only during the pre-breakup, post-breakup, and summer months). Streams near villages and anadromous streams are particularly targeted for regular sampling. Sample locations were determined as part of the surface water hydrology study in the same area and in coordination with locations chosen for fish studies. The locations coincide with monitoring stations used for the hydrology study and include most streams listed in the State's Title 41 anadromous stream catalogue. Locations for collecting surface water quality and sediment samples are shown on Figure 6.2-1.

Surface water at each sampling station is tested in the field for DO, EC, pH, temperature, turbidity, and ORP, using the same methods and instrumentation as in the mine site study area (see Table 6.1-1). At the same time, surface-water samples are collected as composites using an integrated suspended wading-type sampler.

Collected samples are tested for the same laboratory parameters as for surface water samples collected in the mine study area (presented in Table 6.1-2). QA/QC protocols follow procedures outlined in Section 6.1.2.2 above, and described in the QAPP and in the annual FSPs for surface water quality in the transportation corridor/Cook Inlet study areas (Appendix G and Appendix F of the *Pebble Project Environmental Baseline Document, 2004 through 2008*, respectively).

Sediment grab samples are collected periodically, by a gloved hand or trowel. Three grab samples were taken at each water quality sampling site: one from each side of the bank and one from mid-stream. The three grab samples are composited in a stainless-steel bowl then placed in a jar and sent to the analytical laboratory for the analytes listed in Table 6.1-3.

Detailed sampling procedures are outlined in the FSPs for surface-water studies in the transportation corridor/Cook Inlet study areas (Appendix F of the *Pebble Project Environmental Baseline Document, 2004 through 2008*).

6.2.2.3 Major Tasks/Activities

A summary of the tasks performed during the surface water quality study for the transportation corridor/Cook Inlet study areas is presented in Table 6.2-1. A summary of the sampling locations and the sampling conducted at each site in 2004 through 2008 is presented in Table 6.2-2.

Tasks and Activities for 2004

The main tasks and activities for 2004 were as follows:

- Research, compile, document, and review existing surface water data for the area.
- Identify appropriate surface water sampling locations.
- Collect and analyze surface water samples from each established surface water sampling location.
- Evaluate and report the results.

In 2004, 17 sampling stations were established on representative stream crossings in the study area. Sample locations were determined in coordination with locations chosen for fish studies and coincided with monitoring stations used for the hydrology study.

Most locations were sampled on a monthly basis during the field season, from July to October 2004 (Table 6.2-2). Streams near villages and anadromous streams were targeted in particular for regular sampling. One location (GS7A near Pedro Bay) was sampled only in October; the only time this station was sampled during the 3-year duration of the study.

Surface water samples were tested for the field and laboratory parameters listed in Tables 6.1-1 and 6.1-2, respectively. QA/QC protocols followed procedures outlined in Section 6.1.2.2.

Tasks and Activities for 2005

The main tasks and activities for 2005 were as follows:

- Continue with the review of existing surface-water data for the area.
- Collect monthly surface-water samples from each established surface-water sampling location between February and October.
- Evaluate and report the results.

For 2005, nine of the 16 stations established in 2004 were sampled on a monthly basis beginning in February and continuing through October. No samples were collected at any station in April 2005. One new station (GS22) was established in July and was sampled on a monthly basis until October. Two new stations in the general area of Knoll Head near Iniskin Bay (PSC and PSD) were sampled once in July 2005.

BEESC personnel coordinated their sampling with members from other study teams to ensure consistency between sampling at the mine site and in the transportation corridor/Cook Inlet study areas. The procedures for field testing, water sampling, and analysis were the same as those used during 2004.

Tasks and Activities for 2006

No further surface water samples were collected at the 19 transportation corridor study area sites previously sampled in 2004 and 2005. Four additional surface water sample locations (SWQ1, SWQ2, SWQ3, and SWQ4) were established in the Cook Inlet study area to further characterize surface water quality of the drainage area.

The following main tasks and activities were completed in 2006:

- Continued review of existing surface-water data for the area.
- Evaluated and reported the results.
- Collected one set of water quality samples from the four newly established Cook Inlet sample sites.

Tasks and Activities for 2007

The main tasks and activities completed in 2007 were as follows:

- Continued review of existing surface-water data for the area.

- Evaluated and reported the results.
- Collected two additional sets of water quality samples from the four Cook Inlet sample sites established in 2006.

Tasks and Activities for 2008

The main tasks and activities completed in 2008 were as follows:

- Continued review of existing surface-water data for the area.
- Evaluated and reported the results. No additional samples were collected in 2008.

6.2.3 Groundwater Quality Studies

6.2.3.1 Study Area/Scope

A comprehensive study to fully characterize the groundwater hydrology and groundwater quality was not performed for the transportation corridor study area. Existing community water supply wells were sampled in order to establish a baseline of the water quality of these drinking water supplies. The area for the drinking water quality study in the study area is the same as that for the surface water study between the Newhalen River and Cook Inlet. More specifically, drinking water sampling sites are identified at existing community water supplies in Iliamna, Newhalen, Nondalton, and Pedro Bay. Locations for groundwater quality sampling are shown on Figure 6.2-2.

6.2.3.2 Methods/Approach

The methods and approach for groundwater studies in the transportation corridor/Cook Inlet study areas are similar to those used for surface water studies in the same area. They included preliminary research to identify appropriate sampling locations, field visits to take measurements and collect samples for laboratory analysis, data review, and presentation.

Sampling Location Selection

Preliminary research with local communities indicated there was a public database of previously collected information that could be used to identify appropriate sampling locations. Existing public water wells were identified from the Alaska Department of Environmental Conservation and village records, and through contact with local individuals. The records were reviewed to identify the locations of wells, well installation details (e.g., date of installation, well depth, and depth to water), the quality of the water supply, and trends (if any) in analyte concentrations.

Based on this process, four drinking water wells were selected for groundwater sampling. Each well was located in a separate community; in each case, a well with high usage was chosen. The following four wells were identified:

- Nondalton City Well.
- Newhalen Public Well #2.
- Iliamna Weathered Inn.

- Pedro Bay Tribal Council Well.

Established communities and existing formal water supplies do not exist in the Cook Inlet study area.

Sample Collection, Handling, and Analysis

Groundwater samples from each of the four currently identified sites are taken from a water tap in the system. Water is run from the tap for several minutes before sampling. For the Nondalton and Newhalen wells, the water is sampled from where it first left the wellhead, prior to chlorination. Water from the Iliamna and Pedro Bay wells is not treated; therefore, a tap from within the distribution system is used.

Groundwater sample handling and analysis, and data review procedures for these four stations are similar to those used for the groundwater quality study in the mine study area, and as outlined in Section 6.1.3.2. Sample collection was coordinated with existing study teams. Groundwater is tested for the same field and laboratory parameters as for surface water (Tables 6.1-1 and 6.1-2, respectively). QA/QC protocols followed procedures outlined in Section 6.1.2.2, above, and in the QAPP (Appendix G of the *Pebble Project Environmental Baseline Document, 2004 through 2008)*.

6.2.3.3 Major Tasks/Activities

Most of the tasks and activities for groundwater sampling in the transportation corridor/Cook Inlet study areas occurred in 2004 and 2005. The information in Table 6.2-2 identifies the four groundwater sample sites and the period of monitoring for each. A summary of tasks completed is provided in Table 6.2-3. An outline of the work completed is described below.

The main tasks and activities for 2004 and 2005 included the following:

- Researching, compiling, documenting, and reviewing existing groundwater data for the area.
- Conducting an inventory of drinking water supply wells in each community.
- Selecting well(s) from each community as indicator well(s).
- Collecting groundwater samples from each well for laboratory analysis. The three wells in Newhalen, Iliamna and Pedro Bay were sampled in July and October 2004 and in February, July, and October 2005. For the Newhalen well, the fall 2004 sampling event was conducted in November instead of in October.
- Compiling, evaluating, evaluating, and presenting the analytical results.

In 2006, the data collected in the previous 2 years was compiled and incorporated into a draft environmental baseline report.

There were no groundwater studies completed in 2007 or 2008 for the transportation corridor/Cook Inlet study areas.

6.3 References

United States Geological Service (USGS). 2008 (updated). National Field Manual for the Collection of Water Quality Data, Techniques of Water Resources Investigations. Book 9. Handbooks for Water Resources Investigations. US Department of Interior, Washington, DC.

TABLES

TABLE 6.1-1
Field Parameters for Surface Water and Groundwater Quality

Parameter	Method (Meter)	Units (Range)	Detection Limit	Sensitivity	Precision	Accuracy
Depth to water	Electric sounder	feet (0-100)	NA	0.001	0.01	± 0.02
pH	YSI 556	pH units (0 to 14)	NA	0.01	0.01	± 0.2
Specific conductance	YSI 556	mS/cm (0 to 200)	0.001	0.001	0.001 to 0.1 (range dependent)	± 0.5% + 0.001
Temperature	YSI 556	^{o}C (-5 to 45)	NA	0.01	0.01	± 0.15
Dissolved oxygen	YSI 556	mg/L O_2 (0 to 50)	0.2	0.01	0.01	± 20 mg/L to 2 %
		% saturation (0-500)	2% air saturation	0.1%	0.1%	± 2 % of reading to 200%
Oxidation reduction potential	YSI 556	mV (-999 to +999)	0.1	0.1 mV	0.1 mV	± 20 mV
Turbidity	Hach 2100P	NTU (0-1000)	0.01	0.01	0.01 to 1 (range dependent)	± 2% of reading or ± 1 least significant digit; ± 3% of reading at 500 to 1000 NTU

Notes:

°C = degrees Celsius

mg/L = milligrams per liter

mS/cm = millisiemens per centimeter

mV = millivolts

NA = not applicable

NTU = nephelometric turbidity units

TABLE 6.1-2
Surface Water and Groundwater Analytes for Laboratory Determination

Analyte	Method	Method Reporting Limit (µg/L unless otherwise noted)
Aluminum, total and dissolved	E200.8	25
Antimony, total and dissolved	E200.8	0.2
Arsenic, total and dissolved	E200.8	0.5
Barium, total and dissolved	E200.8	0.3
Beryllium, total and dissolved	E200.8	0.4
Bismuth, total and dissolved	E200.8	5
Boron, total and dissolved	E200.7	10
Cadmium, total and dissolved	E200.8	0.1
Calcium, total and dissolved	200.7	50
Chromium, total and dissolved	E200.8	0.2
Cobalt, total and dissolved	E200.8	0.1
Copper, total and dissolved	E200.8	0.2
Iron, total and dissolved	E200.7/200.8	20
Lead, total and dissolved	E200.8	0.2
Magnesium, total and dissolved	E200.7/200.8	20
Manganese, total and dissolved	E200.8	1
Mercury, total and dissolved	E1631	0.001
Molybdenum, total and dissolved	E200.8	1
Nickel, total and dissolved	E200.8	0.2
Potassium, total and dissolved	E200.7/200.8	50
Selenium, total and dissolved	E200.8	1
Silver, total and dissolved	E200.8	0.2
Sodium, total and dissolved	E200.7/200.8	100
Thallium, total and dissolved	E200.8	0.05
Tin, total and dissolved	E200.8	1
Vanadium, total and dissolved	E200.8	0.4
Zinc, total and dissolved	E200.8	1.5
pH	E150.1	NA
Conductivity	E120.1	1 (mS/cm)
Alkalinity	SM20 2320B	10 (mg/L)
Acidity	E305.1	NA
Ammonia	E350.2	0.1 (mg/L)
Chloride	E300.0	0.1 (mg/L)
Cyanide-total	SM20 4500	5
Cyanide-WAD	SM20 4500	5
Fluoride	E300.0	0.1 (mg/L)
Nitrate + Nitrite (in 2006 and 2007, only)	E300.0	0.1 (mg/L)

Analyte	Method	Method Reporting Limit (µg/L unless otherwise noted)
Phosphorus-total (in 2006 and 2007, only)	E365.2	0.1 (mg/L)
Sulfate	E300.0	0.1 (mg/L)
Silicon	E200.7	500
Total dissolved solids	E160.1	10 (mg/L)
Total suspended solids	E160.2	0.5 (mg/L)
Organic carbon, dissolved (surface water in June 2007, only)	n/a	0.5 (mg/L)
Thiocyanate	Lab SOP	1 (mg/L)

Notes:

E – Methods for Chemical Analysis of Inorganic Substances in Environmental Samples, EPA/600/R-93-100, August 1993 and Methods for the Determination of Metals in Environmental Samples, EPA/600/4-91-010, June 1991.

SM – Standard Methods for the Examination of Water and Wastewater, 20th Edition.

mg/L – milligrams per liter

mS/cm – millisiemens per centimeter

µg/L – micrograms per liter

WAD – weak acid dissociable

TABLE 6.1-3
Sediment Analytes for Laboratory Determination

Metals		Non-metals
Aluminum	Magnesium	Cyanide, total
Arsenic	Molybdenum	Chloride
Barium	Manganese	Fluoride
Beryllium	Nickel	Total Sulfate
Bismuth	Potassium	Ammonia as N
Boron	Selenium	Total sulfur
Cadmium	Silver	
Calcium	Sodium	
Chromium	Thallium	
Cobalt	Tin	
Copper	Vanadium	
Iron	Zinc	
Lead	Mercury	

Notes:

All metal analyses are for total content by aqua regia digest (Method SW3050).

Table 6.1-4
Pebble Project Environmental Baseline Studies
Study Summary for Surface Water Quality, Mine Study Area, 2004-2008
Consultant: HDR Alaska, Inc., Water Management Consultants

2004 Data Collected or Tasks Completed	2005 Data Collected or Tasks Completed	2006 Data Collected or Tasks Completed	2007 Data Collected or Tasks Completed	2008 Data Collected or Tasks Completed
Mine Study Area				
Baseline Surface-Water Quality Data Collection (7 Events, 30 Stations)	Baseline Surface-Water Quality Data Collection (8 Events, 32 Stations)	Baseline Surface-Water Quality Data Collection (10 Events, 31 Stations)	Baseline Surface Water-Quality Data Collection (12 Events, 36 Stations)	Baseline Surface Water-Quality Data Collection (12 events, 20 stations)
	Seeps - Inventory	Seeps - Inventory	Seeps - Inventory	Seeps - Inventory
Seeps - Sampling (Flow and Water Quality: 11 in March and September)	Seeps - Sampling (Flow and Water Quality: 9 in March; 24 in July, August and October)	Seeps - Sampling (Flow and Water Quality: 8 of 24 in March [the others were buried], 24 in July, August and October)	Seeps - Sampling Planned for Areas 1-19; and Areas J, L, and UT East Drainage	Seeps - Sampling
Sediment - Field Data Collection (Streams: 18 in June, July and/or September)	Sediment - Field Data Collection (Streams: 15 of 17 in June, 13 of 17 in July, 5 of 17 in September; Lakes: 6 in July, August or September; Seeps: 7 of 7 in July, 5 of 7 in October)	Sediment - Field Data Collection (Streams: 12 in June; Lakes: 1 in July; Seeps: Precipitates in June)	Sediment - Field Data Collection (Streams: 14 in June;	
		Ponds and Lake Sampling (Lakes: 6 in July/August; Ponds: 12 in August)	Ponds and Lake Sampling (Lakes: 6 in August; Ponds: 12 in August)	

TABLE 6.1-5

Period-Of-Record Index by Sample Location, Surface Water Program, Mine Study Area, 2004-2008

Sample Location	Year	Period Of Record By Discipline																							
		Water Quality												Sediment											
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
KC100A	2004				Q	Q	Q	Q	Q	Q	Q								F	F		F			
	2005	Q		Q		Q	Q	Q	Q	Q	Q								F	F					
	2006		Q	Q		Q	Q	Q	Q	Q	Q		Q												
	2007		Q	Q	Q	Q																			
	2008	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
KR100A	2004				Q	Q	Q	Q	Q	Q	Q									F		F			
	2005			Q			Q	Q	Q	Q	Q														
	2006			Q			Q	Q			Q		Q												
	2007		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
	2008		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
NK100A (USGS)	2004				Q	Q	Q	Q	Q	Q	Q								F	F		F			
	2005	Q		Q		Q	Q	Q	Q	Q	Q								F	F					
	2006		Q	Q		Q	Q	Q	Q	Q	Q		Q												
	2007		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
	2008	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
NK100A1	2004																								
	2005																								
	2006																								
	2007		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
	2008	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
NK100B	2004				Q	Q			Q	Q	Q								F						
	2005	Q		Q		Q	Q	Q	Q	Q	Q								F	F		F			
	2006		Q	Q		Q	Q	Q	Q	Q	Q		Q												
	2007		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
	2008	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
NK100C	2004				Q	Q	Q	Q	Q	Q	Q								F	F		F			
	2005	Q		Q		Q	Q	Q	Q	Q	Q								F	F		F			
	2006		Q	Q		Q	Q	Q	Q	Q	Q		Q												
	2007		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
	2008	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
NK100D	2004				Q	Q																			
	2005																								
	2006																								
	2007																								
	2008																								
NK119A	2004				Q	Q	Q	Q	Q	Q	Q								F	F		F			
	2005	Q		Q		Q	Q	Q	Q	Q	Q								F	F					
	2006	Q	Q	Q		Q	Q	Q	Q	Q	Q		Q												
	2007		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
	2008	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
NK119B	2004				Q	Q	Q	Q	Q	Q	Q															
	2005	Q		Q		Q	Q	Q	Q	Q	Q														
	2006																								
	2007				Q	Q	Q			Q	Q	Q	Q												
	2008																								

TABLE 6.1-5

Period-Of-Record Index by Sample Location, Surface Water Program, Mine Study Area, 2004-2008

Sample Location	Year	Period Of Record By Discipline																						
		Water Quality												Sediment										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
SK100A	2004				Q	Q	Q	Q	Q	Q	Q								F						
	2005	Q		Q		Q	Q	Q	Q	Q	Q								F	F					
	2006		Q	Q		Q	Q	Q	Q	Q	Q		Q												
	2007	Q	Q	Q	Q	Q	Q	Q		Q	Q	Q	Q												
	2008	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
SK100B (USGS)	2004				Q	Q	Q	Q	Q	Q	Q								F	F		F			
	2005	Q		Q		Q	Q	Q	Q	Q	Q								F	F					
	2006		Q	Q		Q	Q	Q	Q	Q	Q		Q												
	2007	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
	2008	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
SK100B1	2004																								
	2005									Q	Q														
	2006		Q	Q		Q	Q	Q	Q	Q	Q		Q												
	2007	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
	2008	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
SK100B2	2004																								
	2005						Q	Q	Q	Q	Q														
	2006		Q			Q	Q	Q	Q	Q	Q		Q												
	2007	Q	Q			Q	Q	Q	Q	Q	Q	Q	Q												
	2008	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
SK100C	2004				Q	Q	Q	Q			Q								F	F		F			
	2005	Q				Q	Q	Q		Q	Q								F	F					
	2006					Q	Q	Q	Q	Q	Q		Q												
	2007					Q	Q	Q		Q	Q	Q	Q												
	2008				Q	Q																			
SK100D	2004				Q	Q	Q	Q	Q	Q	Q											F			
	2005	Q		Q		Q	Q	Q	Q	Q	Q														
	2006						Q	Q	Q	Q	Q		Q												
	2007	Q	Q		Q	Q	Q	Q	Q	Q	Q	Q	Q												
	2008	Q	Q	Q		Q																			
SK100E	2004					Q																			
	2005																								
	2006																								
	2007																								
	2008																								
SK100F	2004					Q	Q	Q	Q	Q	Q								F	F		F			
	2005	Q		Q		Q	Q	Q	Q	Q	Q								F						
	2006	Q	Q	Q		Q	Q	Q	Q	Q	Q		Q												
	2007	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
	2008	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
SK100G	2004				Q	Q	Q	Q	Q	Q	Q								F	F	F	F			
	2005	Q		Q		Q	Q	Q	Q	Q	Q								F	F					
	2006	Q	Q	Q		Q	Q	Q	Q	Q	Q		Q												
	2007	Q	Q		Q	Q	Q	Q	Q	Q	Q	Q	Q												
	2008	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												

TABLE 6.1-5

Period-Of-Record Index by Sample Location, Surface Water Program, Mine Study Area, 2004-2008

Sample Location	Year	Period Of Record By Discipline																							
		Water Quality												Sediment											
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
SK100H (SK136A)	2004				Q	Q	Q	Q	Q	Q	Q														
	2005	Q		Q		Q	Q	Q	Q	Q	Q														
	2006	Q	Q	Q		Q	Q	Q	Q	Q	Q		Q												
	2007		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
	2008	Q	Q	Q	Q	Q																			
SK100I (SK136B)	2004				Q	Q	Q	Q	Q	Q	Q														
	2005	Q		Q		Q	Q	Q	Q	Q	Q														
	2006	Q	Q	Q		Q	Q	Q	Q	Q	Q		Q												
	2007		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
	2008	Q	Q	Q	Q	Q																			
SK116A	2004																								
	2005																								
	2006																								
	2007																								
	2008									Q	Q	Q	Q												
SK117A	2004																								
	2005																								
	2006																								
	2007																								
	2008									Q	Q	Q	Q												
SK119A	2004				Q	Q	Q	Q	Q	Q	Q								F	F		F			
	2005	Q		Q		Q	Q	Q	Q	Q	Q								F						
	2006		Q	Q		Q	Q	Q	Q		Q		Q												
	2007	Q	Q		Q	Q	Q	Q	Q	Q	Q	Q	Q												
	2008	Q	Q	Q	Q	Q																			
SK124A	2004																								
	2005	Q		Q		Q	Q	Q	Q	Q	Q														
	2006	Q	Q	Q			Q	Q	Q		Q		Q												
	2007	Q				Q	Q	Q	Q	Q	Q	Q	Q												
	2008					Q																			
SK131A	2004				Q	Q	Q	Q	Q	Q	Q									F		F			
	2005	Q		Q		Q	Q	Q	Q	Q	Q														
	2006		Q	Q		Q	Q	Q	Q	Q	Q		Q												
	2007	Q	Q			Q	Q	Q	Q	Q	Q	Q	Q												
	2008	Q	Q	Q	Q	Q																			
SK133A	2004				Q	Q	Q	Q	Q	Q	Q														
	2005					Q	Q	Q	Q	Q	Q														
	2006		Q	Q		Q	Q	Q	Q	Q	Q		Q												
	2007		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
	2008	Q	Q	Q	Q	Q																			
SK134A	2004				Q	Q	Q	Q	Q	Q	Q														
	2005	Q		Q		Q	Q	Q	Q	Q	Q														
	2006	Q	Q	Q		Q	Q	Q	Q	Q	Q		Q												
	2007		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
	2008	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												

TABLE 6.1-5

Period-Of-Record Index by Sample Location, Surface Water Program, Mine Study Area, 2004-2008

Sample Location	Year	Period Of Record By Discipline																							
		Water Quality												Sediment											
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
UT100A	2004				Q	Q			Q	Q	Q											F			
	2005	Q		Q		Q	Q	Q			Q														
	2006			Q			Q	Q	Q	Q	Q		Q												
	2007		Q	Q	Q	Q	Q	Q																	
	2008																								
UT100B (USGS)	2004				Q	Q	Q	Q	Q	Q	Q								F	F	F	F			
	2005	Q		Q		Q	Q	Q	Q	Q	Q								F	F		F			
	2006		Q	Q		Q	Q	Q	Q	Q	Q		Q												
	2007	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
	2008	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
UT100C	2004					Q	Q		Q										F						
	2005																								
	2006																								
	2007		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
	2008	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
UT100C1	2004																								
	2005																								
	2006																								
	2007		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
	2008	Q	Q	Q	Q	Q																			
UT100C2	2004																								
	2005																								
	2006																								
	2007		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
	2008	Q	Q	Q	Q	Q																			
UT100D	2004				Q	Q	Q	Q	Q	Q	Q								F	F		F			
	2005	Q		Q		Q	Q	Q	Q	Q	Q								F	F		F			
	2006		Q	Q		Q	Q	Q	Q	Q	Q		Q												
	2007	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
	2008	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
UT100D1	2004																								
	2005																								
	2006																								
	2007																								
	2008									Q	Q	Q	Q												
UT100E	2004				Q	Q	Q	Q	Q	Q	Q								F	F		F			
	2005	Q		Q		Q	Q	Q	Q	Q	Q								F						
	2006	Q	Q	Q		Q	Q	Q	Q	Q	Q		Q												
	2007	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
	2008	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
UT119A	2004				Q	Q	Q	Q	Q	Q	Q								F	F		F			
	2005	Q		Q		Q	Q	Q	Q	Q	Q								F						
	2006	Q	Q	Q		Q	Q	Q	Q	Q	Q		Q												
	2007	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
	2008	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												

TABLE 6.1-5

Period-Of-Record Index by Sample Location, Surface Water Program, Mine Study Area, 2004-2008

Sample Location	Year	Period Of Record By Discipline																							
		Water Quality												Sediment											
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
UT119B	2004				Q	Q	Q	Q	Q	Q	Q														
	2005	Q		Q		Q	Q	Q	Q	Q	Q									F					
	2006	Q	Q	Q		Q	Q	Q	Q	Q	Q		Q												
	2007	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
	2008	Q	Q	Q	Q	Q																			
UT135A	2004				Q	Q	Q	Q	Q	Q	Q														
	2005	Q		Q		Q	Q	Q	Q	Q	Q														
	2006		Q	Q		Q	Q	Q	Q	Q	Q		Q												
	2007		Q				Q	Q	Q	Q	Q	Q	Q												
	2008	Q	Q	Q	Q	Q																			
UT135B	2004					Q																			
	2005																								
	2006																								
	2007																								
	2008																								
UT138A	2004				Q	Q	Q	Q	Q	Q	Q									F		F			
	2005	Q		Q		Q	Q	Q	Q	Q	Q														
	2006		Q	Q		Q	Q	Q	Q	Q	Q		Q												
	2007	Q	Q		Q	Q	Q	Q	Q	Q	Q	Q	Q												
	2008	Q	Q	Q	Q	Q																			
UT141A	2004				Q	Q	Q	Q	Q	Q	Q									F		F			
	2005			Q		Q	Q	Q	Q	Q	Q									F					
	2006		Q	Q		Q	Q	Q	Q	Q	Q		Q												
	2007	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												
	2008	Q	Q	Q	Q	Q																			
UT146A	2004				Q	Q	Q	Q	Q	Q	Q									F		F			
	2005	Q		Q		Q	Q	Q	Q	Q	Q														
	2006		Q			Q	Q	Q	Q	Q	Q		Q												
	2007	Q	Q		Q	Q	Q	Q	Q	Q	Q	Q	Q												
	2008	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q												

KEY:

C Continuous stage/discharge hydrometric data collected in streams (gaged stations with dataloggers).

F Sediment samples collected.

I Instantaneous stream discharge measurements taken each month coincident with water quality (ungaged stations without dataloggers).

Q Surface-water quality samples collected for field and laboratory analyses.

Table 6.2-1
Pebble Project Environmental Baseline Studies
Study Summary for Surface Water Quality, Transportation Corridor/Cook Inlet Study Areas, 2004 - 2006
Consultant: BEESC

2004 Data Collected or Tasks Completed	2005 Data Collected or Tasks Completed	2006 Data Collected or Tasks Completed	2007 Data Collected or Tasks Completed	2008 Data Collected or Tasks Completed
Information Gathering	Information Gathering			
Scope, Schedule	Scope, Schedule			
2004 Field Sampling Plan	2005 Field Sampling Plan			
Field Sampling - July - October	Field Sampling - Feb, March, May - October	Field Sampling - Cook Inlet Study Area (1 sampling event)	Field Sampling - Cook Inlet Study Area (2 sampling events)	
Coordination with NDM	Coordination with NDM			
Coordination with Local Communities for Observers	Coordination with Local Communities for Observers			
Data Management	Data Compilation and	Data Compilation and Analysis	Data Compilation and Analysis	Data Compilation and Analysis
Communication				
Presentation Preparation				
Report Writing	2004 Progress Report	Preliminary Environmental Baseline Document	Update Environmental Baseline Document	Update Environmental Baseline Document

Table 6.2-2
Pebble Project Environmental Baseline Studies
Sample Location, Period-of-Record Index
Surface Water and Groundwater Studies, Transportation Corridor/Cook Inlet Study Areas, 2004-2007

Sample Location	Year	Period Of Record By Discipline																						
		Surface Water Quality												Groundwater Quality										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
NHRIV	2004							Q	Q	Q	Q														
	2005		Q	Q		Q	Q	Q	Q	Q	Q														
	2006																								
GS20	2004							Q	Q	Q	Q														
	2005		Q	Q				Q	Q	Q	Q														
	2006																								
GS20A	2004							Q	Q	Q	Q														
	2005		Q	Q																					
	2006																								
GS18A	2004							Q	Q	Q	Q														
	2005		Q	Q																					
	2006																								
GS17A	2004							Q	Q	Q	Q														
	2005		Q	Q		Q	Q	Q	Q	Q	Q														
	2006																								
GS14A	2004							Q	Q	Q	Q														
	2005		Q	Q																					
	2006																								
GS14B	2004							Q	Q	Q	Q														
	2005		Q	Q		Q	Q	Q	Q	Q	Q														
	2006																								
GS12A	2004							Q	Q	Q	Q														
	2005		Q	Q																					
	2006																								
GS11A	2004							Q	Q	Q	Q														
	2005		Q	Q		Q	Q	Q	Q	Q	Q														
	2006																								
GS8A	2004							Q	Q	Q	Q														
	2005		Q	Q		Q	Q	Q	Q	Q	Q														
	2006																								
GS7A	2004										Q														
	2005																								
	2006																								
GS6A	2004							Q	Q	Q	Q														
	2005		Q	Q																					
	2006																								
GS4A	2004							Q	Q	Q	Q														
	2005		Q	Q		Q	Q	Q	Q	Q	Q														
	2006																								
GS4B	2004									Q	Q														
	2005		Q	Q																					
	2006																								
GS3A	2004								Q	Q	Q														
	2005		Q	Q		Q	Q	Q	Q	Q	Q														
	2006																								
GS23	2004							Q	Q	Q	Q														
	2005																								
	2006																								
GS22	2004																								
	2005							Q	Q	Q	Q														
	2006																								

Table 6.2-2
Pebble Project Environmental Baseline Studies
Sample Location, Period-of-Record Index
Surface Water and Groundwater Studies, Transportation Corridor/Cook Inlet Study Areas, 2004-2007

Sample Location	Year	Period Of Record By Discipline																						
		Surface Water Quality												Groundwater Quality										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
GS21	2004								Q	Q	Q														
	2005		Q	Q		Q	Q	Q	Q	Q	Q														
	2006																								
PSC	2004																								
	2005							Q																	
	2006																								
PSD	2004																								
	2005							Q																	
	2006																								
SWQ1	2004																								
	2005								Q																
	2006										Q														
	2007																								
SWQ2	2004																								
	2005								Q																
	2006										Q														
	2007																								
SWQ3	2004																								
	2005								Q																
	2006										Q														
	2007																								
SWQ4	2004																								
	2005								Q																
	2006										Q														
	2007																								
NEWH2	2004																		Q				Q		
	2005															Q			Q				Q		
	2006																								
NONDA	2004																		Q					Q	
	2005															Q			Q				Q		
	2006																								
ILIWI	2004																		Q				Q		
	2005															Q			Q				Q		
	2006																								
PEDRO	2004																		Q				Q		
	2005																Q		Q				Q		
	2006																								

KEY:

I Instantaneous stream discharge measurements taken each month coincident with water quality (ungaged stations without dataloggers).

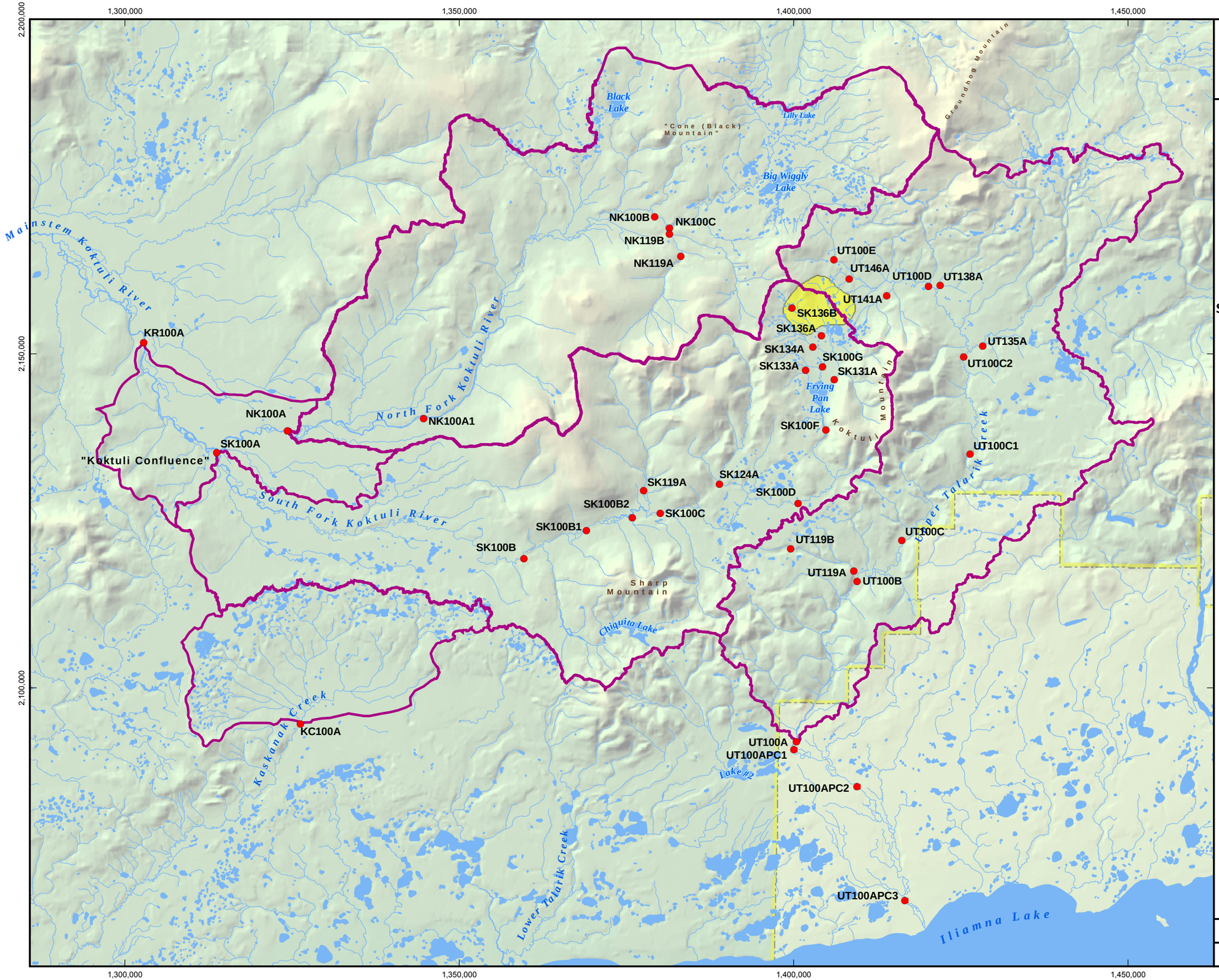
Q Water quality samples collected for field and laboratory analyses.

Note: Only Sites SWQ1, SWQ2, SWQ3, SWQ4 were sampled in 2007.

Table 6.2-3
Pebble Project Environmental Baseline Studies
Study Summary for Groundwater Quality, Transportation Corridor/Cook Inlet Study Areas, 2004 - 2008
Consultant: BEESC

2004 Data Collected or Tasks Completed	2005 Data Collected or Tasks Completed	2006 Data Collected or Tasks Completed	2007 Data Collected or Tasks Completed	2008 Data Collected or Tasks Completed
Information Gathering	Information Gathering			
Scope, Schedule	Scope, Schedule			
2004 Field Sampling Plan	2005 Field Sampling Plan			
Field Sampling - July & October	Field Sampling - March, July, and October			
Coordination with Local Communities for Observers	Coordination with Local Communities for Observers			
Data Management	Data Compilation and Analysis	Data Compilation and Analysis	Data Compilation and Analysis	Data Compilation and Analysis
Communication				
Presentation Preparation				
Report Writing	2004 Progress Report	Preliminary Environmental Baseline Document	Update Environmental Baseline Document	Update Environmental Baseline Document

FIGURES

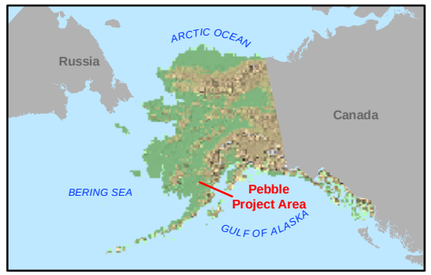


THE pebble PARTNERSHIP

Figure 6.1-1
Consolidated Study Program, 2004-2008
Surface Water Quality
Study Area and Location of Stream and Lake Sampling Stations, Mine Study Area

Legend

- Drainage Boundary
- Stream Sampling Station
- **SK100B** Station Label Example
- Stream
- Waterbody
- General Deposit Location
- Village Corporation Boundary (Private Land)



0 1.25 2.5 3.75 5 Miles

0 1.25 2.5 3.75 5 Kilometers

N

Scale 1:170,000

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

Figure 6.1-1	Date: March 16, 2009
Version: 2	Author: HDR - JC, MC; PLP-JG

Fi igur e F ege6e Fr g5 e Fe. gFee

ugui - gf. e

Black Lake

omgr b nd S2t y P
1 gur - 2Cr o

Lilly Lake

Figure 96.1gur-2Cr

Big Wiggly Lake

Fu

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Frying Pan Lake

3

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6

F

F.

North Fork Kokt uli River

South Fork Kokt uli River

Upper Talarik Creek

6 ur . 1
- 2C or m

Chiquita Lake

Kaskanak Creek

Lake #2

ugu Figue

Figure

Fege6e Fr g5 e Fe. gFee

FigureF u6.

THE pebble PARTNERSHIP

Figure 6.1-2
Consolidated Study Program, 2004-2008
Surface Water Quality
Seep Sampling Stations and
Inventory Locations,
Mine Study Area

Legend

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- br nur edgSt dCemedy . eu
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- Pu4 br nur edgS0gu.
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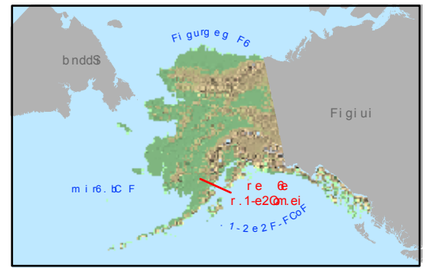
- yg C. ou cdi r a. gS
- General Deposit Location
- pC2ou Fdg- dg edr cdi r a. gS



6.1-2
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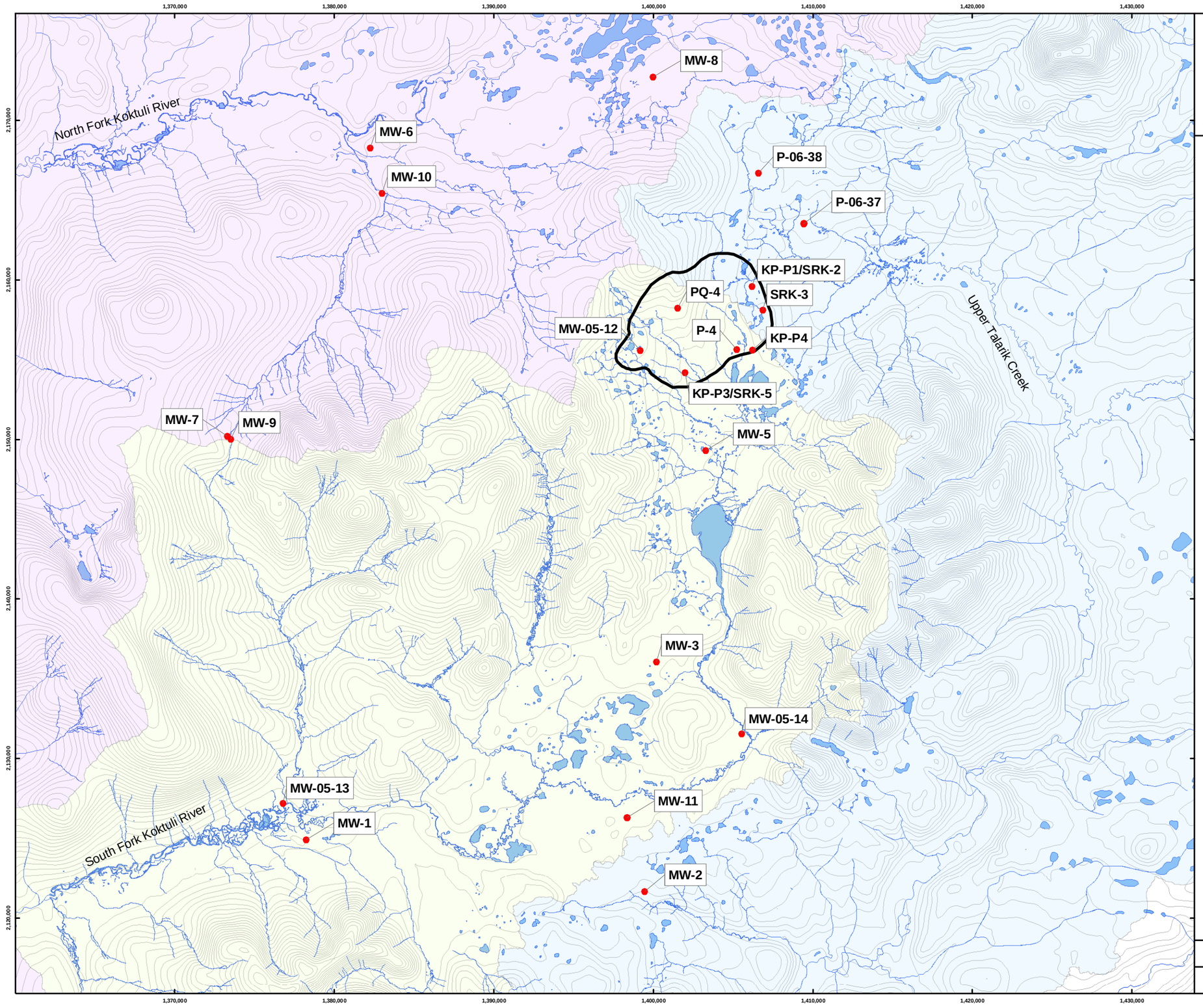


THE pebble PARTNERSHIP

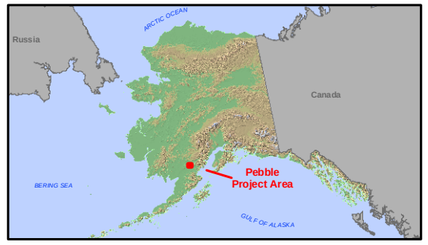
Figure 6.1-3
Consolidated Study Program, 2004-2008
Groundwater Quality Existing Monitoring Well Locations (2008), Mine Study Area

Legend

- MW-5 Example Well Identification
- Monitoring Well
- General g
- Lakes
- Rivers
- 50-ft Contour Interval

Watershed

- North Fork Koktuli River
- South Fork Koktuli River
- Upper Talarik Creek



0 4,000 8,000 12,000 16,000 Feet

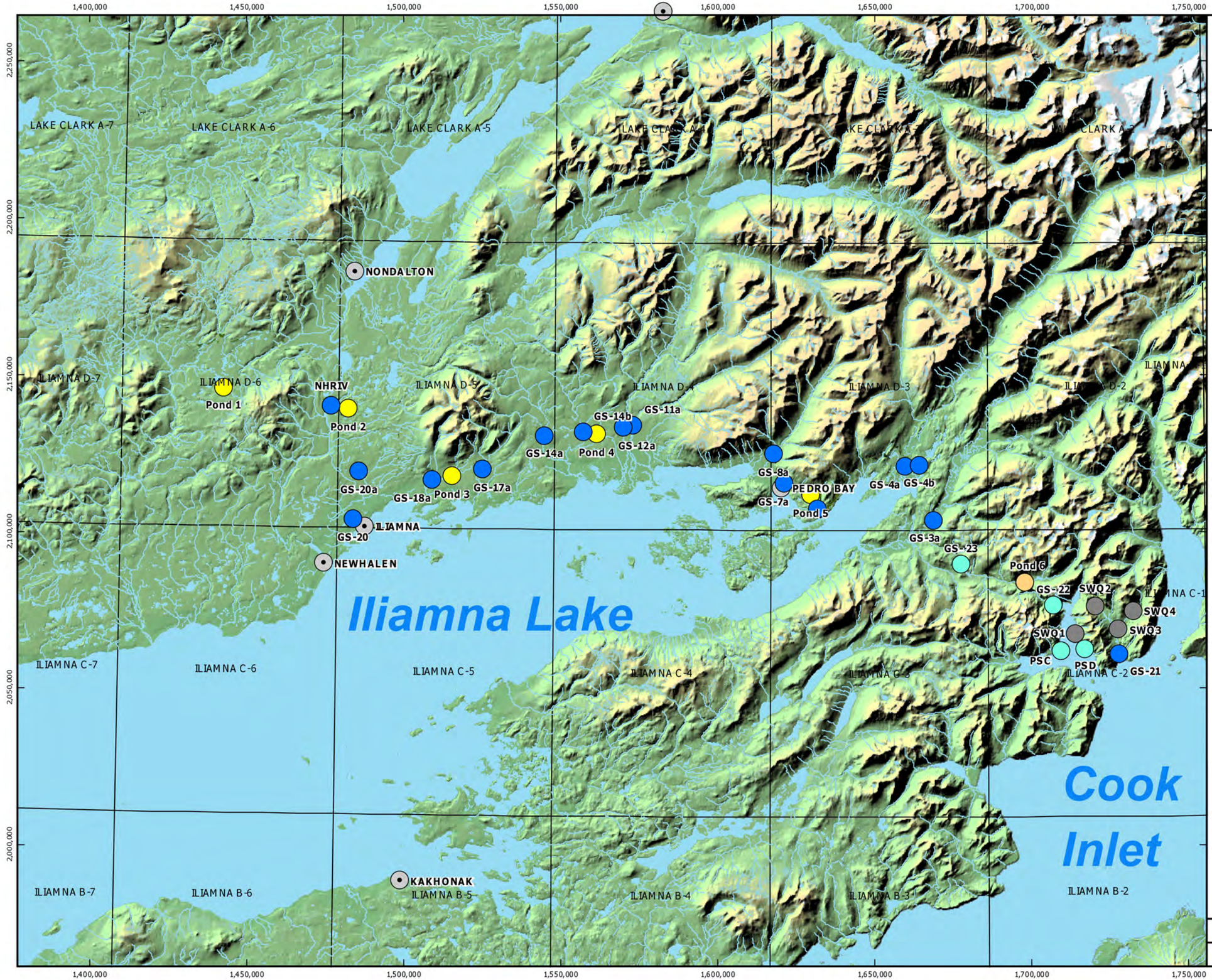
0 1,300 2,600 3,900 5,200 Meters

N

Scale 1:74,110

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

Project No: 7126	Date: March 16, 2009
Version: 7	Author: WMC-LC, PLP-JG

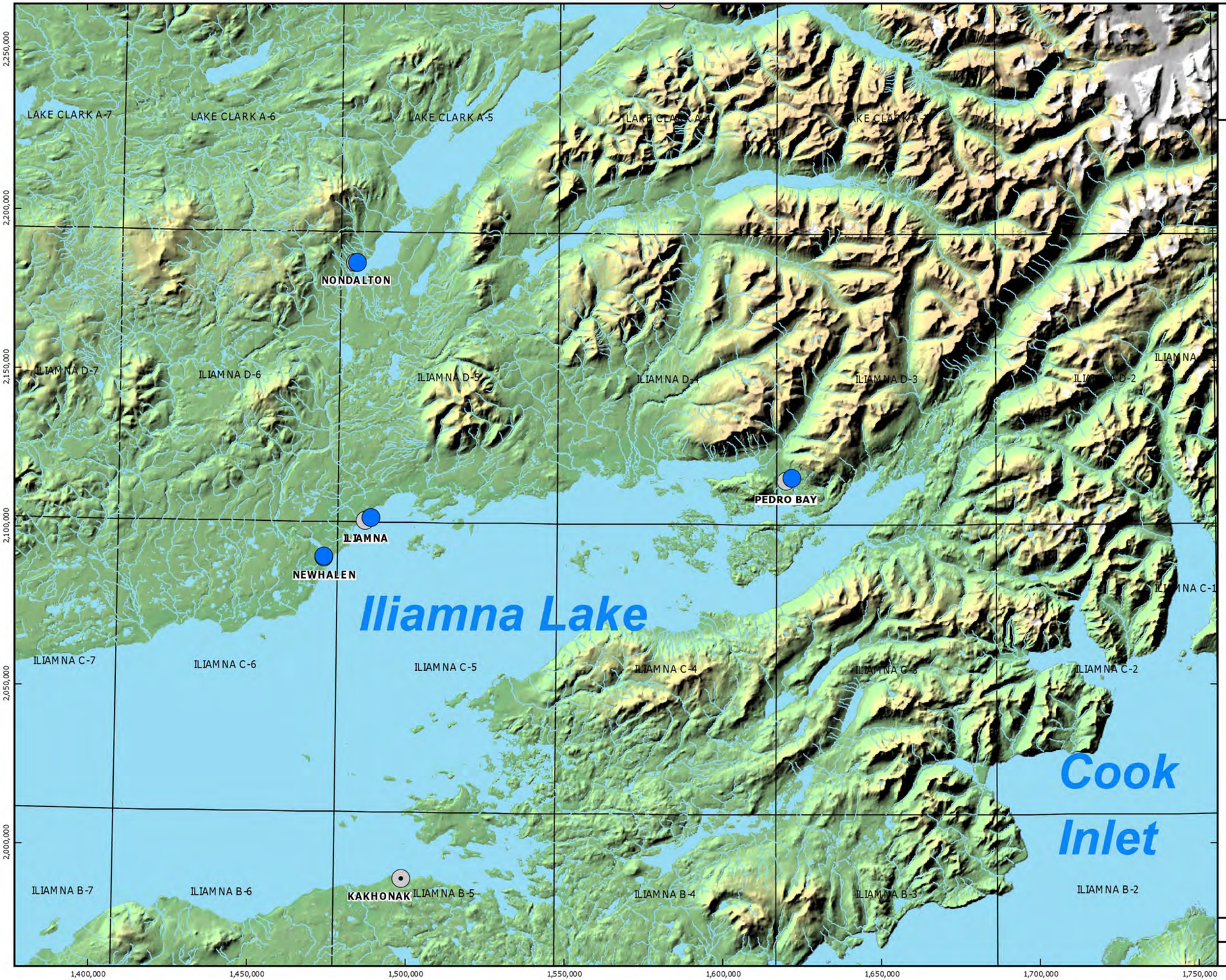


THE pebble PARTNERSHIP

Figure 6.2-1
Consolidated Study Program, 2004-2008
Surface Water Quality
Transportation Corridor
Study Areas and Sampling Locations,
Transportation Corridor /
Cook Inlet Study Areas

- Surface Water Quality/Sediment sampled in 2004 and 2005
- Surface Water Quality/Sediment sampled only in 2005
- Surface Water Quality/Sediment sampled in 2006 and 2007
- Tundra Ponds sampled in 2004 and 2005
- Tundra Ponds sampled in 2006
- GS-3a Station Label Example
- Communities

File: 2006StyPlan_3_V05.mxd	Date: March 16, 2009
Version: 6	Author: BEESC-ME, PLP-JG

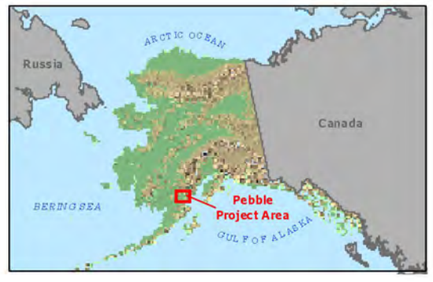


THE pebble PARTNERSHIP

Figure 6.2-2
Consolidated Study Program, 2004-2008
Drinking Water Quality Sampling Locations,
Transportation Corridor /
Cook Inlet Study Areas

Legend

- Drinking Water Quality
- Communities



Miles 0 4 8 12 16
Kilometers 0 4 8 12 16
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Scale 1:363,852
Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: 2006StyPlan_2_V04.mxd	Date: March 17, 2009
Version: 5	Author: BEESC-ME, PLP-JG

Pebble Project
Environmental Baseline Studies
2004 through 2008

CONSOLIDATED STUDY PROGRAM

7. TRACE ELEMENTS

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ACRONYMS AND ABBREVIATIONS

ABR	ABR, Inc.
AS	alpine rock and dwarf scrub habitat
BEESC	Bristol Environmental & Engineering Services Corporation
bgs	below ground surface
BLM	Bureau of Land Management
CSP	consolidated study program
DRO	diesel-range organics
EBD	*Pebble Project Environmental Baseline Document, 2004 through 2008*
FOC	fraction organic carbon
FSP	field sampling plan
GIS	geographic information system
GPS	global positioning system
HDR	HDR Alaska, Inc.
LM	lowland wet graminoid, moss meadow habitat
LS	lowland low and tall alder/willow scrub habitat
MRL	method reporting limit
NOC	naturally occurring constituents
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
RRO	residual-range organics
RS	riverine willow scrub habitat
Shaw	Shaw Environmental, Inc.
SLR	SLR Alaska, Inc.
SS	subalpine dwarf, low and tall scrub habitat
TOC	total organic carbon
TPH	total petroleum hydrocarbons
UF	upland dwarf scrub, lichen flats habitat
US	upland dwarf, low and tall scrub habitat

7. TRACE ELEMENTS

7.1 Introduction

This document provides the 2004 through 2008 study program for the trace element component of the environmental baseline description for the Pebble Project.

The term “trace elements” refers to naturally occurring elements (mostly metals) that are analyzed in various matrices. In Pebble Project documents, the term “trace elements” also is used to refer to the trace elements program. The trace elements study examines not only metals, but also other naturally occurring compounds such as anions, cations, and biogenic hydrocarbons. The term, “naturally occurring constituents” (NOC), is commonly used in this document to refer collectively to the analytical parameters of interest in the trace elements study.

The study includes a field component to collect samples of soil, sediment, vegetation, and fish tissues; analysis of the collected samples for NOC; and data evaluation. The work is being conducted in three study areas: the mine study area and the transportation corridor/Cook Inlet study areas. The mine study area program is discussed separately from the combined transportation corridor/Cook Inlet study areas program in this chapter.

There are several consultants for the trace element study:

- CH2M Hill led the trace element study work in the mine study area in 2004, establishing the original study area and plans for sampling soil, vegetation, and sediments.
- SLR International Corp. (SLR) has led the trace element study for the mine study area since 2005. It has been responsible for collecting surface and subsurface soils, and terrestrial and aquatic vegetation.
- Also since 2005, HDR Alaska, Inc. (HDR) has been responsible at the mine study area for collecting sediment samples in streams, lakes, and seeps, and fish-tissue samples from lakes and streams. HDR has also collected fish-tissue samples in the transportation corridor/Cook Inlet study areas.
- Bristol Environmental and Engineering Services Corporation (BEESC) is responsible for all aspects of the trace element study in the transportation corridor/Cook Inlet study areas, except for fish-tissue sampling. It has been conducting this work since 2004, with SLR providing oversight to maintain consistency between the study areas.
- ABR, Inc. (ABR) provides habitat inventory and mapping information to support SLR and HDR in their selection of sampling sites for soils and vegetation.

7.2 Objectives

The following are objectives of the trace elements baseline study:

- Collect baseline data to characterize the natural levels of NOC existing in solid-phase environmental media, including their spatial and temporal variability.
- Continue and update field procedures established in the 2004 study of NOC.
- Provide data for input to other environmental baseline studies.

7.3 Mine Study Area

7.3.1 Study Area/Scope

The study area for trace element studies in the mine study area is shown on Figure 7.1-1. The area is based on the Bureau of Land Management (BLM) cadastral survey system of range/township/section, and is 16 survey sections long by 10 sections wide. It encompasses the general deposit area and surrounding areas, for a total area of 160 square miles.

The fish tissue component of the trace elements study extends beyond this area to include the full length of the north and south forks of the Koktuli River and all of Upper Talarik Creek. The study area for fish is described in greater detail in consolidated study program (CSP) 11, Fish and Aquatic Resources.

The scope of work for the trace element study included the following:

- Collecting samples of:
  - Surface and near subsurface soil media.
  - Terrestrial vegetation that is used as forage by wildlife or as food or medicine by humans
  - Aquatic vegetation associated with lakes and ponds that is consumed by moose.
  - Surface sediment found beneath tundra lakes, ponds, streams, and seeps.
  - Fish sampled from lakes and streams, including whole fish and organ samples.
- Analyzing collected samples for a range of NOC.
- Documenting statistical variance of the NOC concentrations in each of the above media.
- Evaluating the data to develop an understanding of current conditions.

Trace elements are often detected in sediments at higher concentrations than the overlying surface water and often relate much closer to fish tissue data than water quality results; therefore, sediment sampling is an important component of the trace element study.

7.3.2 Methods and Approach

The trace element study in the mine study area includes four components: developing a methodology for identifying sample site locations; sampling of soils, sediments, vegetation, and fish tissues; sample

analysis; and data evaluation. The main methods and approaches for each are discussed separately below. Variations to these methods and approaches, including changes, deletions, and additions, are discussed separately according to the year in which they were implemented, under the major tasks and activities described in Section 7.3.2.4.

7.3.2.1 Identifying Sample Site Locations

In 2004, the CH2M Hill project team developed two methodologies for identifying suitable locations for sampling: one for soil, lake/pond sediments, and vegetation sampling sites; and a second for stream sediment and fish tissue sample sites. The two methodologies are discussed separately in the following two sections.

Locations for Surface Soil, Tundra Lake and Pond Sediments, and Vegetation Sampling.

The approach to identifying suitable sampling locations for adequately characterizing surface soil, sediment, and vegetation media is based on first identifying landforms in the mine study area, identifying sample types from each environmental medium common to these landforms, and then ensuring that sufficient samples from each of the media are collected to be statistically valid. A valid sampling strategy must include a sufficient distribution of data points (sample locations) to create a statistically representative and technically valid data set. Therefore, the CH2M Hill researchers developed a systematic random sampling program in 2004 to establish sampling locations that ensure an accurate representation of study area conditions.

This systematic random sampling program was based on the BLM's cadastral survey system. A grid using the existing 160 cadastral survey sections encompassing the study area was laid out over the study area, resulting in 160 grid cells. Starting in the southwest corner, each section/cell was assigned a temporary sequential number. A random number generator was used to select 50 of the 160 cells for sampling. Cadastral features in each selected cell were then inspected to identify landform types, and their associated soil, vegetation, and sediment-source (i.e., those from lakes, streams, or ponds) conditions. Representative locations for soil, vegetation, and sediment sampling were identified within the cadastral grid system, allowing for sampling locations to be re-established in the field via global position system (GPS).

It was planned to sample up to three locations in each cell to ensure sufficient representative sample types were collected for each landform and media. Ideally, to be spatially representative and statistically equivalent to a 99 percentile confidence level, 21 samples should be collected for each of the 10 sample types. The sampling strategy described here meets, and in one instance, exceeds the required sample numbers.

Grid cell locations by United States Geological Survey section number and an example of a landform inspection are shown on Figure 7.1-2. The landforms, their estimated physiographic distribution, and their co-related sample types by media are presented in Table 7.1-1. The data in Table 7.1-1 also indicate the number of samples targeted for collection in 2004, as well as the actual number of samples that were collected in 2004.

Locations for Stream Sediments and Fish Sampling

Identifying sampling locations for stream sediments and fish tissues followed a slightly different format. These sample matrices are closely linked to surface water hydrology and water quality monitoring. Therefore, stream sediment and fish tissue sampling is conducted at a subset of the hydrology and water quality monitoring stations that have been established within and adjacent to the deposit area. The locations of surface water monitoring stations that are also used for stream sediment sampling are presented in Figure 4.1-3 of CSP4, Surface Water Hydrology. Sampling for sediments occurs once annually, normally in the fall.

7.3.2.2 Sampling Methods

The sampling method for each matrix is presented below. Sampling of discrete samples is accompanied by the collection of appropriate field quality assurance (QA)/quality control (QC) samples, as described in the field sampling plans (FSPs) for each year (provided in Appendix F of the *Pebble Project Environmental Baseline Document, 2004 through 2008* [EBD]) and the quality assurance project plan (QAPP; Appendix G of the EBD).

Soils

Soil samples are collected using methods following requirements set forth in the QAPP (Appendix G of the EBD). About 90 percent of soil samples are collected to a depth of 0.5 feet below ground surface (bgs [i.e., surface soils]). Samples are collected from the full depth interval, using hand tools such as stainless steel or disposable polyethylene shovels and trowels. Disposable polyethylene equipment is preferentially used to reduce the potential for cross-contamination between samples. If an organic mat occurs at the surface, the mat is removed before the soil sample is collected. The field sampling team removes rocks and twigs and other large particles from the soil samples during collection.

The remaining 10 percent of soil samples are collected from the 0.5- to 1.5-foot depth interval (i.e., subsurface soils). The number of deeper samples to be collected is based on the number and aerial extent of habitats identified in the study area.

Wherever possible, surface soil and vegetation samples are collected from the same location.

Sampling is conducted in accordance with United States Environmental Protection Agency and Alaska Department of Environmental Conservation guidelines for QA/QC. The QA/QC procedures are described in the 2007 QAPP (Appendix G of the EBD). In all cases, sample collection procedures are followed to minimize contamination of samples, prevent cross-contamination of samples, and ensure sample validity by following proper preservation and storage procedures in the field. All soil samples are delivered to Shaw Environmental, Inc. (Shaw), for packaging and shipping to the contract analytical laboratories for analysis. Upon receipt, laboratory technicians sieve soil samples through a 2-millimeter- (mm-) mesh (No. 10) stainless-steel screen; analysis is conducted on the less than 2-mm fraction.

Lake, Pond, and Stream Sediments

Lake and tundra pond sediment samples are collected from a boat. Because wind-induced sediment re-suspension and focusing are common in exposed lakes and ponds, and had been observed in the area,

samples are collected on the leeward side of shallow ponds or the deepest area of deeper ponds (greater than 4 to 15 feet, depending on fetch). Sediment samples are collected from the top 0.5 foot of sediment by using a Lexan tube, Ponar dredge, or Eckman dredge (depending on field conditions). The tundra pond and lake-sediment sampling is coordinated with the sampling conducted for the fish and aquatic habitats study.

Stream-sediment samples are composited from grab samples taken at three locations across the channel at each sample site. For a subset of streams, discrete samples also may be collected from each of the three locations used for compositing. The discrete samples are analyzed in parallel with the composites to evaluate cross-channel variations in metal concentrations in sediment. This is done to determine if significant or consistent variation in discrete samples occurs; if so, the sampling protocol is re-evaluated.

Stream-sediment sampling focus on those sediments that are exposed to the water column and are expected to be moved on an annual basis, as well as sediments that are not available for re-suspension and therefore represent long-term stable sediments. Specific sampling locations at the subset of streams where discrete samples are collected also focused on these different types of sediments. Stream sediment sampling is carried out in close coordination with the surface water hydrology and water quality studies (CSPs 4 and 6).

The sediments from most lakes and ponds have been sampled only once during the 4 years of study. The frequency of stream sediment sampling is different than that for lake/pond sediment sampling because of the dynamic changes to stream sediments expected from variation in stream flow. Stream-sediment sampling occurred up to four times annually to encompass the greatest variation in hydrologic conditions (e.g., flows vary because of breakup and storm events). Stream-sediment samples are collected concurrent with and at the same locations as surface-water-quality samples (CSP 6). Sediment sampling occurs less frequently than does surface water quality sampling, because the concentration of trace elements in stream sediments are expected to be less dynamic than in stream water.

Terrestrial Vegetation

The settling of dust on above-ground vegetation and subsequent plant uptake is a pathway of interest for characterizing trace elements in vegetation. Sampling that considers dust on vegetation occurs a minimum of four days after rain. Both vegetative tissue and fruit tissue (berry) samples are taken, where appropriate, to ensure edible portions of the plant species are collected for analysis. Vegetative tissue (non-woody material consisting of aggregated samples of leaves and browse-able shoots and twigs) is kept separate from fruit tissue. Samples are collected using clippers and sealed into plastic bags. The vegetation samples are collected from the same areas as the surface soil samples.

Each sample is a composite from at least three plants within a taxonomic group (genus or species). The taxonomic groups were initially identified in the mine study area during surveys conducted in 2004, and listed in Table 7.1-2. Species selection is based on overall dominance, bio-uptake potential, use as wildlife forage, or use for subsistence or medicinal purposes.

Aquatic Vegetation

Aquatic vegetation associated with lakes and ponds in the mine site area is first sampled in 2005. Aquatic vegetation is of interest because it is browsed by moose and used for human subsistence purposes.

Collection methods are similar to those outlined above for terrestrial vegetation, with one major difference. Human subsistence use and moose browse include the roots and tubers of aquatic plants (e.g., *Calthra palustra*); therefore, entire aquatic plants will be collected, including the vegetative portions above the water line and roots and tubers (where feasible) below the water line. Above-water vegetative portions are kept separate from roots and tubers. Different tools than those used for terrestrial plant collection may be necessary to clip and collect aquatic vegetation, depending on location (e.g., edge of lake versus deeper areas) and type of plant (e.g., grasses need to be clipped at the sediment surface, while flowering plants can be clipped above the water surface, if sufficient mass is available).

Fish Tissues

One or more key fish species are selected for each drainage and/or monitoring site and sampled for tissue trace element analysis. Juvenile salmonids (primarily Coho salmon and/or rainbow trout), when present, are selected as key species. For juvenile fish collected from streams, 15 fish from each key species were collected for individual, whole-body analysis to provide an adequate measure of variability. Individual-sample fish are placed directly into acid washed jars with minimal handling by gloved personnel and are frozen at the earliest opportunity for transport to an analytical laboratory.

In addition to juvenile salmonids, adult fish are also sampled. These include northern pike, because of its position as an apex predator, as well as Arctic grayling and/or whitefish because of their use in subsistence and sport fisheries. Collecting whole body samples of adult fish (i.e., northern pike, grayling, or whitefish that might be consumed by people) is not practical because of the size of the fish and the potential for false signals from tissues not normally consumed. Therefore, specific tissues, such as liver and skeletal muscle tissue, are removed for analysis. Northern pike are typically captured either by angling or gill nets. Grayling and whitefish are captured using gill nets. For sampling resident fish in lakes, 10 fish of each species are collected from each lake.

During the first 2 years of the study (2004 and 2005), yearling and older juvenile salmonids were collected from stream sampling stations in the mine study area and analyzed for whole-body burdens of trace elements. In 2006 and 2007, the sampling program was changed to collecting adult fish from lakes for assessing human consumption risk. In 2006, both livers and fillets of adult fish were sampled to establish the tissue-burden relationship between these two tissue types. This relationship was established; therefore, only fillets (the tissue most commonly ingested by humans) are now analyzed. Liver samples are collected, freeze-dried, and archived for possible future analysis.

Prior to 2007, fish were dissected in the field, and dissected tissues (liver and muscle) were shipped to Columbia Analytical Services for analysis. In 2007, the process changed: the whole fish is now frozen, placed on ice, and shipped to Columbia Analytical Services for laboratory dissection and analysis.

7.3.2.3 Sample Handling and Chemical Analysis

Sampling-handling procedures—including packing, chain-of-custody, and shipping—follow the guidelines described in the FSPs for NOC, sediment, and fish and aquatic resources (provided in Appendix F of the EBD), as well as those in the 2005 QAPP (Appendix G of the EBD).

Chemical analyses for the matrices sampled at the mine site include the parameters identified in Table 7.1-3. Appropriate field and laboratory QA/QC samples are tested and the data are validated by the

Pebble Partnership Analytical QA/QC Manager (see Section 6.1.2.2, CSP 6, Water Quality). Method reporting limits (MRLs) are sufficiently low to detect risk-based concentrations of these constituents in the media of concern.

Upon receipt of the samples, analytical laboratory personnel sieve all surface-soil samples through a No. 10 (2-mm mesh) stainless steel sieve. Analysis is done on the less-than-2-mm fraction. All soil samples were analyzed for trace metals, anions, ammonia, and total cyanide as outlined in the FSP (Appendix F of the EBD) and the QAPP (Appendix G of the EBD). At about 5 percent of the soil sampling locations, surface soil is additionally analyzed for total organic carbon (TOC, also referred to as fraction organic carbon or FOC) and total petroleum hydrocarbons (TPH) as diesel-range organics (DRO) and residual-range organics (RRO) according to Method AK102/103 (ADEC, 2004). This analysis provides a biogenic "fingerprint" from which site-specific alternative cleanup levels can be calculated (18 AAC 75.341) for realistic application during cleanup in the event of petroleum spills caused by mining operations.

Analytical laboratory personnel sieve all sediment samples through a No. 10 stainless steel sieve. Analysis is done on the less-than-2-mm fraction. All sediment samples are analyzed for trace metals, anions, ammonia, and total cyanide as outlined in the FSP for surface water/sediment (Appendix F of the EBD) and in the QAPP (Appendix G of the EBD).

Laboratory personnel dry and grind all terrestrial and aquatic vegetation samples prior to analysis. All samples are analyzed for trace metals, ammonia, and total cyanide as outlined in the FSPs (Appendix F of the EBD).

Fish tissues are analyzed for a subset of trace metals, as outlined in the QAPP (Appendix G of the EBD). Based on a comparison of total mercury and methyl-mercury in fish muscle and liver tissues collected in 2004, it was established that approximately 90 percent of the mercury in both types of fish tissue is in the form of methyl-mercury. Therefore, since 2005, mercury analyses have been limited to total mercury in muscle tissue, only.

Details on analytical methods are discussed in the applicable FSPs and in the QAPP (Appendix F and Appendix G of the EBD, respectively).

7.3.2.4 Data Evaluation

At the end of each field season, field notes and the analyses results for each sample medium are compiled for review. The data for each analyte are compiled into summary tables by sample medium and linked to the sampling location on the BLM cadastral map of the study area. Summary statistics are prepared for each landform, habitat type, and sample medium by year and by sample type (i.e., by depth for soils, by tissue type for vegetation and fish tissue). Statistical comparisons are made for each medium between landform and habitat type. The data are presented for use by members of other study teams (e.g., water quality, fish and aquatic habitats, or geochemistry). The results of the data evaluation also are used to refine the location of sampling sites and procedures for subsequent field seasons, as necessary.

7.3.3 Major Tasks and Activities

The tasks and activities for 2004 through 2008 for trace elements in the mine study area are summarized in Table 7.1-4. The sampling locations for the mine study area are presented on Figure 7.1-1. A record of soil, vegetation and pond sediment sampling, organized according to sample location in the mine study area from 2004 through 2008 is presented in Tables 7.1-5a and 7.1-5b. The record of stream sediment and fish tissue sampling for the same period in the mine study area is provided in Table 6.1-4 (CSP 6, Surface Water Quality).

7.3.3.1 Tasks and Activities for 2004

The 2004 research and field work were conducted by CH2M Hill.

Pre-field Planning: Prepare Work Plan and Oversight

To ensure clear direction for field sampling and adequate QA, a work plan was prepared consisting of an FSP and a QAPP (Appendix F and Appendix G of the EBD, respectively) to be followed in the field. In addition, CH2M Hill researchers reviewed the parallel trace element work plan developed by others for the transportation corridor/Cook Inlet study areas, to ensure consistency across the sampling programs.

Conduct Field Sampling Studies

Soil and Vegetation. Before soil and vegetation sampling began, general sample locations in sections/cells selected from the random grid system, described above, were translated into longitude/latitude coordinates and transferred to an on-board, helicopter navigational GPS. These GPS data were recorded in a format compatible with the geographic information system (GIS) mapping tool used for the trace element study, so that field locations could be linked to subsequent maps.

The field team used the helicopter to locate each section/cell where it was planned to mark and stake up to three locations for sampling soil and vegetation. As a general rule, field teams begin on-the-ground work after approximately 20 sample locations have been laid out, while surveying of new locates continues.

Sample locations for stream and lake sediment and for fish tissue were also recorded by GPS.

Surface soil and vegetation samples were collected once, in August 2004. For soils, 82 primary soil samples from the upper 0.5 foot of soil profile, and nine primary soil samples from a depth to 1.5 feet bgs were collected. For vegetation, six major taxa were sampled: forbs, grasses/sedges, lichens, mosses, shrubs, and trees. Primary species sampled included fireweed (representing forbs), various species of sedges, caribou moss (representing lichens), green terrestrial moss (representing mosses), and bog blueberry (representing shrubs). Few trees are present in the mine study area; therefore, willows were sampled where possible as representative of tree species.

Sediments. Stream sediment sampling was carried out in close coordination with surface water hydrology and water quality sampling (CSPs 4 and 6). Specifically, it was planned to collect stream sediment samples concurrent with surface water samples at 19 surface water monitoring stations, as summarized in Table 7.1-6 and shown in Figure 4.1-3 (CSP 4, Surface Water Hydrology). It was planned to conduct two

stream sediment sampling events from June to September in 2004 to encompass the greatest variation in hydrologic conditions represented by summer and autumn flows.

Fish Tissue. In 2004, CH2M Hill researchers selected for fish tissue sampling two lakes and 16 of the water-quality and hydrology monitoring stations established on streams within and adjacent to the mine study area. Juvenile salmonids (primarily Coho salmon, Chinook salmon, Dolly Varden, and/or rainbow trout) were selected as key species in streams when present. In addition to juvenile salmonids, fish tissue sampling in lakes included samples of northern pike, Arctic grayling, and/or whitefish. For juvenile fish collected from streams, whole body samples were taken and 15 fish from each key species were collected for individual analysis. This resulted in 255 whole body fish samples of each species for analysis. For sampling resident fish in lakes, 10 fish of each species were collected from each of two lakes and two organs (liver and muscle tissue) were analyzed. This resulted in 120 separate samples for trace element analysis.

Data Evaluation and Reporting

Upon receipt of the validated analytical laboratory results, the data were evaluated and summarized in a summary report. The report included the following:

- Figures showing the study area and sampling locations.
- Field photographs of sample locations.
- Vegetation descriptions, maps, and representative photographs.
- Basic soil descriptions.
- Data summary tables.
- Summary statistics for each landform and medium.
- Statistical comparison of the differences between landforms.

7.3.3.2 Tasks and Activities for 2005

The trace element study in 2005 continued with field procedures established in 2004, updating those procedures as appropriate based on knowledge gained during previous sampling events.

Major tasks and activities in 2005 included the following:

- FSPs to be followed in the mine study area by SLR and HDR field personnel were prepared to ensure clear direction for field sampling and adequate QA. (See Appendix F of the EBD.)
- A data review was conducted to research, compile, document, and review existing data, including past soil and vegetation studies, aerial photography, topographic maps, and other documents to determine target sites for sampling. Conditions at selected sites were visually verified in the field prior to establishing the sample points.
- Samples for each media were collected from the mine study area.
- Field and laboratory data were analyzed and the results reported.

Details are described below.

Sample Site Selection for Soil and Vegetation

To adequately characterize soil and vegetation, a sufficient number of samples from each medium must be collected to be statistically valid. The sampling strategy for 2005 was designed to collect sufficient samples to be statistically meaningful and to identify differences between baseline conditions and future conditions.

In 2004, the types and relative abundance of the different habitats was unknown; therefore, sample sites were located based on landform (e.g., geology, topography, amount of vegetative coverage). As can be seen from Table 7.1-7, insufficient numbers of samples were collected in some cases, both on the basis of landform and sample type. At several locations, plant numbers were insufficient or only one or two species were sufficiently abundant for collection. For example, only 13 samples were collected from talus slopes instead of the 48 planned for this terrain type. Therefore, a different sampling approach was implemented in 2005 to ensure representative coverage of the plant species of interest. The approach was to base the number of samples on habitat type rather than on landform.

By 2005, ABR field personnel had compiled habitat information, identifying and mapping seven terrestrial habitat types and applying a unique "ecosystem" symbol to each type. The types are listed below (along with the ecosystem symbol and the number of plant sampling locations from 2004 in parentheses):

- Alpine rock and dwarf scrub (AS; 0).
- Lowland low and tall alder/willow scrub (LS; 0).
- Lowland wet graminoid, moss meadow (LM; 0).
- Riverine willow scrub (RS; 1).
- Subalpine dwarf, low and tall scrub (SS; 8).
- Upland dwarf scrub, lichen flats (UF; 5).
- Upland dwarf, low and tall scrub (US; 4).

The ABR habitat maps were overlain onto the study area map to estimate the relative distribution of each habitat type and to correlate habitat to the landforms identified by CH2M Hill researchers in 2004. The mapping exercise also allowed SLR researchers to correlate habitat to the total number of soil and plant samples that CH2M Hill field personnel had collected. In 2004, 18 locations for plant sampling were distributed across four habitat types, and no plant samples were collected in three habitat types (i.e., AS, LM, and LS, Table 7.1-8). Up to seven species of plants were sampled at any given location. Based on this record, the sections/cells identified for sampling in 2005 are modified appropriately.

The numbers of soil and vegetation samples are presented by habitat type in Table 7.1-8. Locations of the soil and vegetation sampling sites are shown on Figure 7.1-3. The values in parentheses in the table represent the targeted number of samples for each sampling event in 2005. SLR researchers expected that approximately the same number of total soil samples would be collected in 2005 as in 2004, but at least some of the sample locations would differ. Where possible, the locations sampled for vegetation in 2004

were re-sampled in 2005 to provide an indication of annual variability in trace-element concentrations in vegetation. For some habitats (e.g., UF), fewer plant samples were collected than in 2004. For habitats where additional sampling locations were needed (e.g., AS), section/cell locations were randomly selected until an appropriate number containing the target habitat types were identified.

Soil was also collected from the locations where plants were sampled (Table 7.1-8). For habitats where fewer soil samples than in 2004 were planned for collection (e.g., SS and US), locations where no plants would be sampled were preferentially removed from the sampling program using a randomized approach. It was expected that a single section/cell would be identified within the grid for soil and plant sampling in each of the LS and RS habitat types, and two sections/cells would be identified for sampling in each of the AS and LM habitats.

Conduct Field Sampling Studies

Soil and Terrestrial Vegetation. It was planned to sample for soil and vegetation during two events in July and late August 2005.

Surface and subsurface soils were sampled according to the same methods used in 2004. Samples were collected from two depths, using hand tools such as stainless steel, aluminum, or disposable polyethylene shovels or trowels. If present, organic mats, rocks, twigs, and other large particles were removed from the soil samples during collection. Consistent with the approach used in 2004, the deeper, subsurface soils were only collected at about 10 percent of locations. The number of deeper samples to be collected within a given habitat was based on the aerial extent of each habitat type, as shown in Table 7.1-8.

Vegetation samples were always collected from the same locations as soil samples. Each sample was a composite from at least three plants within a taxonomic group (genus or species) previously identified in the mine study area in the 2004 surveys. The particular species sampled was based on overall dominance, bio-uptake potential, and use as wildlife forage, or as human subsistence or medicinal use. Where possible, the same species collected in 2004 were collected in 2005 to enable an evaluation of annual elemental variability within a species. It was expected that the field team would sample the same primary species representing six taxa that were sampled in 2004: fireweed (representing forbs), various species of sedges, caribou moss (representing lichens), green terrestrial moss (representing mosses), and bog blueberry (representing shrubs). In the absence of trees, willows were sampled where possible.

Aquatic Vegetation. Aquatic vegetation associated with lakes and ponds in the mine study area was sampled in 2005 for the first time. Aquatic vegetation is used as browse by moose and as dietary consumption for human subsistence. Aquatic vegetation sampling was planned for late August or early September 2005, concurrent with soil and terrestrial vegetation sampling, and as close as possible to HDR's late-season sediment and surface water sampling to maximize the value of the resulting data. Aquatic vegetation samples were collected at the same water bodies as sampled for sediment and surface-water samples, whenever practical. Collection methods are described in Section 7.3.2.2.

Sediments. HDR sampled sediment from seeps, lakes/ponds, and rivers/streams. Stream-sediment sampling occurred three times in June, July, and September 2005 to encompass the greatest variation in hydrologic conditions (i.e., varying flows due to spring breakup, summer baseflow, and autumn baseflow conditions). Stream-sediment samples were collected at the same times and locations as surface water quality samples (CSP 6). The same 16 stream sampling locations sampled for sediments in 2004 were

planned for sediment sampling in 2005. The locations are identified in Table 7.1-9 and presented in CSP 4, Figure 4.1-3.

Sediment samples also were collected from 12 seep locations in July and October 2005. Sediment samples were collected at a subset of the seeps where water-quality samples were collected (CSP 6).

It was planned to collect sediment from six lakes in the summer of 2005:

- Frying Pan Lake and Big Wiggly Lake.
- Two new lake sites, one south of the mine study area (Lake No. 2) and one to the north (Black Lake), co-located with proposed fish-tissue monitoring sites. Final locations are to be determined as described in CSP 11, Fish and Aquatic Resources.
- Two lake sites considered prime moose pond habitat and co-located with aquatic vegetation sampling sites. Final locations were determined in the field as Mud Lake (near Lily Lake to the north) and Chiquita Lake to the south.

The sample collection methodology for sediments is described in Section 7.3.2.2.

Fish Tissue. In 2004, fish-tissue samples were collected from 16 streams and from two lakes in the mine study area. During the 2005 field season, each stream-sampling station was sampled again for the same species and by the same methods and for the same analyses as in 2004 (see CSP 11). In response to agency comment, two lakes in addition to the two (Big Wiggly and Frying Pan Lake) sampled in 2004 were sampled in 2005: one additional lake south of the South Fork Koktuli River drainage (determined to be Lake No. 2 during field work) and one additional lake (Black Lake) northwest of the Pebble Deposit within the dominant southeasterly wind direction. The sampling locations are shown on Figure 11.1-1 (CSP 11).

Additional fish sampling in lakes was suggested to provide sufficient baseline data. Black Lake is known to contain robust populations of both grayling and humpback whitefish and may contain northern pike, all target species for trace-element sampling. Candidate lakes south of the South Fork Koktuli River were not sampled for fish presence.

It was planned to make final selection of additional lakes for fish-tissue sampling pending determination of the presence of target species, especially northern pike. It was planned to select one lake to the north and one lake to the south of the Pebble Deposit for sampling, if target species were present. If no northern pike were found in candidate lakes, sampling of grayling or whitefish or another species would be conducted, pending discussions with the Pebble Partnership and agency representatives.

Details of the fish-tissue sampling program are discussed in CSP 11, Fish and Aquatic Resources.

Data Evaluation and Reporting

The data collected during 2005 were compiled and reported in accordance with the methods and format used in 2004.

7.3.3.3 Tasks and Activities for 2006

The tasks and activities for the 2006 trace element study built on the work completed during 2004 and 2005. The field work component consisted of collecting samples of the following:

- Surface soil.
- Terrestrial vegetation that is used as forage by wildlife or as food or medicine by humans.
- Aquatic vegetation associated with lakes and ponds.
- Sediment found in streams and in tundra lakes and ponds.

The rationale for sampling different media in 2006 was twofold:

- A short-term goal of the trace element study was to collect soil and vegetation data from 2 years at each location. Because some locations were only added in 2005, an additional round of sampling was needed at these new locations. Sampling was not conducted at those 2005 locations that had been sampled in 2004.
- Characterization of baseline conditions in the watershed in the vicinity of the eastern ore deposit (Pebble East) identified in 2005. This meant collecting soil, terrestrial and aquatic vegetation, and pond and lake sediment samples from selected sites in the Pebble East area. Stream sediment and fish tissue samples to characterize the Pebble East area were adequately represented by existing sampling locations.

The number and kinds of samples planned for collecting in 2006 are summarized by area and study in Table 7.1-10 (stream sediment sampling is summarized in Table 6.1-5, CSP 6, Water Quality). The record of sampling at each sample location, organized according to Pebble West and Pebble East, are summarized in Tables 7.1-5a and 7.1-5b. The locations of existing and proposed sampling sites for soil, vegetation and sediment are shown on Figure 7.1-4.

Sampling events for soil and terrestrial vegetation in both Pebble East and Pebble West occurred in July and August. Subsurface soil samples were not collected in 2006 because review of data from the 2004 and 2005 sampling programs indicated that the results from samples collected at depth were equal to or less than the concentrations from surface samples. A subset of surface-soil samples collected in 2006 was analyzed for TOC (or FOC) and TPH (as DRO and RRO). All other soil and vegetation sampling and analytical methods were consistent with methods used in 2005.

Three sampling events were planned in June, July, and September for stream and lake sediments in the Pebble West area (Table 7.1-5a). Two tundra ponds were sampled for sediments. No other pond sediments were sampled in this area in 2006.

Seventeen ponds in Pebble East were sampled for water quality, sediments, and aquatic vegetation in July and August 2006 (Table 7.1-5b).

Methods for stream and lake sampling and analysis were followed as outlined in 2005, with the addition of chemical analysis of sediments for total sulfur and acid volatile sulfide-simultaneously extracted metals

(AVS-SEM). The additional analysis was included to evaluate the bioavailability of trace elements in sediments.

7.3.3.4 Tasks and Activities for 2007

The 2007 trace element study characterized NOC in the following media:

- Terrestrial vegetation (including lichens and mosses).
- Aquatic vegetation associated with lakes and ponds.
- Freshwater sediments associated with lakes and ponds.
- Surface soil (including soil bacteria).

It was planned in 2007 to collect samples from the same locations that were sampled in 2006 (Tables 7.1-5a and 7.1-5b and Figure 7.1-5). The number and locations of samples collected in 2007 are summarized by area and sample media in the 2007 FSP for NOC in surface soil, sediment, and vegetation (Appendix F of the EBD), and briefly described in the following paragraphs.

Because a short-term goal of the sampling program is to collect data over 2 years at each location, soil and terrestrial plant sampling in the area near the western ore deposit (Pebble West) was not repeated except at sites where 2 years of data had not yet been collected. Sampling at Pebble West occurred in July and August and targeted soil and terrestrial vegetation at the three sites (335011, 335081, and 335101) where only 1 year of sampling had been done as well as sediment and aquatic vegetation from several tundra ponds and lakes (Table 7.1-5a).

In addition, a new soil study was conducted in Pebble West in 2007 to test the hypotheses of cyanogenic bacteria as a cyanide source in soil. It was planned to collect soil samples at 11 locations for a soil bacteriological study. Bacteriological analysis focused on the presence or absence of cyanide producing bacteria in native soils. In addition to vascular plants, mosses and lichens were collected concurrently with and at the same location as each bacteriological soil sample. The 11 planned sample locations were selected based on previous analytical data that showed high levels of cyanide in soil and plants. Their locations are identified in Table 7.1-5a and on Figure 7.1-5.

Sampling for the eastern ore deposit (Pebble East) is summarized in Table 7.1-5b. Sampling locations are shown on Figure 7.1-5. It was planned in 2007 to collect surface soil, terrestrial and aquatic vegetation, and pond and lake sediments from the same locations that were sampled in 2006.

It was also planned in 2007 to collect aquatic vegetation samples in 12 small ponds to complete 2 years of data collection which started in 2006. These samples would be collected from the same locations as in 2006. All aquatic vegetation sampling from these ponds was coordinated with the water quality study team, which is collecting surface water and sediment samples, so that water, sediment, and aquatic vegetation samples are temporally and spatially co-located. The surface water and stream sediment sampling is described in CSP 6 and in the 2007 FSP for surface water quality, hydrology, and sediment (Appendix F of the EBD).

Terrestrial vegetation sampling included specific mosses and lichens that are relevant to other mine projects in Alaska. These vegetative types were first collected for the Pebble Partnership baseline studies

in 2006. Additional moss and lichen samples were collected in 2007 in both the Pebble East and Pebble West deposit areas.

7.3.3.5 Tasks and Activities for 2008

No field studies or sampling were conducted in 2008 for trace elements study program in the mine study area. The 2008 program efforts were focused on interpreting and reporting the data collected from 2004 through 2007.

7.4 Transportation Corridor/Cook Inlet Study Areas

7.4.1 Study Area/Scope

The Cook Inlet drainages study area encompasses the area between the western Cook Inlet drainages boundary and Iniskin Bay and includes both coastal and upland sampling locations (Figure 7.2-1). Sampling is intended to adequately characterize trace element concentrations in the different soil, vegetation, sediment and fish types present along the transportation corridor/Cook Inlet study areas for current baseline conditions.

7.4.2 Methods and Approach

The methods and approach for the trace element study in the transportation corridor/Cook Inlet study areas are similar to those in the mine study area. The approach includes identifying sample site locations; conducting field events to sample soils, vegetation, sediments and fish tissues; analyzing samples for a range of NOC; and data evaluation. The methods for site identification, sampling, analysis and data evaluation are discussed in Section 7.3.2, above. Variations to these methods and approaches, including changes, deletions and additions, are discussed separately according to the year in which they were implemented, under the major tasks and activities described in Section 7.4.3, below.

7.4.3 Major Tasks and Activities

The tasks and activities for 2004 through 2008 for the trace elements study in the transportation corridor/Cook Inlet study areas are summarized in Tables 7.2-1a and 7.2-1b. Table 7.2-2 presents a summary of sampling at each sample location throughout the duration of the study.

7.4.3.1 Tasks and Activities for 2004

The main tasks and activities for 2004 were as follows:

- Research, compile, document, and review existing data for the study area, including past soil and vegetation studies, aerial photography, topographic maps, and other documents to determine target sample areas.
- Collect samples from the transportation corridor/Cook Inlet study areas as described for each medium above.
- Analyze field and laboratory data.

- Report results.

Sampling activities are intended to adequately characterize the entire length of the transportation corridor/Cook Inlet study areas. At each target sample collection area identified during the initial data review, conditions are visually verified in the field prior to establishing a sampling point. For soil and vegetation sampling locations, the sample location is selected to represent the most common soil and vegetation in the area. The geographic coordinates of each sample location are determined using GPS, consistent with the study coordinate system. Details for each sample type collected in 2004 are provided below.

Soil Samples

Two predominant soil types have been identified in the literature for the study area. From the deposit area to the east side of Pile Bay, unconsolidated materials consist of outwash plains, terraces, and moraines. The soil is reported to predominantly comprise well-drained gravelly material with interbedded coarse volcanic ash. Poorly drained, fibrous peat caps the sequence in specific locations. From Pile Bay to Iniskin Bay, exposed bedrock predominates. The unconsolidated material is talus and locally derived glacial till expressed on mountain-foot slopes and as moraine hills. Soils consist of shallow silt loam over gravelly loam or sandy loam with locations of poorly drained, fibrous peat cover (Selkregg, 1976). The soil sampling effort collects samples that are both representative of the predominant soil types encountered and to establish spatial distribution of trace elements along the transportation corridor and at Cook Inlet.

Soil samples were collected during a single sampling event, planned for August 2004. Soil samples were collected at regular intervals along the transportation corridor; one sample for every 4 miles, for a total of 19 sample locations (Figure 7.2-1, Table 7.2-2).

At each sample location, the soil type and approximate amount of organic materials were documented. Samples were collected to characterize predominant soil types. Soil samples were collected to 0.5 foot bgs following the same procedures used for the sample collection in the mine study area. Organic mats, twigs, and stones, if present, were removed before the soil was sampled. Soil samples were submitted to Shaw for packing and shipping to the project laboratory. The analytical parameters are listed in Table 7.2-3.

Vegetation Samples

Two predominant vegetation types have been identified from a literature search for the study area: high brush and upland spruce – hardwood forest. The west side of the study area, west of the Chekok River is reported to be a caribou winter range, and the area east of the Chekok River is reported to be year-round moose range. Grizzly and brown bear are reported to be present along the streams where fish are present (Selkregg, 1976). Vegetation sampling is intended to define the types present and to characterize baseline trace element concentrations, particularly in and on vegetation that may be a food source for upland mammals or birds, or humans. In addition, vegetation traditionally used for medicinal purposes is sampled.

Vegetation sampling occurred during a single sampling event in autumn 2004, concurrent with and at the same approximate locations as for soil sampling. Vegetation samples were collected at regular intervals

along the transportation corridor; one sample for every 4 miles, for a total of 19 sample locations (Figure 7.2-1, Table 7.2-2).

At each sample site, a sample area encompassing a 10-foot radius from the soil sample location was designated. Within each sample area, all vegetation species present were documented. Up to four species were sampled at each location, including moss, lichen, grass, shrub, or berry-producing plants, depending on type and density present. Vegetation samples were collected following the same procedures as used for sample collection in the mine study area.

The vegetation samples were submitted to Shaw for packing and shipping to the project laboratory. Samples were analyzed for the analytes listed in Table 7.2-3.

Sediment Samples

Stream sediment samples were collected on two occasions, concurrent with surface water sampling events. It was planned to collect stream sediments at 16 locations (Figure 7.2-1, Table 7.2-2).

As was done in the mine study area, stream sediment samples were taken from the same locations where surface water quality samples were taken, as discussed in CSP 6. Stream sediment samples are composited from three locations across the channel at each sample site. For one stream, discrete samples also are collected from each of the sample locations used for compositing. The discrete samples were analyzed in parallel with the composite to evaluate the variation in metal concentrations in cross-channel sediments. The results of these analyses were used to re-evaluate the sampling protocol, as discussed in Section 7.3.2.2 for the mine study area.

It was also planned to sample five tundra ponds along the transportation corridor to provide baseline characteristics of these sediments (Figure 7.2-1, Table 7.2-2). Sediment samples were collected following the same procedures as used in the mine study area.

7.4.3.2 Tasks and Activities for 2005

Tasks and activities planned for the transportation corridor/Cook Inlet study areas for 2005 included collecting sediments from streams and tundra ponds and fish tissue sampling. Soil and vegetation were not sampled in 2005 because data from 2004 (consisting of one soil and vegetation sample collected for every 4 miles along the corridor) provided an adequate indication of baseline conditions for these media. Sediment and fish tissue samples were also collected in 2005 along representative stream crossings.

All activities were coordinated with SLR researchers to ensure consistency between methods used in the transportation corridor/Cook Inlet study areas and those used in the mine study area. Sampling procedures as outlined in the QAPP and the FSP (Appendix G and Appendix F of the EBD, respectively) were followed to ensure continuity with sampling efforts completed in 2004 and that data for both seasons would be comparable.

Sediment Samples

In 2004, sediment samples were collected from 15 of the planned 16 streams, at the same locations as those for surface water quality samples and in five selected tundra ponds. In 2005, sediments were

collected from a subset of the streams sampled in 2004: eight streams were sampled, as identified on Figure 7.2-2. As in 2004, stream sediment samples collected in 2005 were three-part composites, sampled across the channel at each sample site. One set of three discrete samples was taken from one stream channel to compare with the parallel composite sample to evaluate cross-channel variations in sediment-metal concentrations and potential changes to the sampling protocol.

The five tundra ponds sampled in 2004 were revisited and re-sampled in 2005 (Figure 7.2-2). Predominant wind direction and resulting sediment deposition were observed at the tundra ponds sampled. Samples were collected from the leeward side of the pond in the upper 5 inches of sediment. Sediment samples were collected following the same procedures as used for sediment sampling in the mine study area.

Stream and pond sediments were collected in conjunction with the May, July, and September water quality sampling events. Sediment samples were analyzed for inorganic compounds and trace elements as shown in Table 7.2-4. Analytical methods are described in the surface water/sediment FSP for the transportation corridor/Cook Inlet study areas and in the QAPP (Appendix F and Appendix G of the EBD, respectively).

Fish Tissue Sampling

In 2005, for the first time, HDR researchers proposed collecting fish tissue samples from five streams along the transportation corridor. It was planned to collect fish tissue samples once during the month of August in coordination with tissue sampling in the mine study area. Details of the sampling methods and analyses are described in CSP 11, Fish and Aquatic Resources.

7.4.3.3 Tasks and Activities for 2006

The study program for the transportation corridor/Cook Inlet study areas in 2006 was the same as for 2005, except that additional sampling of soil and vegetation was conducted in areas east of Summit Lake (Figure 7.2-3). In addition to locations sampled in 2004 and 2005, new locations sampled in 2006 included natural drainages and habitats typical of the areas east of the lake.

The methodology for sampling was identical to that used previously and discussed above. Sampling in 2006 included soil, terrestrial vegetation (berries and vegetative portions kept separate), aquatic vegetation, pond and stream sediment, and surface water quality. Fish-tissue samples were not taken in 2006. Consistent with other trace element work done in the study areas, only a single sampling event occurred in 2006.

The number of samples of each medium proposed for 2006 is summarized in Table 7.2-5.

7.4.3.4 Tasks and Activities for 2007

The number of samples of each sample medium proposed for 2007 in the transportation corridor/Cook Inlet study areas is summarized in the 2007 FSP for naturally occurring constituents (Appendix F of the EBD). In 2007, sampling was conducted only in the Cook Inlet drainages.

The 2007 study characterized NOC in the following media:

- Surface soil.
- Terrestrial vegetation.
- Aquatic vegetation associated with lakes and ponds.
- Pond and stream sediments.
- Stream surface water.

The study program for the transportation corridor/Cook Inlet study areas was conducted according to the same approach and methods as for 2005 and 2006. The 2007 season focused on achieving a second year of sampling east of Summit Lake and included a minimum of 12 locations (Figure 7.2-4, Table 7.2-2).

7.4.3.5 Tasks and Activities for 2008

No field studies or sampling were conducted in 2008 for the trace elements transportation corridor/Cook Inlet study areas. The 2008 efforts focused on interpreting and reporting the data collected from 2004 through 2007.

7.5 References

Alaska Department of Environmental Conservation (ADEC). 2004. Method AK102 for Determination of Diesel Range Organics and Method AK103 for Determination of Residual Range Organics. Department of Environmental Health, Environmental Health Laboratory. Anchorage, Alaska.

Selkregg, L.L. 1976. Alaska Regional Profiles—Southwest Region. University of Alaska Anchorage, Arctic Environmental Information and Data Center.

TABLES

TABLE 7.1-1
Sample Numbers for Surface Soil, Vegetation, and Sediment Sample Type in 2004, Mine Study Area

Sample Types	Ground Moraines	Outwash Plains	Talus Slopes	Stream Channel & Flood Plains	Tundra Lakes & Ponds	Totals
Estimated Physiographic Distribution						
	37%	16%	24%	17%	6%	100%
Media: Surface Soil and Sample Numbers						
1. Organic-rich silts (OL)	10	5	6	0	0	21
2. Fine sands with silts and clay (ML and CL)	10	5	6	0	0	21
3. Poorly graded gravel with sands and silts (GP and GM)	10	5	6	0	0	21
4. Glacial till (GM and GC)	10	5	6	0	0	21
Media: Vegetation and Sample Numbers						
5. High brush shrubs including species such as willow, American green elder and blueberry	10	5	6	0	0	21
6. High brush sedges, grasses such as lichen, bluejoint, horsetail, fireweed	10	5	6	0	0	21
7. Alpine tundra shrubs, such as dwarf arctic birch, crowberry	10	5	6	0	0	21
8. Alpine sedges	10	5	6	0	0	21
Media: Sediments and Sample Numbers						
9. Stream[a]	0	0	0	57	0	57
10. Lake and Ponds	0	0	0	0	21	21
Total						**246**

Note:

a. Stream sediment sampling locations and frequency is based on surface water quality sampling (CSP 8) and will occur at 19 surface water stations two times during 2004 and once in 2005.

TABLE 7.1-2
Taxonomic Groups Identified in Mine Study Area

Taxonomic Group	Mapping / Ecosystem Symbol
Alpine rock and dwarf scrub	AS
Lowland low and tall alder/willow scrub	LS
Lowland wet graminoid, moss meadow	LM
Riverine willow scrub	RS
Subalpine dwarf, low and tall scrub	SS
Upland dwarf scrub, lichen flats	UF
Upland dwarf, low and tall scrub	US

TABLE 7.1-3
Analytes for Soil, Vegetation, and Sediment Samples

Analyte	Method
Surface Soil, Vegetation and Sediment	
Hg	SW7471 (CVAA)
Al, Sb, As, Ba, Be, Bi, B, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mo, Mn, Ni, K, Se, Ag, Na, Tl, Sn, V, Zn	SW 6010/6020 (ICP/ICP-MS)
Total Cyanide	E335.2
Chloride	E300.0
Fluoride	SM4500-FC
Sulfate	E300.0
Ammonia as N	E350.3
Surface Soils Only	
Total Organic Carbon	ASTM D4129-82M
Total Petroleum Hydrocarbons (biogenic “fingerprinting)	Gas Chromatography
Fish	
Sb, As, Cd, Cu, Pb, Ni, Se, Ag	SW6020 (ICPMS)
Hg	SW7471 (CVAA)

Notes:

ASTM = American Society for Testing and Materials

E = Methods for Chemical Analysis of Inorganic Substances in Environmental Samples, EPA/600/R-93-100, August 1993 and Methods for the Determination of metals in Environmental samples, EPA/600/4-91-010, June 1991.

SM = Standard Methods for the Examination of Water and Wastewater, 20th Edition.

SW = U.S. EPA Test Methods for Evaluating Solid Waste Physical/Chemical Methods, Third edition, September 1986.

Table 7.1-4
Pebble Project Environmental Baseline Studies
Study Summary for Trace Elements, Mine Study Area, 2004 - 2007
Consultant: SLR International Corp.

2004 Data Collected or Tasks (completed by CH2M Hill)	2005 Data Collected or Tasks Completed	2006 Data Collected or Tasks Completed	2007 Data Collected or Tasks Completed
Information gathering	Information gathering	Information gathering	Information gathering
Scope, schedule, field sampling plan	Scope, schedule, field sampling plan	Scope, schedule, field sampling plan	Scope, schedule, field sampling plan
2004 study plan	2005 study plan	2006 study plan	2007 study plan
Soil sampling (August and September)	Soil sampling (July and August)	Soil sampling (July)	Surface soil sampling (July)
			Bacteriological soil, lichens and moss sampling (July)
Terrestrial vegetation sampling (August and September - leaves and berries)	Terrestrial vegetation sampling (July - leaves; August - leaves and berries)	Terrestrial vegetation sampling (July - leaves; August - leaves and berries)	Terrestrial vegetation sampling (July - leaves; August - leaves and berries)
	Aquatic plant sampling (August)	Aquatic plant sampling (August)	Aquatic plant sampling (August, coordinated with HDR)
Fish tissue sampling streams amd lakes (August)	Fish tissue sampling streams and lakes (August); mercury/methylmercury fish-tissue data analysis	Fish tissue sampling lakes; data analysis	Fish tissue sampling lakes; data analysis
Sediment sampling: streams (June, July, August and September)	Sediment sampling: streams (June, July, August and September)	Sediment sampling: streams (June); lakes (July); ponds (August)	Sediment sampling; streams (June); ponds and lakes (August and September)
		Sediment and surface-water data analysis	Sediment and surface-water data analysis
Coordination with BEESC	Cooridination with HDR and BEESC	Coordination with HDR and BEESC	Coordination with HDR and BEESC
	Coordination with NDM & agencies, monthly reporting	Coordination with NDM, agency meetings, monthly reporting	Coordination with NDM, agency meetings, monthly reporting
	Communication and data management	Communication and data management	Communication and data management
	Data entry and analysis	Data entry and analysis	Data entry and analysis
QAPP review	QAPP update	QAPP update: aquatic species	
	2004 progress report		
		Draft environmental baseline document	Update draft environmental baseline document

Note: No trace elements sampling was conducted in 2008.

Table 7.1-5a
Pebble Project Environmental Baseline Studies
Sample Location, Period-of-Record Index, Trace Elements, Mine Study Area, Pebble West, 2004 - 2007
Consultant: SLR International Corp.

Monitoring Location	Year[a]	Period-of-Record by Discipline																																	Notes
		Soil												Vegetation												Sediment											
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
235271	2004																																				
	2005							X												X	X																
	2006							X												X	X																
	2007							X												X																	Bacteriological Soil Study
235281	2004																																				
	2005							X												X	X																
	2006							X												X	X																
	2007																																				
235361	2004								X												X																
	2005							X												X	X																
	2006																																				
	2007							X												X																	Bacteriological Soil Study
235281	2004																																				
	2005							X													X																
	2006							X													X																
	2007																																				
235282	2004																																				
	2005																				X																Tundra pond
	2006																				X											X					Tundra pond
	2007																				X											X					Tundra pond
236221	2004																																				
	2005																				X																Tundra pond
	2006																				X											X					Tundra pond
	2007																				X											X					Tundra pond
236271	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
236272	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
236273	2004									X																											
	2005							X																													
	2006																																				
	2007																																				

Table 7.1-5a
Pebble Project Environmental Baseline Studies
Sample Location, Period-of-Record Index, Trace Elements, Mine Study Area, Pebble West, 2004 - 2007
Consultant: SLR International Corp.

Monitoring Location	Year[a]	Period-of-Record by Discipline																																	Notes
		Soil												Vegetation												Sediment											
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
236281[b]	2004								X												X																
	2005																																				
	2006																																				
	2007																																				
236351	2004								X												X																
	2005							X																													
	2006																																				
	2007																																				
236352	2004																																				
	2005							X																													
	2006							X																													
	2007																																				
236353	2004																																				
	2005							X												X	X																
	2006							X												X	X																
	2007							X												X																	Bacteriological Soil Study
335021	2004								X												X																
	2005							X	X											X	X																
	2006																																				
	2007																																				
335031	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
335032	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
335051	2004																																				
	2005																				X																Tundra Pond
	2006																				X												X				Tundra Pond
	2007																				X												X				Tundra Pond
335091	2004									X																											
	2005							X																													
	2006																																				
	2007																																				

Table 7.1-5a
Pebble Project Environmental Baseline Studies
Sample Location, Period-of-Record Index, Trace Elements, Mine Study Area, Pebble West, 2004 - 2007
Consultant: SLR International Corp.

Monitoring Location	Year[a]	Period-of-Record by Discipline																																		Notes
		Soil												Vegetation												Sediment												
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
335092	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
335093	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
335131	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
335132	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
335161	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
335162	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
335163	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
335171	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
335172	2004									X																											
	2005							X																													
	2006																																				
	2007																																				

Table 7.1-5a
Pebble Project Environmental Baseline Studies
Sample Location, Period-of-Record Index, Trace Elements, Mine Study Area, Pebble West, 2004 - 2007
Consultant: SLR International Corp.

Monitoring Location	Year[a]	Period-of-Record by Discipline																																	Notes
		Soil												Vegetation												Sediment											
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
335173	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
335174	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
335175	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
335176[b]	2004									X																											
	2005																																				
	2006																																				
	2007																																				
335191	2004									X																											
	2005							X												X																	
	2006																																				
	2007																																				
335192	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
335193	2004									X												X															
	2005							X												X	X																
	2006																																				
	2007																																				
335201	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
335231	2004																																				
	2005							X																													
	2006							X																													
	2007																																				

Table 7.1-5a
Pebble Project Environmental Baseline Studies
Sample Location, Period-of-Record Index, Trace Elements, Mine Study Area, Pebble West, 2004 - 2007
Consultant: SLR International Corp.

Monitoring Location	Year[a]	Period-of-Record by Discipline																																		Notes
		Soil												Vegetation												Sediment												
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
335232	2004																																				
	2005							X																													
	2006							X																													
	2007																																				
335261	2004								X												X																
	2005							X												X	X																
	2006																																				
	2007																																				
335281	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
335282	2004									X																											
	2005							X	X											X	X																
	2006																																				
	2007																																				
335283	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
335284	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
335301	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
335302	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
335311	2004									X																											
	2005							X																													
	2006																																				
	2007																																				

Table 7.1-5a
Pebble Project Environmental Baseline Studies
Sample Location, Period-of-Record Index, Trace Elements, Mine Study Area, Pebble West, 2004 - 2007
Consultant: SLR International Corp.

Monitoring Location	Year[a]	Period-of-Record by Discipline																																	Notes
		Soil												Vegetation												Sediment											
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
335321	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
335322	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
336011	2004								X												X																
	2005							X												X	X																
	2006																																				
	2007							X												X																	Bacteriological Soil Study
336012	2004																																				
	2005							X																													
	2006							X																													
	2007																																				
336013	2004																																				
	2005							X																													
	2006							X																													
	2007																																				
336041	2004									X												X															
	2005							X																													
	2006																																				
	2007																																				
336042	2004									X																											
	2005							X												X	X																
	2006																																				
	2007																																				
336043	2004																																				
	2005							X																													
	2006								X																													
	2007																																				
336131	2004								X												X																
	2005							X												X	X																
	2006																																				
	2007							X												X																	Bacteriological Soil Study

Table 7.1-5a
Pebble Project Environmental Baseline Studies
Sample Location, Period-of-Record Index, Trace Elements, Mine Study Area, Pebble West, 2004 - 2007
Consultant: SLR International Corp.

Monitoring Location	Year[a]	Period-of-Record by Discipline																																	Notes
		Soil												Vegetation												Sediment											
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
336132	2004																																				
	2005							X												X	X																
	2006							X												X	X																
	2007																																				
336133	2004																																				
	2005							X																													
	2006							X																													
	2007																																				
336211	2004																																				
	2005							X																													
	2006							X																													
	2007																																				
336212	2004																																				
	2005							X												X	X																
	2006							X												X	X																
	2007																																				
336231	2004									X												X															
	2005							X												X	X																
	2006																																				
	2007							X												X																	
336241	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
336242	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
336261	2004								X												X	X															
	2005							X	X											X	X																
	2006																																				
	2007							X												X																	
336281	2004									X																											
	2005							X																													
	2006																																				
	2007																																				

Table 7.1-5a
Pebble Project Environmental Baseline Studies
Sample Location, Period-of-Record Index, Trace Elements, Mine Study Area, Pebble West, 2004 - 2007
Consultant: SLR International Corp.

Monitoring Location	Year[a]	Period-of-Record by Discipline																																		Notes
		Soil												Vegetation												Sediment												
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
336282	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
336341	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
336342	2004									X																											
	2005							X												X	X																
	2006																																				
	2007																																				
336361	2004																																				
	2005							X																													
	2006							X																													
	2007																																				
336362	2004																																				
	2005							X												X	X																
	2006							X												X	X																
	2007							X												X																	Bacteriological Soil Study
435061	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
435062	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
435161	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
435162	2004									X																											
	2005							X																													
	2006																																				
	2007																																				

Table 7.1-5a
Pebble Project Environmental Baseline Studies
Sample Location, Period-of-Record Index, Trace Elements, Mine Study Area, Pebble West, 2004 - 2007
Consultant: SLR International Corp.

Monitoring Location	Year[a]	Period-of-Record by Discipline																																	Notes
		Soil												Vegetation												Sediment											
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
435221	2004								X												X	X															
	2005								X												X															
	2006																																			
	2007																																			
435222	2004																																			
	2005								X																											
	2006								X																											
	2007																																			
435223	2004																																			
	2005								X																											
	2006								X																											
	2007																																			
435301	2004								X												X															
	2005							X												X	X															
	2006																																			
	2007							X												X																Bacteriological Soil Study
435302	2004								X													X														
	2005							X												X	X															
	2006																																			
	2007																																			
435341	2004									X																										
	2005							X																												
	2006																																			
	2007																																			
435342	2004									X																										
	2005							X																												
	2006																																			
	2007																																			
436041	2004								X													X														
	2005							X												X	X															
	2006																																			
	2007							X												X																Bacteriological Soil Study
436221	2004								X												X	X														
	2005							X	X											X	X															
	2006																																			
	2007							X												X																Bacteriological Soil Study

Table 7.1-5a
Pebble Project Environmental Baseline Studies
Sample Location, Period-of-Record Index, Trace Elements, Mine Study Area, Pebble West, 2004 - 2007
Consultant: SLR International Corp.

Monitoring Location	Year[a]	Period-of-Record by Discipline																																	Notes
		Soil												Vegetation												Sediment											
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
436222	2004																																				
	2005							X																													
	2006							X																													
	2007																																				
436223	2004																																				
	2005							X																													
	2006							X																													
	2007																																				
436361	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
535051	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
535052	2004									X																											
	2005							X																													
	2006																																				
	2007																																				
536051	2004																																				
	2005																				X																Tundra Pond
	2006																				X																Tundra Pond
	2007																				X																Tundra Pond
335011	2004																																				
	2005																																				
	2006							X												X	X																
	2007							X												X	X																
335081	2004																																				
	2005																																				
	2006							X												X	X																
	2007							X												X	X																
335101	2004																																				
	2005																																				
	2006							X												X	X																
	2007							X												X	X																

Table 7.1-5a
Pebble Project Environmental Baseline Studies
Sample Location, Period-of-Record Index, Trace Elements, Mine Study Area, Pebble West, 2004 - 2007
Consultant: SLR International Corp.

Monitoring Location	Year[a]	Period-of-Record by Discipline																																	Notes
		Soil												Vegetation												Sediment											
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
WL-P01	2004																																				
	2005																																				
	2006																				X																Pond Study
	2007																				X																Pond Study
WL-S04D	2004																																				
	2005																																				
	2006																				X																Pond Study
	2007																				X																Pond Study
28B1	2004																																				
	2005																																				
	2006																				X																Pond Study
	2007																				X																Pond Study
28B2	2004																																				
	2005																																				
	2006																				X																Pond Study
	2007																				X																Pond Study
TPS1	2004																																				
	2005																																				
	2006																				X																Pond Study
	2007																				X																Pond Study
TPS2	2004																																				
	2005																																				
	2006																				X																Pond Study
	2007																				X																Pond Study
TPS3	2004																																				
	2005																																				
	2006																				X																Pond Study
	2007																				X																Pond Study
TPS4	2004																																				
	2005																																				
	2006																				X																Pond Study
	2007																				X																Pond Study
TPS5	2004																																				
	2005																																				
	2006																				X																Pond Study
	2007																				X																Pond Study

Table 7.1-5a
Pebble Project Environmental Baseline Studies
Sample Location, Period-of-Record Index, Trace Elements, Mine Study Area, Pebble West, 2004 - 2007
Consultant: SLR International Corp.

Monitoring Location	Year[a]	Period-of-Record by Discipline																																	Notes
		Soil												Vegetation												Sediment											
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
TPS6	2004																																				
	2005																																				
	2006																				X																Pond Study
	2007																				X																Pond Study
TPS7	2004																																				
	2005																																				
	2006																				X																Pond Study
	2007																				X																Pond Study
TPS8	2004																																				
	2005																																				
	2006																				X																Pond Study
	2007																				X																Pond Study
Section 3, Grid 10[b]	2004									X																							X				
	2005																																				
	2006																																				
	2007																																				
Section 2, Grid 5[b]	2004									X																											
	2005																																				
	2006																																				
	2007																																				
Section 3, Grid 4[b]	2004									X																											
	2005																																				
	2006																																				
	2007																																				
Section 36, Grid 20[b]	2004									X																											
	2005																																				
	2006																																				
	2007																																				
Section 32, Grid 16[b]	2004									X																									X		
	2005																																				
	2006																																				
	2007																																				
Section 27, Grid 28[b]	2004									X																											
	2005																																				
	2006																																				
	2007																																				

Table 7.1-5a
Pebble Project Environmental Baseline Studies
Sample Location, Period-of-Record Index, Trace Elements, Mine Study Area, Pebble West, 2004 - 2007
Consultant: SLR International Corp.

Monitoring Location	Year[a]	Period-of-Record by Discipline																																Notes
		Soil												Vegetation												Sediment										
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
Section 17, Grid 106[b]	2004																																X				
	2005																																				
	2006																																				
	2007																																				
Section 34, Grid 72[b]	2004																																X				
	2005																																				
	2006																																				
	2007																																				
Section 32, Grid 76[b]	2004																																X				
	2005																																				
	2006																																				
	2007																																				
Section 28, Grid 81[b]	2004																																X				
	2005																																				
	2006																																				
	2007																																				
Section 21, Grid 91[b]	2004																																X				
	2005																																				
	2006																																				
	2007																																				
Section 3, Grid 128[b]	2004																																X				
	2005																																				
	2006																																				
	2007																																				
Section 12, Grid 120[b]	2004																																X				
	2005																																				
	2006																																				
	2007																																				
Section 27, Grid 142[b]	2004																																X				
	2005																																				
	2006																																				
	2007																																				
Section 22, Grid 158[b]	2004																																X				
	2005																																				
	2006																																				
	2007																																				

Table 7.1-5a
Pebble Project Environmental Baseline Studies
Sample Location, Period-of-Record Index, Trace Elements, Mine Study Area, Pebble West, 2004 - 2007
Consultant: SLR International Corp.

Monitoring Location	Year[a]	Period-of-Record by Discipline																																	Notes
		Soil												Vegetation												Sediment											
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
Section 11, Grid 53[b]	2004									X																							X				
	2005																																				
	2006																																				
	2007																																				
Section 4, Grid 67[b]	2004									X																							X				
	2005																																				
	2006																																				
	2007																																				
Section 26, Grid 23[b]	2004									X																							X				
	2005																																				
	2006																																				
	2007																																				
Section 23, Grid 39[b]	2004									X																							X				
	2005																																				
	2006																																				
	2007																																				
Section 16[b]	2004																																	X			
	2005																																				
	2006																																				
	2007																																				
Section 12, Grid 54[b]	2004									X																											
	2005																																				
	2006																																				
	2007																																				
Section 19, Grid 35[b]	2004									X																							X				
	2005																																				
	2006																																				
	2007																																				
Section 28[b]	2004																																	X			
	2005																																				
	2006																																				
	2007																																				

NOTES:

a. No trace elements sampling occurred in 2008.

b. Site removed from program after 2004.

Table 7.1-5b
Pebble Project Environmental Baseline Studies
Sample Location, Period-of-Record Index, Trace Elements, Mine Study Area, Pebble East, 2004 - 2007
Consultant: SLR International Corp.

Monitoring Location	Year[a]	Period-of-Record by Discipline																																	Notes
		Soil												Vegetation												Sediment											
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
335245	2004																																				
	2005																																				
	2006							X												X	X																Lowland wet graminoid moss meadow habitat
	2007							X												X	X																
335244	2004																																				
	2005																																				
	2006							X												X	X																Riverine willow scrub habitat
	2007							X												X	X																
335246	2004																																				
	2005																																				
	2006							X																													Riverine willow scrub habitat
	2007							X																													
335141	2004																																				
	2005																																				
	2006							X												X	X																Upland dwarf, low & tall scrub habitat
	2007							X												X	X																
335142	2004																																				
	2005																																				
	2006							X												X	X																Upland dwarf, low & tall scrub habitat
	2007							X												X	X																
335143	2004																																				
	2005																																				
	2006							X												X	X																Upland dwarf, low & tall scrub habitat
	2007							X												X	X																
335144	2004																																				
	2005																																				
	2006							X												X	X																Upland dwarf shrub habitat
	2007							X												X	X																
335132	2004																																				
	2005																																				
	2006							X																													Upland dwarf shrub habitat
	2007							X																													
335145	2004																																				
	2005																																				
	2006							X												X	X																Upland dwarf shrub habitat
	2007							X												X	X																

Table 7.1-5b
Pebble Project Environmental Baseline Studies
Sample Location, Period-of-Record Index, Trace Elements, Mine Study Area, Pebble East, 2004 - 2007
Consultant: SLR International Corp.

Monitoring Location	Year[a]	Period-of-Record by Discipline																																		Notes
		Soil												Vegetation												Sediment												
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
335233	2004																																				
	2005																																				
	2006							X												X	X																Subalpine dwarf & low scrub habitat
	2007							X												X	X																
335234	2004																																				
	2005																																				
	2006							X												X	X																Subalpine dwarf & low scrub habitat
	2007							X												X	X																
335235	2004																																				
	2005																																				
	2006							X																													Subalpine dwarf & low scrub habitat
	2007							X																													
335243	2004																																				
	2005																																				
	2006							X												X	X																Alpine rock & dwarf shrub habitat
	2007							X												X	X																
335242	2004																																				
	2005																																				
	2006							X												X	X																Alpine rock & dwarf shrub habitat
	2007							X												X	X																
335131	2004																																				
	2005																																				
	2006							X												X	X																Alpine rock & dwarf shrub habitat
	2007							X												X	X																
335241	2004																																				
	2006																																				
	2007							X												X	X																Alpine rock & dwarf shrub habitat
	2006							X												X	X																
335133	2004																																				
	2005																																				
	2006																				X											X					Tundra Pond
	2007																				X											X					Tundra Pond

NOTES:

a. No Trace Elements sampling occurred in 2008.

TABLE 7.1-6
Proposed Sampling Locations for Stream Sediments in 2004, Mine Study Area

Stream	Identification Number for Monitoring Sites (Figure 4-1)
South Fork Koktuli River (SK)	SK100G, SK131A, SK100F, SK100C, SK119A, SK100B
North Fork Koktuli River (NK)	NK100C, NK119A, NK100A
Main Stem Koktuli River (KR)	KR100A
Kaskanak Creek (KC)	KC100A
Upper Talarik Creek (UT)	UT100E, UT146A, UT141A, UT100D, UT138A, UT119A, UT100B, UT100A

TABLE 7.1-7
Numbers[a] of Soil, Vegetation, and Sediment Samples by Type and Landform in 2004, Mine Study Area

Sample Types	Ground Moraines	Outwash Plains	Talus Slopes	Stream Channel & Flood Plains	Tundra Lakes & Ponds	Total
	Estimated Physiographic Distribution					
	37%	16%	24%	17%	6%	100%
	Number of Surface-Soil Samples					
Organic-rich silts (OL)	10 (15)	5 (7)	6 (4)	0 (4)	0 (0)	21 (30)
Fine sands with silts and clay (ML and CL)	10 (15)	5 (8)	6 (0)	0 (0)	0 (0)	21 (23)
Poorly graded gravel with sands and silts (GP and GM)	10 (12)	5 (9)	6 (5)	0 (3)	0 (0)	21 (29)
Glacial till (GM and GC)	10 (2)	5 (0)	6 (0)	0 (0)	0 (0)	21 (2)
	Number of Vegetation Samples					
High brush shrubs including species such as willow, American green elder, and blueberry	10 (10)	5 (6)	6 (1)	0 (1)	0 (0)	21 (18)
High brush sedges and, grasses such as blue joint	10 (15)	5 (10)	6 (2)	0 (3)	0 (0)	21 (30)
Alpine tundra shrubs, such as dwarf arctic birch, crowberry	10 (1)	5 (2)	6 (0)	0 (1)	0 (0)	21 (4)
Alpine sedges	10 (6)	5 (4)	6 (1)	0 (1)	0 (0)	21 (12)
	Number of Sediment Samples					
Stream[b]	0 (0)	0 (0)	0 (0)	57 (39)	0 (0)	57 (39)
Lake and Pond	0 (0)	0 (0)	0 (0)	0 (0)	21 (21)	21 (21)
Total						**246 (208)**

Notes:

a. Numbers without parentheses represent proposed numbers in 2004; numbers in parentheses represent number of samples actually collected in 2004.

b. Stream-sediment sampling locations and frequency are based on surface water-quality sampling (consolidated study program 6) and will occur at 16 surface-water stations three times during 2005.

TABLE 7.1-8
2004 and Proposed 2005 Numbers[a] of Samples for Soil and Vegetation by Habitat Type, Mine Study Area

Habitat/Medium	SS	UF	US	AS	LM	RS	LS	Total
Estimated Physiographic Distribution								
(qualitative estimate)	35%	25%	25%	5%	5%	4%	1%	100%
Number of Soil Samples								
Surface-soil Samples	35 (28)	11 (20)	29 (20)	1 (4)	2 (4)	2 (3)	0 (1)	80 (80)
Subsurface-soil Samples	2 (2)	1 (2)	5 (2)	0 (0)	0 (1)	1 (1)	0 (0)	9 (8)
							Total Soil	**89 (88)**
Number of Vegetation Samples[b]								
Non-woody Vegetation	26 (26)	25 (19)	17 (19)	0 (4)	0 (4)	6 (3)	0 (1)	74 (78)
Fruits and Berries[c]	4 (6)	4 (5)	3 (5)	0 (1)	0 (1)	1 (1)	0 (1)	12 (20)
							Total Plant	**86 (98)**

Notes:

a. Values in parentheses are number of samples targeted for collection during each event in 2005.

b. Each species collected from a given location is counted as a separate sample (excluding duplicates).

c. August sampling event only.

TABLE 7.1-9
Stream-sediment Sampling Locations in 2005, Mine Study Area

Stream	Identification Number for Monitoring Sites
South Fork Koktuli River	SK100A, SK100B, SK100C, SK100F, SK100G, SK119A
North Fork Koktuli River	NK100A ,NK100B, NK100C, NK119A
Kaskanak Creek	KC100A
Upper Talarik Creek	UT100B, UT100C, UT100D, UT100E, UT119A

Notes:

Sediment sampling sites are co-located with fish, macroinvertebrate, and water-quality sampling sites.

Table 7.1-10
Pebble Project Environmental Baseline Studies
Proposed Analytical Sampling Estimate for 2006, Trace Elements, Mine Study Area
Consultant: SLR International Corp.

Pebble West - July (SLR)

	Soil	Terrestrial Veg[1]	Aquatic Veg[1]	Pond Sed[2]	Stream SW	Stream Sediment	Totals
Primary	30	36	24	9	0	0	99
Duplicate	3	3	3	1	0	0	10
QA	3	3	3	1	0	0	10
Totals	36	42	30	11	0	0	119

Pebble East - July (SLR)

	Soil	Terrestrial Veg[1]	Aquatic Veg[1]	Pond Sed	Stream SW	Stream Sediment	Totals
Primary	16	28	0	0	0	0	44
Duplicate	2	3	0	0	0	0	5
QA	2	3	0	0	0	0	5
Totals	20	34	0	0	0	0	54

Pebble West - August (SLR)

	Soil	Terrestrial Veg[1]	Aquatic Veg[1]	Pond Sed[2]	Stream SW	Stream Sediment	Totals
Primary	0	54	40	15	0	0	109
Duplicate	0	5	4	2	0	0	11
QA	0	5	4	2	0	0	11
Totals	0	64	48	19	0	0	131

Pebble East - August (SLR)

	Soil	Terrestrial Veg[1]	Aquatic Veg[1]	Pond Sed[3]	Stream SW	Stream Sediment	Totals
Primary	0	42	4	3	0	0	49
Duplicate	0	4	1	1	0	0	6
QA	0	4	1	1	0	0	6
Totals	0	50	6	5	0	0	61

Notes:

[1] Assumes four species per location, plus two berry samples per upland location.

[2] Assumes three samples for every two ponds (two samples at larger ponds, one at smaller ponds).

[3] Assumes three samples from one pond.

Table 7.2-1a
Pebble Project Environmental Baseline Studies
Study Summary for Trace Elements, Transportation Corridor/Cook Inlet Study Areas, 2004 - 2007
Consultant: SLR International Corp.

2004 Data Collected or Tasks Completed	2005 Data Collected or Tasks Completed	2006 Data Collected or Tasks Completed	2007 Data Collected or Tasks Completed
None	Information Gathering	Information Gathering	Information Gathering
		Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan
	BEESC Study Plan Review	2006 Study Plan Summary	2007 Study Plan Summary
		Coordination with HDR and BEESC	Coordination with HDR and BEESC
	Coordination with NDM & Agencies	Coordination with NDM and Resource Agencies, Monthly Reporting	Coordination with NDM and Resource Agencies, Monthly Reporting
	Data Analysis	Data Entry and Analysis	Data Entry and Analysis
	2004 Progress Report	Prepare Preliminary Environmental Baseline Document	Update Preliminary Environmental Baseline Document

Note: No trace elements sampling was conducted in 2008.

Table 7.2-1b
Pebble Project Environmental Baseline Studies
Study Summary for Trace Elements in Vegetation and Sediment, Transportation Corridor/Cook Inlet Sudy Areas, 2004-2007
Consultant: BEESC

Discipline	2004 Data Collected or Tasks Completed	2005 Data Collected or Tasks Completed	2006 Data Collected or Tasks Completed	2007 Data Collected or Tasks Completed
Trace Elements, Soil and Vegetation	Information Gathering	None	Information Gathering	Information Gathering
	Scope, Schedule, Field		Scope, Schedule, Field	Scope, Schedule, Field
	Field Sampling--August		Field Sampling--August	Field Sampling--August
	Communication and Data		Communication and Data	Communication and Data
	Coordination with local communities for observers		Coordination with local communities for observers	Coordination with local communities for observers
	Preparation of presentation		Data Compilation	Data Compilation
	Report Writing		Report Writing	Report Writing
Trace Elements, Sediment	Information Gathering	Information Gathering	Information Gathering	Information Gathering
	Scope, Schedule, Field	Scope, Schedule, Field	Scope, Schedule, Field	Scope, Schedule, Field
	Field Sampling--July,	Field Sampling--May, July,	Field Sampling--August	Field Sampling--August
	Communication and Data Management	Communication and Data Management	Communication and Data Management	Communication and Data Management
	Coordination with NDM	Coordination with NDM	Coordination with NDM	Coordination with NDM
	Coordination with local communities for observers	Coordination with local communities for observers	Coordination with local communities for observers	Coordination with local communities for observers
	Preparation of presentation	Data Compilation and Analysis	Data Compilation and Analysis	Data Compilation and Analysis
	Report Writing	Report Writing	Report Writing	Report Writing

Table 7.2-2
Pebble Project Environmental Baseline Studies
Sample Location, Period-of-Record Index, Trace Elements, Transportation Corridor/Cook Inlet Study Areas, 2004 - 2007
Consultant: BEESC

Sample Location	Year[a]	Period-of-Record by Discipline																																		Comment
		Soil												Vegetation												Sediment											
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
NHRIV	2004																															F		F				
	2005																													F		F		F				
	2006																																					
	2007																																					
GS20	2004																															F		F				
	2005																															F		F				
	2006																																					
	2007																																					
GS20A	2004																															F		F				
	2005																																					
	2006																																					
	2007																																					
GS18A	2004																															F		F				
	2005																																					
	2006																																					
	2007																																					
GS17A	2004																															F		F				
	2005																													F		F		F				
	2006																																					
	2007																																					
GS14A	2004																															F		F				
	2005																																					
	2006																																					
	2007																																					
GS14B	2004																															F		F				
	2005																													F		F		F				
	2006																																					
	2007																																					
GS12A	2004																															F		F				
	2005																																					
	2006																																					
	2007																																					
GS11A	2004																															F		F				
	2005																													F		F		F				
	2006																																					
	2007																																					

Table 7.2-2
Pebble Project Environmental Baseline Studies
Sample Location, Period-of-Record Index, Trace Elements, Transportation Corridor/Cook Inlet Study Areas, 2004 - 2007
Consultant: BEESC

Sample Location	Year[a]	Period-of-Record by Discipline																																		Comment
		Soil												Vegetation												Sediment											
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
GS8A	2004																															F		F				
	2005																													F		F		F				
	2006																																					
	2007																																					
GS7A	2004																																					
	2005																																					
	2006																																					
	2007																																					
GS6A	2004																															F		F				
	2005																																					
	2006																																					
	2007																																					
GS4A	2004																															F		F				
	2005																													F		F		F				
	2006																																					
	2007																																					
GS4B	2004																																	F				
	2005																																					
	2006																																					
	2007																																					
GS3A	2004																																F	F				
	2005																													F		F		F				
	2006																																					
	2007																																					
GS23	2004																															F		F				
	2005																																					
	2006																																F					
	2007																																					
GS22	2004																																					
	2005																															F		F				
	2006																																F					
	2007																																					
GS21	2004																																F	F				
	2005																													F		F		F				
	2006																																F					
	2007																																					

Table 7.2-2
Pebble Project Environmental Baseline Studies
Sample Location, Period-of-Record Index, Trace Elements, Transportation Corridor/Cook Inlet Study Areas, 2004 - 2007
Consultant: BEESC

Sample Location	Year[a]	Period-of-Record by Discipline																																		Comment
		Soil												Vegetation												Sediment												
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
PSC	2004																																				
	2005																															F					
	2006																																				
	2007																																				
PSD	2004																																				
	2005																															F					
	2006																																				
	2007																																				
POND1	2004																															F		F			
	2005																													F		F		F			
	2006																																				
	2007																																				
POND2	2004																															F		F			
	2005																													F		F		F			
	2006																																				
	2007																																				
POND3	2004																															F		F			
	2005																													F		F		F			
	2006																																				
	2007																																				
POND4	2004																															F		F			
	2005																													F		F		F			
	2006																																				
	2007																																				
POND5	2004																															F		F			
	2005																													F		F		F			
	2006																																				
	2007																																				
POND6	2004																																				
	2005																																				
	2006																			V													F				
	2007																			V													F				
TE01	2004								S											V	V																
	2005																																				
	2006																																				
	2007																																				

Table 7.2-2
Pebble Project Environmental Baseline Studies
Sample Location, Period-of-Record Index, Trace Elements, Transportation Corridor/Cook Inlet Study Areas, 2004 - 2007
Consultant: BEESC

Sample Location	Year[a]	Period-of-Record by Discipline																																		Comment
		Soil												Vegetation												Sediment												
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
TE02	2004								S												V																
	2005																																				
	2006																																				
	2007																																				
TE03	2004								S												V																
	2005																																				
	2006																																				
	2007																																				
TE04	2004								S												V																
	2005																																				
	2006																																				
	2007																																				
TE05	2004								S												V	V															
	2005																																				
	2006																																				
	2007																																				
TE06	2004								S												V																
	2005																																				
	2006																																				
	2007																																				
TE07	2004								S												V																
	2005																																				
	2006																																				
	2007																																				
TE08	2004								S												V	V															
	2005																																				
	2006																																				
	2007																																				
TE09	2004								S												V																
	2005																																				
	2006																																				
	2007																																				
TE10	2004								S												V																
	2005																																				
	2006																																				
	2007																																				

Table 7.2-2
Pebble Project Environmental Baseline Studies
Sample Location, Period-of-Record Index, Trace Elements, Transportation Corridor/Cook Inlet Study Areas, 2004 - 2007
Consultant: BEESC

Sample Location	Year[a]	Period-of-Record by Discipline																																		Comment
		Soil												Vegetation												Sediment												
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
TE11	2004								S												V																
	2005																																				
	2006																																				
	2007																																				
TE12	2004								S												V	V															
	2005																																				
	2006																																				
	2007																																				
TE13	2004								S												V																
	2005																																				
	2006																																				
	2007																																				
TE14	2004								S												V																
	2005																																				
	2006																																				
	2007																																				
TE15	2004								S												V																
	2005																																				
	2006																																				
	2007																																				
TE16	2004								S												V																
	2005																																				
	2006																																				
	2007																																				
TE17	2004								S												V	V															
	2005																																				
	2006																																				
	2007																																				
TE18	2004								S												V																
	2005																																				
	2006								S												V																
	2007								S												V																
TE19	2004								S												V																
	2005																																				
	2006								S												V																
	2007								S												V																

Table 7.2-2
Pebble Project Environmental Baseline Studies
Sample Location, Period-of-Record Index, Trace Elements, Transportation Corridor/Cook Inlet Study Areas, 2004 - 2007
Consultant: BEESC

Sample Location	Year[a]	Period-of-Record by Discipline																																		Comment
		Soil												Vegetation												Sediment											
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
TE20	2004								S												V																
	2005																																				
	2006								S												V																New Loc: North Head - East
	2007								S												V																
TE21	2004								S												V																
	2005																																				
	2006								S												V																New Loc: Knoll Head
	2007								S												V																
TE22	2004								S												V																
	2005																																				
	2006								S												V																New Loc: Just west of Port Site 1
	2007								S												V																
TE23	2004																																				
	2005																																				
	2006								S												V																
	2007								S												V																
TE24	2004																																				
	2005																																				
	2006								S												V																
	2007								S												V																
SWQ1[b]	2004																																				
	2005																																				
	2006																																F				
	2007																																F				
SWQ2[b]	2004																																				
	2005																																				
	2006																																F				
	2007																																F				
SWQ3[b]	2004																																				
	2005																																				
	2006																																F				
	2007																																F				

Table 7.2-2
Pebble Project Environmental Baseline Studies
Sample Location, Period-of-Record Index, Trace Elements, Transportation Corridor/Cook Inlet Study Areas, 2004 - 2007
Consultant: BEESC

Sample Location	Year[a]	Period-of-Record by Discipline																																	Comment
		Soil												Vegetation												Sediment											
	Month	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
SWQ4[b]	2004																																				
	2005																																				
	2006																																F				
	2007																																F				

KEY:

F	Sediment samples collected.
V	Vegetation samples collected from various plant species.
S	Soil samples collected.

NOTES:

a. No trace elements sampling was conducted in 2008.

b. Water-quality samples, as well as sediment, are being collected at these sites.

TABLE 7.2-3
Analytes for Soil, Sediment, and Vegetation Samples in 2004, Transportation Corridor/Cook Inlet Study Areas

Analyte	Method
Surface Soils, Sediments, and Vegetation	
Hg	SW7471 (CVAA)
Al, Ag, As, Ba, Be, Bi, B, Cd, Ca, Cr, Co, Cu, Fe, K, Mg, Mo, Mn, Na, Ni, Pb, Se, Tl, Sb, Sn, V, Zn	SW 6010/6020 (ICP/ICP-MS)
Total Cyanide	E335.2
Chloride	E300.0
Fluoride	SM4500-FC
Sulfate	E300.0
Ammonia as N	E350.3
Surface Soils Only	
Total Organic Carbon	ASTM D4129-82M
Total Petroleum Hydrocarbons (biogenic “fingerprinting)	Gas Chromatography

Notes:

ASTM = American Society for Testing and Materials

E = Methods for Chemical Analysis of Inorganic Substances in Environmental Samples, EPA/600/R-93-100, August 1993 and Methods for the Determination of metals in Environmental samples, EPA/600/4-91-010, June 1991.

SM = Standard Methods for the Examination of Water and Wastewater, 20th Edition.

SW = U.S. EPA Test Methods for Evaluating Solid Waste Physical/Chemical Methods, Third edition, September 1986.

TABLE 7.2-4
Analytes for Stream and Pond Sediment Samples in 2005, Transportation Corridor/Cook Inlet Study Areas

Analyte
Total Hg
Total Metals
Total Cyanide
Chloride
Fluoride
Sulfate
Ammonia as N

Table 7.2-5
Pebble Project Environmental Baseline Studies
Trace Element Analytical Sampling Estimate for 2006, Transportation Corridor/Cook Inlet Study Areas
Consultant: BEESC

	Soil	Terrestrial Veg[1]	Aquatic Veg[1]	Pond Sed[2]	Stream SW	Stream Sediment[3]	Totals
Primary	12	72	4	3	7	7	105
Duplicate	2	7	1	1	1	1	13
QA	2	7	1	1	1	1	13
Totals	16	86	6	5	9	9	131

Notes:

1. Assumes four species per location, plus two berry samples per upland location.
2. Assumes three samples from one pond.
3. Assumes two samples per location.

FIGURES

155°36'0"W 155°24'0"W 155°12'0"W

60°0'0"N

North Fork Koktuli River

Upper Talarik Creek

South Fork Koktuli River

59°48'0"N

155°36'0"W 155°24'0"W 155°12'0"W

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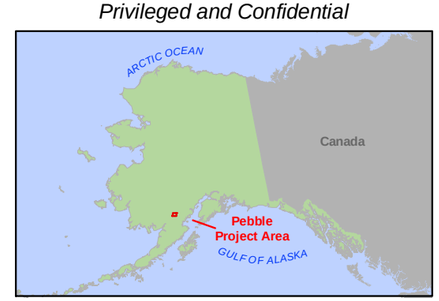
Figure 7.1-1
Consolidated Study Program, 2004 - 2008
Study Area for Trace Elements,
Mine Study Area

Legend

General Deposit Location

Study Boundary

Privileged and Confidential



N

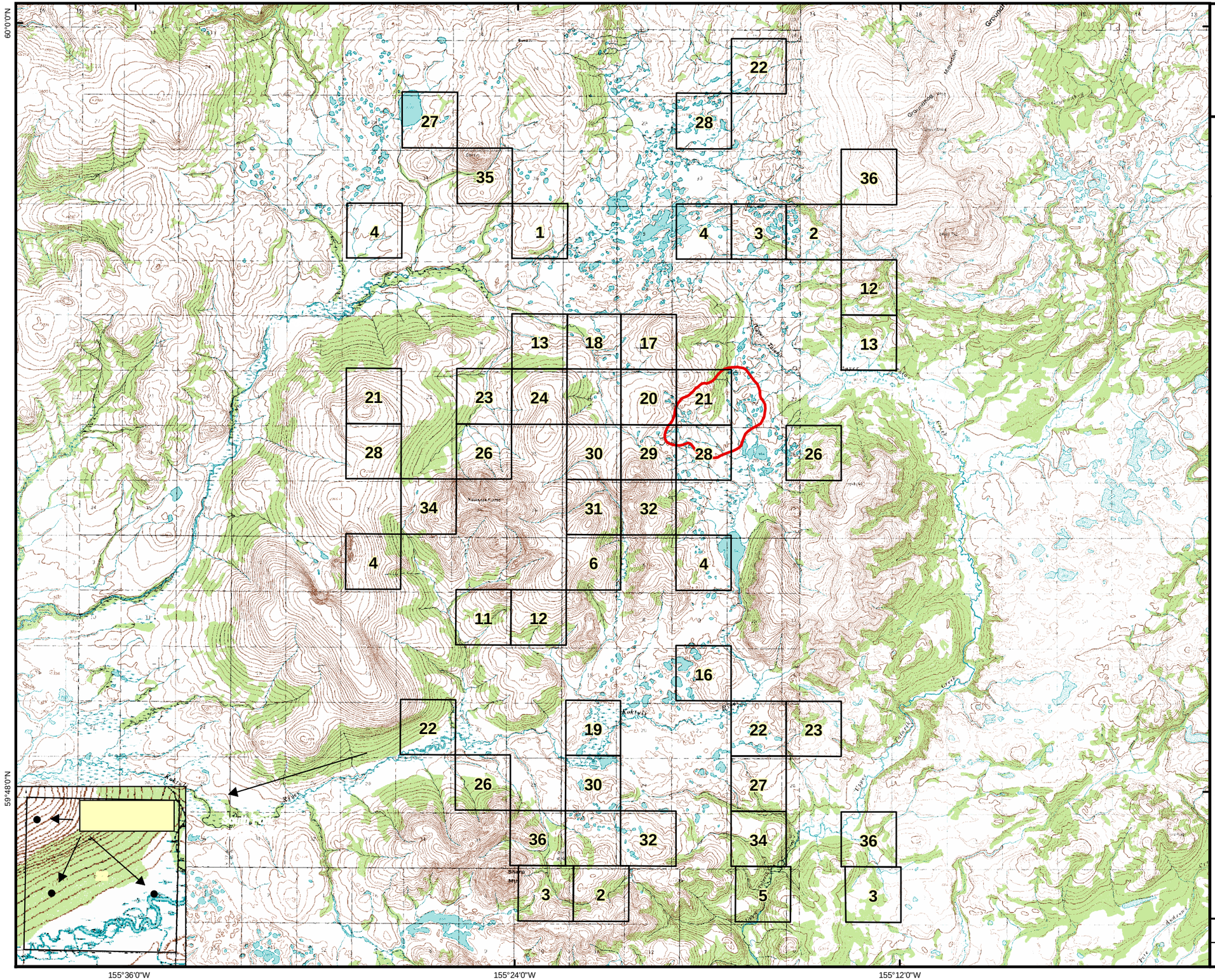
Miles
0 1 2 3 4

Kilometers
0 1 2 3 4 5 6

Scale 1:110,508

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: 11X17Sections_bndV2.mxd	**Date: April 3, 2009**
Version: 2rev	**Author: CH - BS, PLP-JG**



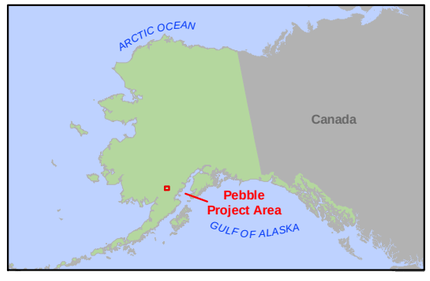
THE pebble PARTNERSHIP

Figure 7.1-2
Consolidated Study Program, 2004-2008
Trace Elements Section Grids/Cells Sampled for Naturally Occurring Constituents in Soil, Vegetation, Sediment and Fish, Mine Study Area

General Deposit Location

Section to be Sampled

Privileged and Confidential



N

Miles
0 1 2 3 4

Kilometers
0 1 2 3 4 5 6

Scale 1:109,994

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: 11X17SectionsV2.mxd	**Date: April 3, 2009**
Version: 2rev	**Author: CH - BS, PLP-JG**

1,400,000

2,150,000

2,150,000

236221
236272 236273
236271
235282
235271
235281 236281
236352 236353
236351
235361
335051
336012 336013
336011
335021
336042 336043
336041
335031 335032
335092 335093
335091
335162 335163
335161
335131 335132
336132 336133
336131
335172 335173
335171
335175 335176
335174
336241 336242
336231
335191 335192
335193
336211 336212
335201
335231 335232
335283 335284
336281 336282
336261
335301
335302
335261
336341 336342
336361 336362
335311
335322
436041
435061 435062
435161 435162
436222 436223
436221
435222 435223
435221
435301 435302
436361 436362
435341 435342
535052
535051
536051

Privileged and Confidential

Scale 1:85,000
Alaska State Plane Zone 5 (units feet)
1983 North American Datum

Legend

Sample location type

- Soil
- Aquatic Vegetation
- Soil and Terrestrial Vegetation
- 335132 Example Station Label
- General Deposit Location

THE pebble PARTNERSHIP

Figure 7.1-3
Consolidated Study Program, 2004-2008
Trace Elements
Sampling Locations for Soil and Vegetation in 2005 - Mine Study Area

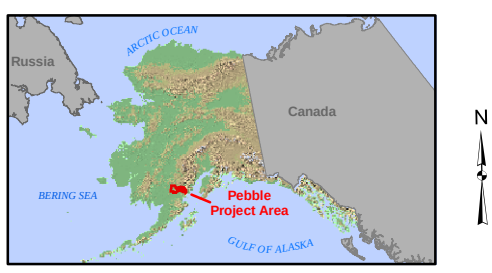
File: RDI_SLR_trace7_2_11x17P_v2.mxd	Date: April 3, 2009
Version: 2rev	Author: RDI, PLP

Note: Sample stations are often located in close proximity to each other and may not be individually discernible without magnification.

1,400,000

2,150,000

2,150,000



N

Miles
0 1 2 3

Kilometers
0 1 2 3

Scale 1:85,000
Alaska State Plane Zone 5 (units feet)
1983 North American Datum

Legend

435061 Station Label Example

- Proposed 2006 Sample Location (pre-existing)
- Proposed 2006 New Sample Location
- Locations Sampled in 2004 and 2005
- 2004 Sample Location
- Study Boundary
- General Deposit Location

THE pebble PARTNERSHIP

Figure 7.1-4
Consolidated Study Program,
2004-2008
Trace Elements
Sampling Locations for Soil and
Vegetation in 2006 - Mine Study Area

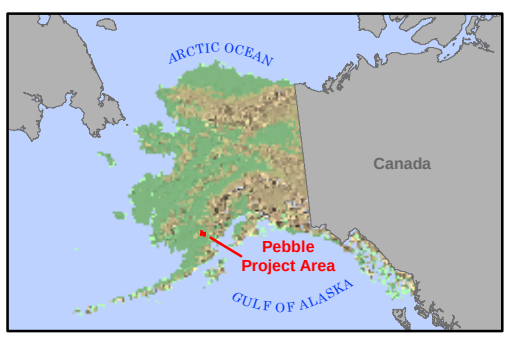
RDI_SLR_2004-06_sample_loc_11x17P_v06.mxd	Date: April 3,2009
Version: 6rev	Author: RDI-DS,LS PLP-JG

Note: Sample Stations are often located in close proximity to each other and may not be individually discernible without magnification.

155°24'0"W 155°18'0"W 155°12'0"W

59°57'0"N 59°54'0"N 59°51'0"N 59°48'0"N

236221 235282 235271 TPS4 235361 236353 335051 336011 TPS3 TPS1 335011 335081 TPS2 335144 335132 335141 335142 335245 335246 335143 335145 335133 335131 335235 335233 335242 335243 335234 335241 335244 336131 336231 WL-P01 336261 28B2 28B1 336362 TPS7 436041 335101 TPS5 WL-S04D TPS6 TPS8 436221 435301 536051



Miles 0 1 2 3

Kilometers 0 1 2 3

N

Scale 1:80,000

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

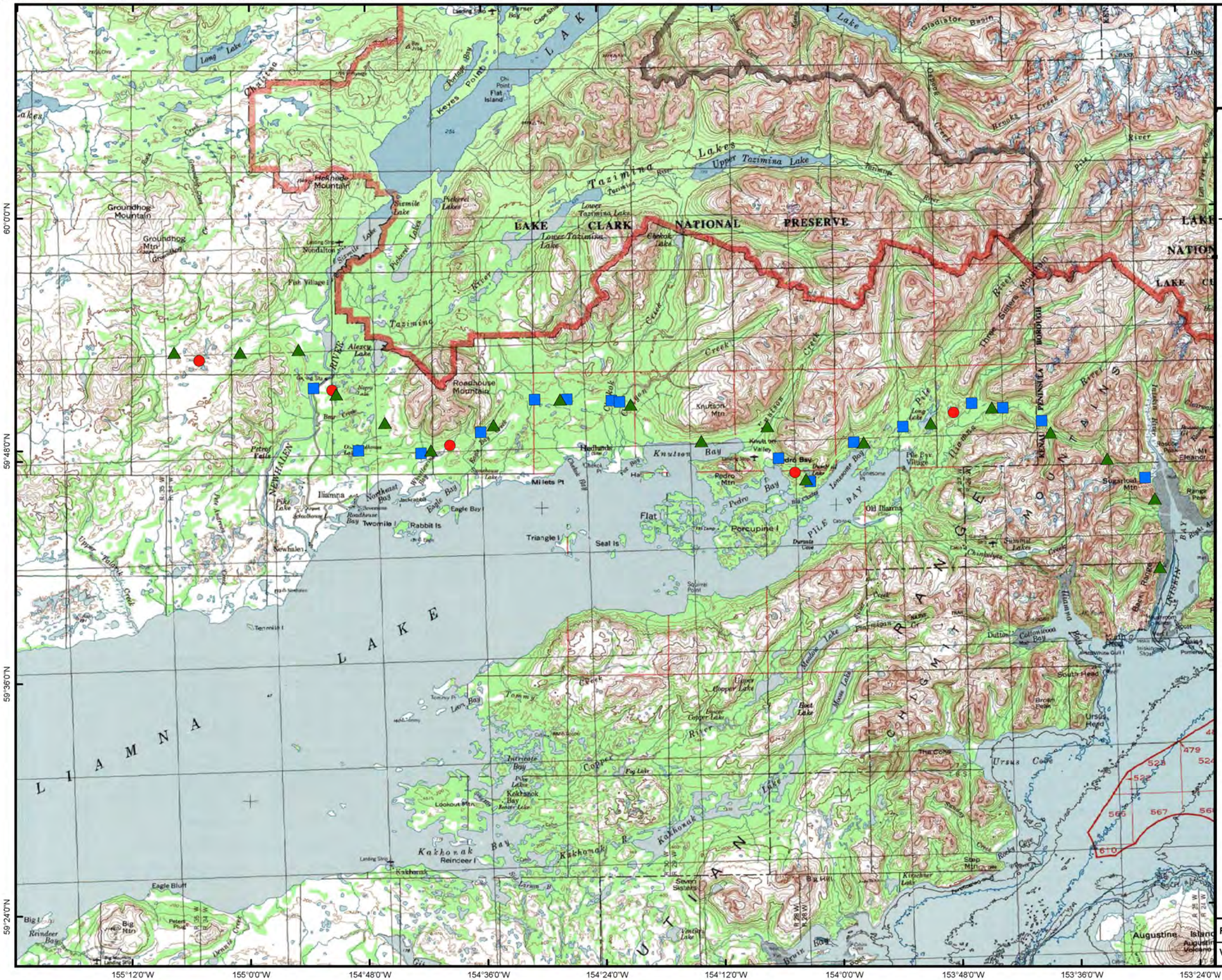
Legend

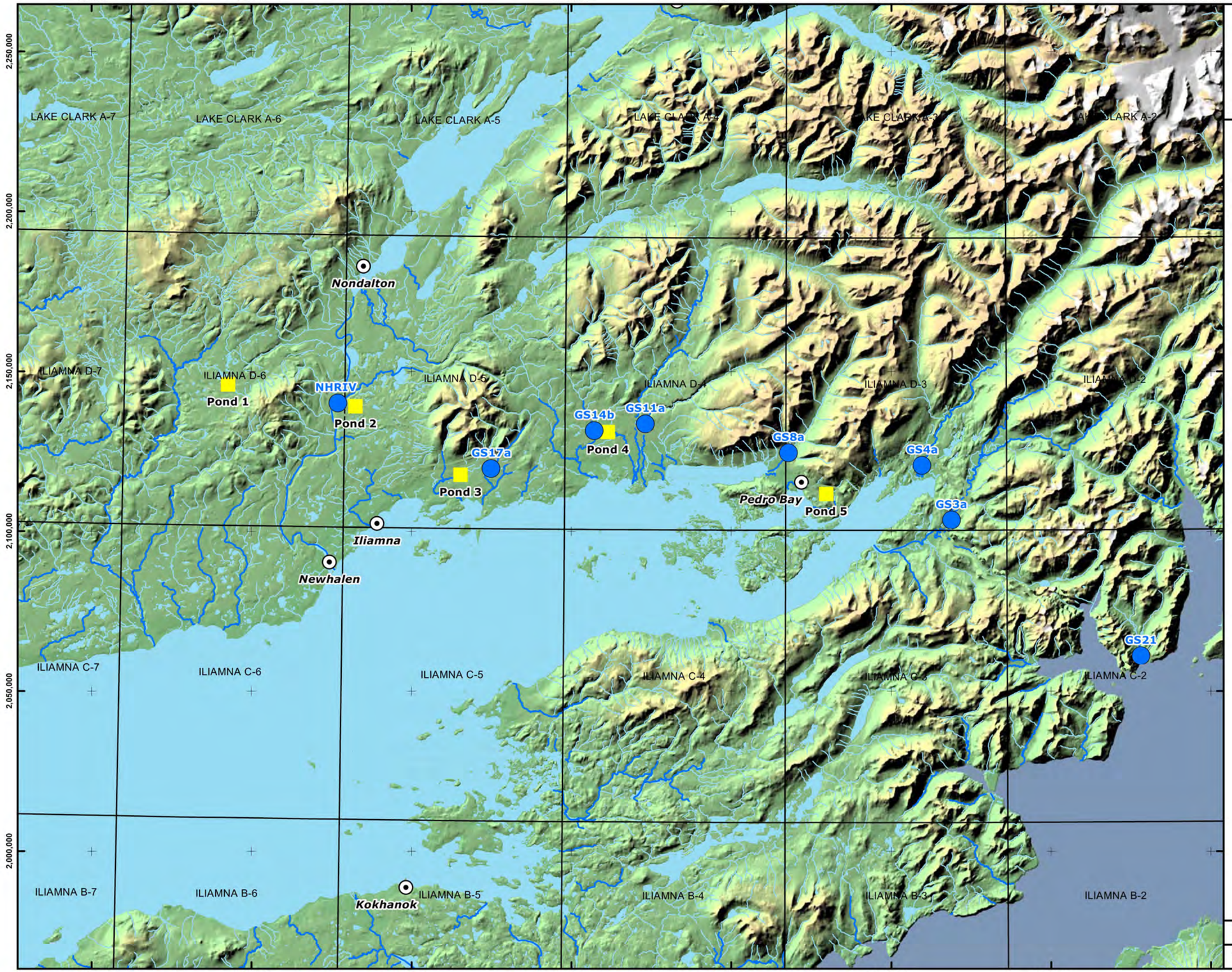
- 435301 **Example Station Label**
- **Bacteriology Soil, Surface Soil, and Terrestrial Vegetation Sample Locations**
- **Surface Soil and Terrestrial Vegetation Sample Locations**
- **Surface Soil Sample Locations**
- **Aquatic Vegetation and Sediment Sample Locations**
- **Aquatic Vegetation (Small Pond Study) Sample Locations**
- Study Boundary
- General Deposit Location

THE pebble PARTNERSHIP

Figure 7.1-5
Consolidated Study Program, 2004-2008
Trace Elements
Sampling Locations for Soil, Vegetation and Sediment in 2007
Mine Study Area

RDI_SLR_2007_StudyPlan_TE_Fig7.1-1_11x17P_v06.mxd	Date: April 3, 2009
Version: 6rev	Author: RDI-LS,PLP-JG


155°24'0"W
155°12'0"W
155°0'0"W
154°48'0"W
154°36'0"W
154°24'0"W
154°12'0"W
154°0'0"W
153°48'0"W
153°36'0"W
153°24'0"W
60°0'0"N
59°48'0"N
59°36'0"N
59°24'0"N
LAKE CLARK NATIONAL PRESERVE
LAKE CLARK NATIONAL
LAKE
ILIAMNA LAKE
Lake Clark
Upper Tazimina Lake
Lower Tazimina Lake
Tazimina River
Chekok Lake
Pickerel Lakes
Sixmile Lake
Fishhook Mountain
Groundhog Mountain
Groundhog Mtn
Roadhouse Mountain
Knutson Mtn
Pedro Mtn
Sugarloaf Mtn
Old Iliamna
Iliamna
Kokhanok
Kakhonak
Kakhonak Reindeer I
Eagle Bluff
Big Mtn
Big I
Reindeer Bay
Twomile I
Rabbit Is
Triangle I
Seal Is
Porcupine I
Tennile I
Sewhalen
Flat
Knutson Bay
Pedro Bay
Iliamna Bay
Eagle Bay
Northeast Bay
Roadhouse Bay
Tommy Bay
Intricate Bay
Kakhonak Bay
Bruin Bay
Pile Bay
Lonesome Bay
Ursus Cove
Ursus Head
Augustine Island
Augustine Volcano
Chinitna Bay
Tazimina River
Alexy River
Copper River
Kakhonak R
Newhalen
Pile Bay Village
Iliamna Volcano
Three Sisters Mountains
Pile Mountains
Neacola Mountains
Aleutian Range
Chigmit Mountains
Alaska Peninsula
Bear Creek
Tommy Creek
Fog Lake
Lookout Mtn
Sewn Sisters
Big Hill
Stop Mtn
Cottonwood Bay
Brown Peak
Summit Lakes
Meadow Lake
Moose Lake
Boot Lakes
Upper Copper Lake
Lower Copper Lake
Kreacher Lake
VanGilder Lake
Knutson Valley
Pile Bay Village
Old Iliamna
Mt Eleanor
Ranger Peak
Big Mountain Landing Strip
Kakhonak Landing Strip
Fish Village
Nondalton
Lake Clark Pass
Lake Clark Gap
Chekok Pass
Chinitna Pass
Tazimina Pass
Kakhonak Pass
Kakhonak Gap
Iliamna Gap
Iliamna Pass
Iliamna Lake Pass
Iliamna Lake Gap
Iliamna Lake Valley
Iliamna Lake Creek
Iliamna Lake Bay
Iliamna Lake Island
Iliamna Lake Peninsula
Iliamna Lake Mountains
Iliamna Lake Volcano



THE pebble PARTNERSHIP

Figure 7.2-2
Consolidated Study Program, 2004-2008
Sampling Locations for Sediments
in Streams and Ponds in 2005,
Transportation Corridor/Cook Inlet Study Area

Legend

- GS3a — Example Station Label
- 2005 Surface Water Quality and Sediment Sampling Locations
- Tundra Ponds
- Anadromous Fish Stream
- Stream
- Communities

Privileged and Confidential

0 16,000 32,000 48,000 64,000 Feet
0 4,600 9,200 13,800 18,400 Meters
Scale 1:361,929

N

Alaska State Plane Zone 5 (units US feet)
1983 North American Datum

File: Sample_Map_20050804.mxd	Date: April 3, 2009
Version: 1rev	Author: BEESC-ME, PLP-JG

1,400,000 1,450,000 1,500,000 1,550,000 1,600,000 1,650,000 1,700,000 1,750,000

2,250,000 2,200,000 2,150,000 2,100,000 2,050,000 2,000,000

LAKE CLARK A-7 LAKE CLARK A-6 LAKE CLARK A-5 LAKE CLARK A-4 LAKE CLARK A-3 LAKE CLARK A-2

NONDALTON

TE01 TE02 TE03 TE04 TE05 TE06 TE07 TE08 TE09 TE10 TE11 TE12 TE13 TE14 TE15 TE16 TE17 TE18 TE19 TE20 TE21 TE22 TE23 TE24

ILIAMNA D-7 ILIAMNA D-6 ILIAMNA D-5 ILIAMNA D-4 ILIAMNA D-3 ILIAMNA D-2 ILIAMNA

ILIAMNA

NEWHALEN

PEDRO BAY

ILIAMNA C-7 ILIAMNA C-6 ILIAMNA C-5 ILIAMNA C-4 ILIAMNA C-3 ILIAMNA C-2 ILIAMNA C-1

KAKHONAK

ILIAMNA B-7 ILIAMNA B-6 ILIAMNA B-5 ILIAMNA B-4 ILIAMNA B-3 ILIAMNA B-2

THE pebble PARTNERSHIP

Figure 7.2-3
Consolidated Study Program, 2004-2008
Trace Elements Sampling Locations
for Soil and Vegetation in 2004 and 2006
Transportation Corridor/Cook Inlet
Study Area

Legend

- Soil and Vegetation sampled in 2004
- Soil and Vegetation sampled in 2004 and 2006
- Soil and Vegetation sampled in 2006
- TE14 Example Station Label
- Communities

0 4 8 12 16 Miles

0 4 8 12 16 Kilometers

N

Scale 1:363,852

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: 2006StyPlan_4_V05.mxd	Date: April 3, 2009
Version: 5rev	Author: BEESC-ME,PLP-JG

THE pebble PARTNERSHIP

Figure 7.2-4
Consolidated Study Program, 2004-2008
Trace Elements Sampling Locations for Soil, Vegetation and Sediment in 2007, Transportation Corridor/ Cook Inlet Study Area

Legend

- Soil and Vegetation Collection Locations
- Stream Sediment Collection Locations
- TE23 Example Station Label
- Communities
- Bristol Bay/Cook Inlet Drainages Boundary

0 1 2 3 Miles

0 1 2 3 4 Kilometers

N

Scale 1:80,000

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: RDI_SLR_Figure35-1-1_11X17L_1of1_D06.mxd	Date: May 19, 2011
Version: 6	Author: RDI-LS

Pebble Project
Environmental Baseline Studies
2004 through 2008
(with updates through 2010)

CONSOLIDATED STUDY PROGRAM

8. GEOCHEMICAL CHARACTERIZATION AND METAL LEACHING/ACID ROCK DRAINAGE

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Figure 8-3, Consolidated Study Program, 2004-2008, Collars of Diamond Drill-holes Sampled for Humidity Cell and Subaqueous Column Testwork, 2008, Mine Study Area.

ACRONYMS

AA	atomic absorption spectrophotometry
ABA	acid-base accounting
ASTM	American Society for Testing and Materials
CSP	consolidated study program
ICP	inductively coupled plasma
ML/ARD	metal leaching/acid rock drainage
SRK	SRK Consulting (Canada) Inc.

8. GEOCHEMICAL CHARACTERIZATION AND METAL LEACHING/ACID ROCK DRAINAGE

In the study program for geochemical characterization and metal leaching/acid rock drainage, work is being conducted to characterize the geochemical nature of mine rock and tailings that could be produced from a typical mining and milling process at the Pebble Deposit. The study is designed to assess the potential for acid rock drainage (ARD) and the related phenomenon of metal leaching (ML). Acid rock drainage is produced when iron sulfide minerals in mine rock and/or tailings oxidize to produce sulfuric acid, and the presence/quantities of base minerals are insufficient to naturally consume the acid. Metal leaching is a process that occurs as part of acid generation, but it can also occur under non-acidic conditions, depending on what types of minerals are present. These two processes are usually referred to jointly as metal leaching/acid rock drainage (ML/ARD).

In this consolidated study program (CSP), the term “mine rock” includes waste rock, waste rock that could be used for typical mine construction, the walls and floor of a typical open pit mine and/or underground workings, broken rock that could be produced by block-caving, and stockpiled rock. At the Pebble Deposit, two ages of rock are present: pre-Tertiary (or Cretaceous) rock that hosts the Pebble West and Pebble East ore-grade mineralization; and Tertiary rock that overlies the mineralization. The term “tailings” refers to the sand-grain-sized waste material and associated process water that results from milling the ore-grade rock.

SRK Consulting (Canada) Inc. ([SRK] formerly, Steffen Robertson and Kirsten (Canada) Inc. is the lead consultant for the geochemical and ML/ARD studies for the mine study area.

Table 8-1 summarizes tasks for the geochemical characterization and ML/ARD studies for 2004 through 2010.

8.1 Objectives of Study

The overall objective for the geochemical characterization and ML/ARD study is to characterize the geochemistry and, particularly, water chemistry of the materials that could be produced from a typical mining and milling process. Characterization is accomplished through a geochemical testing program that occurs in association with a metallurgical program (conducted to test different milling processes on different ore grades that may be discovered). The data produced from geochemical testing can be used for predicting representative tailings and mine-rock water chemistry, to evaluate potential for ML/ARD, and for evaluating alternative mine-rock and tailings storage plans to assess and reduce the risk of ML/ARD during operation and closure of possible projects.

It is well recognized in the mining industry that sound environmental design can substantially reduce the potential for adverse environmental effects and long-term environmental liabilities. Thus, the specific objectives of the geochemical characterization and ML/ARD study are as follows:

- Generate baseline data for assessing the potential for adverse environmental effects from possible mine-rock or tailings management facilities.
- Collect data for developing engineering design and mitigation measures to minimize potential effects from possible mine operations and closure plans.

8.2 Proposed Work

These objectives will be accomplished through the following proposed activities:

- Define typical conceptual project descriptions and project alternatives with respect to mine-rock and tailings management in order to design a representative sampling and testing program.
- Determine the amount and types of representative mine rock and ore that may be anticipated over a mine life based on the ultimate resource (including the potential limits of an open pit and underground workings).
- Develop a mine-rock sampling program for pre-Pebble-Partnership cores (i.e., "existing" cores from pre-2004 exploration drilling conducted by Cominco American Incorporated and others in the late 1980s and 1990s) and "fresh" cores (i.e., from ongoing drilling since 2004), and similarly for representative tailings generated from metallurgical testing.
- Characterize, through laboratory testing, the geochemistry and potential variability of representative mine rock from the open pit and underground workings.
- Characterize, through laboratory testing, the geochemistry and potential variability of representative tailings-solids and tailings-water chemistry.
- Quantify the potential rate and extent of the geochemical reactions controlling drainage water chemistry for representative mine rock and tailings.
- Apply quantitative mathematical modeling techniques to these data to predict water chemistry from representative mine-rock and tailings storage, open-pit, and underground workings, during possible typical operations and closure.
- Develop, and evaluate with respect to water chemistry and environmental effects, alternative options for waste and water management for the mine-rock and tailings facilities, the open pit, and the underground workings.

8.2.1 Study Area/Scope

The assessment for environmental geochemistry and representative mine-rock/tailings management is focused on the geology of the Pebble West and Pebble East deposits in the immediate area of these deposits, with a lesser emphasis on the regional setting and geology. Geochemistry studies are not planned for the transportation corridor/Cook Inlet study areas.

The overall scope of the study is to characterize representative materials that could be produced from typical mining and milling processes in terms of their geochemical behavior and the chemistry of waters that come in contact with the materials. The study includes sampling and characterization testwork being completed in detail for the mineable reserve at the Pebble Deposit. This reserve is defined for this study

as a resource of 4.48 billion short tons (Bt). The work currently includes evaluating representative materials for the following:

- Mine rock (including pre-Tertiary and Tertiary rock, some of which could be used for construction or other purposes).
- Ore stockpiles.
- Process tailings.
- Open pit walls and floor rock.
- Walls and floors of underground workings.
- Broken rock produced by block-caving.
- Surficial materials in the vicinity of the deposit area for possible tailings and mine-rock storage areas.

This CSP describes activities that are, in part, environmental and, in part, engineering design. The environmental aspects—namely the sampling and testing of representative mine rock and tailings—are emphasized.

The baseline data collected in this study are also being used to support site surface water/groundwater flow models and a site wide water balance.

8.2.1.1 Mine Rock

The mine rock program begins with exploration and infill drilling, followed by selecting representative rock and ore samples from drill cores for geochemical characterization.

Exploration drilling prior to 2004 was used to define a preliminary geologic model and resource estimate for the Pebble West deposit, and to direct subsequent infill drilling. As drilling continues, the geologic model is regularly updated and continues to be used as the basis for selecting specific samples of representative mine rock from the Pebble West deposit and the Pebble East deposit. It is recognized that as drilling and resource modeling proceed, the feasible reserve (i.e., the economic mine limits) may be different than the deposit size considered herein.

Although this approach is recognized to be potentially conservative, it is considered reasonable to sample and test the maximum potential range of geologic materials (and therefore, representative mining materials generated during operations) that may be encountered over a full mine life cycle. Within this larger database, the study limits for water chemistry prediction can address either a defined maximum mine plan and resource or various interim mine development concepts.

8.2.1.2 Tailings

The geochemical characterization of representative tailings is being done in parallel with the representative mine rock program. Thus, as various ore types are identified and alternatives for milling processes are evaluated in the metallurgical laboratory, samples of tailings solids and process water will be characterized with respect to environmental geochemistry. As a consequence, the scope of the tailings characterization program may include a variety of tailings that are not representative of the final process.

However, and similar to the representative mine rock characterization work, this broad tailings characterization work provides an additional benefit for project design, in that environmental considerations can be included in selecting a preferred alternatives for tailings storage.

8.2.2 Methods and Approach

The methods for and approach to the geochemical characterization and ML/ARD study is based on best-practice industry methods for mine-rock and tailings characterization. Geochemical characterization relies on two main groups of tests:

- Static tests, which assess the potential for materials to produce acid drainage and/or leach metals. They comprise a group of tests including microscopic examinations to determine the types of minerals present, and analysis for general parameters (e.g., rinse pH, total organic carbon, or alkalinity), parameters of potential concern if they occur at high levels (e.g., metals), parameters for acid-base accounting (ABA), sulfur (which is an important parameter for assessing ARD potential), and short-term leach extraction (or contact testing). ABA is a procedure that evaluates the potential to generate acid and the capacity to neutralize acid. It results in an estimate of the balance of acid potential and neutralization potential.
- Kinetic tests, which assess the rates at which acid drainage and metal release occur when materials are exposed to ambient conditions. Kinetic testing is usually laboratory-based, consisting of placing materials in plastic columns and leaching them with water to simulate drainage chemistry, or placing them in closed "humidity cells" to measure primary reaction rates. These tests are performed over many months and years to evaluate how the rates of acid generation and metal leaching change over time.

Characterization for the Pebble Project is on-going as drilling proceeds and is performed on rock samples obtained from drill cores and on representative tailings generated from bench-scale metallurgical process-testing of ore-grade materials. Multiple samples have been chosen from more than 16,000 mine rock samples taken from more than 450 holes drilled for resource exploration, geotechnical investigations, and groundwater quality and flow measurements. More than 600 samples have been tested to determine the ML/ARD potential of the rock and for ABA. A subset of rock samples is tested to determine their mineralogy. Rates of ML/ARD have been evaluated in more than 30 kinetic tests, some of which have been running for more than 500 days. Tailings samples are subjected to the same static and kinetic tests. Twenty individual samples have been tested for their potential for ML/ARD, and four samples have been tested in two different types of kinetic tests. Two samples are still being tested as of January 2009.

The study comprises the following sequence of major activities:

- Consider possible project concepts and geologic model to identify range of geologic units for sampling.
- Representative sampling and testing of pre-2004 and ongoing drilling cores and of simulated tailings samples derived from the metallurgical program.
- Staged geochemical testing composed of static and kinetic testing.
- Calculating oxidation rates, acid generation, neutralization potential, and soluble-metal production rates for each sample/material type in kinetic testing.

8.2.3 Major Tasks/Activities

It was planned to conduct the geochemical sampling and testing program in two main phases:

- Initiate a preliminary sampling and geochemical testing program based on a typical geologic model and mine plan that had been derived from pre-2004 drilling exploration results.
- As drilling and mine planning proceeded over subsequent years, expand the sampling and testing program, as required, to ensure complete geochemical representation of geology, mineralogy, and spatial distribution and to accurately predict/treat water quality during a typical mine operation and closure.

The following sections discuss the major task and activities for the sampling, testing, and water quality prediction work that has occurred since 2004.

8.2.3.1 Tasks and Activities for 2004

In 2004, only the Pebble West deposit had been defined. Tasks and activities for 2004 addressed geochemistry studies primarily as they related to the operation and closure of a typical open pit mine. Work focused on selecting and testing samples collected prior to 2004.

Activity 1: Sample Selection and Collection

The work consisted of conducting a preliminary review of existing project information and scope, followed by sample collection.

The following are activities in the preliminary review:

- Reviewing the definition of deposit geology, the typical mine plan, and project description to estimate representative mine rock quantities, the sizes of overburden, mine rock and tailings stockpiles, requirements for construction rock, and pit wall geology and mineralogy.
- Confirming regulatory requirements and guidelines.
- Examining existing drill core and sample data from previous drilling programs, the existing geologic database, core logs, and availability of core samples.
- Geostatistical analyses of drillhole data with respect to environmental parameters and model information.
- Reviewing the metallurgical program and geology, to assess the scope for tailings testing.
- Characterizing mine rock geology and distribution.
- Defining representative pit wall geology for estimating representative pit lake geochemistry.
- Reviewing the planned drilling program, including exploration, geotechnical, metallurgical, and geo-environmental holes for possible mine rock and pit walls, and to define additional drilling requirements.
- Identifying key parameters for geochemical testing and for baseline environmental monitoring.

- Incorporating environmental geochemistry parameters and rock management criteria into the geologic database (preliminary database for directing sampling).
- Evaluating surrogates and analyses for rock management (preliminary results for directing sampling).
- Developing a geochemical sampling and testing plan, including numbers of samples and descriptions, test methods and laboratory procedures, a quality management program, and data handling protocols.

Sample collection consisted of the following:

- A site visit to review available core information to develop a specific understanding of the site geology as it related to environmental geochemistry, and to initiate collection of representative mine-rock samples.
- Mine-rock sampling, including sample selection and collection from existing cores, pulps and rejects, and fresh cores from the 2004 drilling program. Site geologists collected these samples, using rigorous protocols consistent with geological sampling.
- Selection of representative tailings samples from batch metallurgical testing, and from detailed metallurgical testing. These samples were provided by the metallurgical testing laboratory upon discussion with SRK investigators.

Selecting representative samples for testing is the most critical component of a technically sound and practical geochemical characterization program. Samples for the Pebble Project were selected to address a wide variety of variables that may affect geochemistry:

- Geologic features in the Pebble Project area and resulting variations in geology/lithology/mineralogy and metal content.
- Spatial distribution of the ore deposit (horizontal extent and depth).
- In situ weathering, oxidation, or mineral enrichment as a result of geologic processes.
- Open pit (and, after 2005, underground mine) typical design parameters, including reserve estimate, total tonnages by rock type, strip ratio, pit/mine wall geology.
- Processing alternatives.
- Deposition alternatives for process wastes.

In addition, samples also included native soils and rock from representative tailings and mine-rock storage areas to assess the potential for native materials to attenuate seepage from these types of facilities. These samples were collected as part of the geotechnical test pit sampling program.

Selecting Representative Mine Rock Samples. Based on the pre-2004 geologic model and the analytical information from approximately 16,000 samples from previous exploration programs, it was anticipated that up to 1,000 representative mine rock samples (both Tertiary and pre-Tertiary) would be collected in 2004. It was planned to select samples from both existing (i.e., pre-2004) and fresh cores, because testing both old and fresh samples of comparable geology can provide valuable information on the weathering characteristics of a rock type, and provide an empirical basis for calibrating water chemistry predictions

for mine rock and pit walls. Of the proposed 1000 samples selected, it was planned to test approximately 500 samples for initial static testing and, subsequently, 25 kinetic tests.

To ensure complete geochemical representation, it was proposed to select further samples for analysis, as required, to resolve uncertainties or gaps in sampling. Addressing the potential variability in the geology/geochemistry of the deposit, as described earlier, is considered the key to a representative sampling program. For this reason, a large number of samples were collected and tested in a staged approach to ensure that there were no information gaps. It is not sufficient or appropriate to select the number of samples simply proportional to the amount of rock that each represents. Table 8-2 summarizes the approximate number and type of samples that SRK planned to collect from existing cores and from the 2004 drilling program. Figure 8-1 shows the locations of proposed drillholes for 2004 and from which samples were to be collected in 2004.

All exploration geologic samples were logged in the field with respect to geology and alteration, and were assayed. These data, as well as the resultant geologic models, are also considered in the geochemical characterization study.

Selecting Representative Tailings Samples. Tailings samples were collected from each stage of metallurgical testing (including batch testing and locked-cycle testing) and from each ore-sample composite. It was planned to select up to 12 tailings samples, depending on the number of feed/tailings streams that were maintained throughout the metallurgical testing program. In addition, samples of process-water derived from bench-scale tests of simulated milling processes and of the final tailings solutions were collected for detailed water quality analyses.

Activity 2: Geochemical Testing

Geochemical testing included both static and kinetic tests. The combined results of these tests provided a complete and detailed characterization of the range of mine rock geology and mineralogy in the deposit, as it was known then. In addition, the data provides information that can be used for design and closure planning including assessing options for managing mine wastes (e.g., use of rock for construction, potential for co-disposal of rock with tailings), estimating changes in pit wall geochemistry over time, and evaluating options for stockpile management.

The scope of kinetic testing changed as results of static tests became available. This change of scope was required to ensure that all key variables that determine the geochemistry of the sample, and thus the measures required for managing mine wastes, were addressed in the testing.

A detailed geochemical testing plan, complete with specific methods, number of samples, and laboratory procedures, was prepared for review for each of the static and kinetic phases of testing proposed. In addition, the plan included procedures, or modifications to procedures, that provided important information for assessing the water chemistry and water management programs. The methods used for geochemical characterization of both mine rock and tailings are consistent with international industry standards and protocols. The approach and principles described in the document *EPA and Hardrock Mining: A Source Book for Industry in the Northwest and Alaska* (EPA, 2003), provides the basis for the testing program. The test procedures follow those documented by the American Society for Testing and Materials (ASTM), Environmental Protection Agency, or the Mine Environment Neutral Drainage (MEND) program.

Testing Mine Rock. The representative mine rock geochemical testing program was conducted according to a phased approach, beginning with a small group of static and kinetic tests to provide an initial understanding of mine rock geochemistry, followed by a more targeted approach on a larger number of samples, based on possible project needs.

Thus, the main activities for geochemical testing of mine rock for 2004 were to implement the first, preliminary phase of work, consisting of the following:

- Static testing – testing a small suite of both Tertiary and pre-Tertiary rock samples to provide initial data for input into subsequent testwork design. Static testing procedures included metal analysis by inductively coupled plasma (ICP) and atomic absorption (AA) spectrophotometry, ABA (using standard and modified procedures), and short-term leach extractions.
- Kinetic testing – running a small number of tests (primarily on pre-Tertiary rock) to provide initial kinetic information, to be used to plan a test program to address specific mine design questions and water quality prediction needs. This work was proposed but not completed in 2004.

Testing Tailings. The same phased approach was employed for representative tailings geochemical testing, with the exception that samples were initially selected from the batch metallurgical testing that was being conducted on a large variety of ore types, composites, or processing methods. This was followed by a second phase of selecting products from locked-cycle metallurgical testing that was being conducted on a fewer number of ore samples. It was expected that this phased approach could provide the data necessary for future assessment of alternatives for tailings deposition (number and type of facilities), constraints for managing tailings water, and requirements for water treatment.

The scope of the tailings geochemical testing program is determined by the range of ore processing options evaluated in the metallurgical testing program. Priorities for tailings testing are to sample and test a representative range of tailings samples, including those potentially placed in a tailings impoundment and those used for dam construction. Both solids (i.e., tailings) and process water are tested.

The major activities for tailings geochemical testing in 2004 were as follows:

- Static testing – testing a subset of tailings samples selected (as above) from metallurgical testing of various process alternatives and metallurgical composites and of tailings products from flowsheet design testing.
- Kinetic testing – testing a subset of tailings samples selected from metallurgical testing of process alternatives.

Data Analysis. Static and kinetic test results are used to define the geochemical units that determine drainage water chemistry. These geochemical units may be the same as the lithologic definitions, or may also be based on factors such as alteration, metal content, location in pit, etc. From these definitions of the distinct geochemical units, the block model and pit designs could be used to quantify the amount of each unit in pit walls and mine rock.

Data from the static and kinetic testing programs are reviewed on a regular basis for quality management, and to evaluate the geochemical behavior of the materials.

Bench-scale testing of aquifer materials from the deposit area was also conducted. The results of this testing allowed SRK to estimate the natural attenuation properties of these materials along potential groundwater flow paths down-gradient from the study area

Activity 3: Water Chemistry Prediction

Predicting water chemistry consists of three steps:

- Predicting drainage-water chemistry by rock type and then applying the information to possible types of mine facilities (i.e., open pit walls, mine rock storage piles, and tailings impoundment[s], including beaches, dams, and saturated tailings mass).
- Geochemical modeling using commercially or publicly available software.

8.2.3.2 Tasks and Activities for 2005

The main tasks and activities for 2005 were to build on work initiated in 2004, including selecting and collecting additional representative rock and tailings samples for geochemical characterization, conducting static tests, initiating the kinetic testing for rock samples, continuing/expanding the kinetic testing for tailings, analyzing water samples derived from kinetic tests, and evaluating data (including water chemistry predictions).

Activity 1: Sample Selection and Collection

The sample selection and collection activity in 2005 began with a re-examination of existing information, including the following:

- Review of the evolving definition of deposit geology, revision of estimates of possible quantities of mine rock, sizes of mine-waste piles/stockpiles, requirements for construction rock, pit-wall geology, and mineralogy.
- Review of the most current definition of possible pit-wall geology for pit-lake geochemistry.
- Ongoing assessment of regulatory requirements and guidelines.
- Geostatistical analyses of 2004 drillhole data with respect to environmental parameters.
- Cooperation with the metallurgical and geology studies with respect to tailings testing.
- Incorporation of environmental geochemistry parameters and rock-management criteria into the revised geologic database.

Based on this information, the following types of samples were selected for testing:

- Mine rock samples from the 2004 drilling program, collected by site geologists using the same protocols as in 2004.
- Tailings samples from batch metallurgical testing and from detailed-design metallurgical testing, provided by the metallurgical testing laboratory.
- Soils and rock from possible tailings and mine-rock storage areas, collected as part of the geotechnical test-pit sampling program.

Representative samples of both mine rock and tailings were selected to assess the full range of variables that affect geochemistry, as discussed above (Section 8.2.3.1)

Selecting Mine Rock Samples. The scope of work for the first phase of representative mine rock sampling (completed in 2004) focused on the distribution of rock types indicated by pre-2004 diamond drilling. The second phase of work in 2005 focused on selecting rocks within the extensively drilled central part of the mineralized zone; specifically, sampling 2004 cores that had been drilled near the eventual vicinity of possible open pit walls. It was proposed to collect a total of 600 mine-rock samples from both phases of work (i.e., the pre-2004 and the 2004 drilling programs) for static testing.

It was also proposed to refine earlier sample selection and select additional samples for the kinetic tests on mine-rock samples that were collected in 2004.

In addition to sampling for static and kinetic testing, additional samples were selected in 2005 for analysis as required to resolve any uncertainties or gaps in sampling—to fulfill the criteria for representative sampling.

Selecting Tailings Samples. As in 2004, SRK investigators in 2005 collected representative tailings samples from each stage of metallurgical testing (including batch and locked-cycle testing) that was being conducted on each representative ore sample/composite identified to date. Collected samples were subjected to both static and kinetic testing.

Activity 2: Geochemical Testing

A detailed geochemical testing plan, complete with specific methods, number of samples, and laboratory procedures was prepared in 2004 for each of the static and kinetic phases of testing (see Section 8.2.3.1). Both static and kinetic tests were conducted on representative mine rock and tailings samples, as described in the following sections.

Testing Mine Rock. The main activities in the mine rock testing program in 2005 were as follows:

- Static testing – characterizing Tertiary and pre-Tertiary mine rock in the vicinity of possible pit walls. Testing procedures included solids analysis by ICP and AA, ABA (using both standard and modified procedures), and short-term leach extractions.
- Kinetic testing – Kinetic testing of both Tertiary and pre-Tertiary mine rock was initiated in 2005 to characterize rock type, support water-quality predictions, and address specific mine design questions. Test procedures included humidity cells (according to ASTM methodology), leach columns, and, as required, saturated columns or sequential kinetic tests for evaluating storage options such as underwater storage of mine rock or co-storage of mine rock with tailings. Specifically, SRK investigators proposed implementing 28 “long-term” humidity cell tests and five subaqueous column tests (six subaqueous columns were eventually set up, one of which was stopped because regular water quality test data showed a stable trend).

Testing Tailings. The representative tailings characterization program continued according to the phased approach started in 2004. During Phase 1, samples were selected from the batch metallurgical testing on a large variety of ore types, composites, and/or processing methods. In 2005, a second phase of samples

was proposed for the products of the locked-cycle tests that were expected to be conducted on a fewer number of ore samples (i.e., only those that were considered most representative of the deposit).

The major activities for the tailings geochemical testing in 2005 were as follows:

- Static testing – ongoing testing of tailings products from metallurgical work.
- Kinetic testing – testing samples from metallurgical-scoping work and of tailings products from flowsheet work, as testing was completed, and samples from modified flowsheets, as required, to address tailings-management options. It was proposed to conduct up to 15 kinetic tests (humidity cells and columns, including the 12 tests that had been proposed in 2004), depending on the number of tailings-impoundment alternatives proposed and the number of feed/tailings streams that were being maintained throughout the metallurgical testing program.

In addition, process-water samples from bench-scale tests of possible milling processes and of the associated final tailings solutions were collected for detailed water quality analyses.

Data Analysis. Data analysis continued according to the same methods described for 2004.

Activity 3: Water-Chemistry Prediction

As described in Section 8.2.3.1, above, predicting water chemistry involves data collection, geochemical modeling, and water-balance and geochemical loading balance calculations. This work continued in 2005:

8.2.3.3 Tasks and Activities for 2006

The proposed work for 2006 was primarily a continuation of kinetic testing started in 2005. The following kinetic testing was under way at the beginning of 2006:

- Mine rock humidity cells—13 tests (on both Tertiary and pre-Tertiary rock).
- Mine rock subaqueous leach columns—six tests (on pre-Tertiary rock, only).
- Tailings humidity cells—two tests.
- Tailings sub-aerial leach columns—six tests.

The data from these tests were reviewed in June 2006 to determine which, if any, tests could be terminated. Four of the mine-rock humidity cells and one of the mine-rock subaqueous leach columns were stopped because water quality data from the tests had reached a stable trend; the balance of the tests continued through 2006.

In addition to the kinetic testwork, SRK investigators continued with ABA testing of selected overburden samples provided by the Pebble Partnership's exploration geologist from the 2006 drilling program. Other static testing (i.e., metal analysis, etc.) was conducted by the exploration team.

8.2.3.4 Tasks and Activities for 2007

The work for 2007 continued and expanded some components of existing studies on the Pebble West deposit and, because of the Pebble East discovery, began the characterization of representative mine rock

and tailings for the Pebble East deposit. Studies conducted in 2007 were performed as in 2004 and 2005, with some exceptions, as described below.

Figure 8-2 shows the locations of the drillholes from which cores were expected to be sampled for the 2007 geochemical study.

Pebble West Studies

For Pebble West, 2007 studies focused primarily on improving understanding of the weathering and leaching of Tertiary rock, which is needed for construction. In addition, characterization of some tailings and overburden samples also continued.

Tertiary Rock: Evaluation of Tertiary rock included the following:

- Determining the presence and types of carbonate minerals in Tertiary rock to obtain an accurate understanding of the neutralization potential of these minerals. These data were needed so that potentially acid-generating (PAG) mine rock can be segregated for separate storage rather than be used for construction. Samples were tested using x-ray diffraction, and individual mineral grains were analyzed using microprobes.
- Characterizing the mineral forms of arsenic and selenium in individual mineral grains found in Tertiary rock. These data were needed to understand the potential for these elements to leach from Tertiary rock and to develop a source term (i.e., a predictor for the quality of leachate chemistry) for Tertiary rock.
- Constructing small-scale on-site leaching tests to evaluate weathering of Tertiary rock under field conditions. These were planned to consist of "barrel tests" containing about 250 kilograms of rock, each. It was planned to initiate the tests after breakup and monitor them through the open-water season in 2007. Waters were sampled once a month and analyzed for the same suite of water quality parameters as for the kinetic tests. Parallel bench-scale leach tests were conducted in the laboratory on the same material to calibrate the barrel tests.
- Conducting water quality tests to evaluate the leaching behavior of Tertiary rock under sub-aqueous conditions. The test protocols were comparable to those previously used for assessing the subaqueous columns set up in 2005 and continued in 2006 for pre-Tertiary rock.
- Testing seven existing Tertiary rock humidity cells.

Pre-Tertiary Rock: The proposed work for 2007 was primarily the continuation of kinetic testing started in 2005. The following kinetic testing was under way:

- Mine rock humidity cells—two tests.
- Mine rock subaqueous leach columns—four tests.

Tailings. The proposed work for 2007 was primarily the continuation of kinetic testing started in 2005. The following kinetic testing was under way:

- Tailings humidity cells—two tests.
- Tailings subaerial leach columns—two tests.

Up to 2007, metallurgical studies and geochemical testing had only been done on "non-pyritic" tailings. In 2007, kinetic testing began on pyritic tailings derived from metallurgical process tests of Pebble West ores.

Overburden. Samples of overburden collected in 2006 were analyzed in 2007 for total and leachable parameters (e.g., such as metals and ABA parameters).

Pebble East Studies

Although the gross geochemical characteristics of the Pebble East deposit are expected to be similar to those of the Pebble West deposit, there are several aspects of the Pebble East deposit that indicated a need for significant additional characterization:

- Pebble East is richer in copper. The reactivity of the ore and associated mine rock may be different from that for the Pebble West ore deposit.
- Possible underground-mining methods such as block caving presumably will result in broken, ore-grade rock remaining in the mine.
- If mining occurs, the underground workings will flood afterwards, resulting in long-term subaqueous conditions for broken and fractured, weathered pre-Tertiary and Tertiary rocks.

Pre-Tertiary and Tertiary rock in the vicinity of Pebble East have not been characterized to date. The following studies were planned for 2007:

- Selecting a suite of rock samples from existing diamond drill core using a similar approach to that used for Pebble West in 2005. Samples were selected to characterize Tertiary and pre-Tertiary rock. Roughly 400 samples were selected.
- Analyzing the samples for ABA calculations using the same methods as for Pebble West samples. Element concentrations were determined on the samples by ICP and AA analysis, if this was not previously done as part of the exploration program.
- Using the ABA and element concentration data to select samples for kinetic testing. It was proposed to start approximately 28 humidity cell tests.
- Starting subaqueous column tests on Tertiary and pre-Tertiary rock.

Metallurgical studies on Pebble East ores provided representative tailings for testing. Testwork initiated on these samples included the following:

- Static testing (i.e., ICP and AA analysis, ABA, and short-term leach extraction).
- Mineralogical characterization to determine forms and composition of minerals.
- Kinetic testing, including humidity cells, sub-aerial columns, and subaqueous columns depending on the types of samples provided by the metallurgists.

8.2.3.5 Tasks and Activities for 2008

The work for 2008 was largely a continuation from 2005, 2006, and 2007. Laboratory tests conducted on samples taken from previous years will be continued for samples collected in 2008. More recent assessment of the distribution of sulphur in the Tertiary cover rocks showed that most lithologies were associated with two distinct sub-populations. To ensure that samples included in the characterization program had covered the complete range of sulphur characteristics shown by the Tertiary lithologies, attributes of the Tertiary samples selected for inclusion in humidity cell testwork were compared to attributes of these sub-populations. For the most part, the selected samples were considered representative of both sulphur sub-populations identified. However, in the case of the dacite (TD) and mudstone (TY), the samples do not fully represent the high-sulphur populations. For this reason, two extra samples were added to the 2008 sampling program. Figure 8-3 shows the sample locations.

8.2.3.6 Tasks and Activities for 2009

The work for 2009 was largely a continuation of the following programs from the 2005, 2006, 2007, and 2008 Study Plans: kinetic testing on Pebble West rock samples, kinetic testing on Pebble West representative tailings samples, field weathering (barrel tests) and parallel laboratory studies, and kinetic testing on Pebble East rock samples.

8.2.3.7 Tasks and Activities for 2010

The work for 2010 was largely a continuation of 2009 with the following additional activities: characterization of Pebble East representative tailings and characterization of representative pyritic tailings.

8.3 References

Environmental Protection Agency (EPA). 2003. EPA and Hardrock Mining: A Handbook for Industry in the Northwest and Alaska. EPA Region 10 with the technical assistance of Science Applications International Corporation. Seattle, Washington.

TABLES

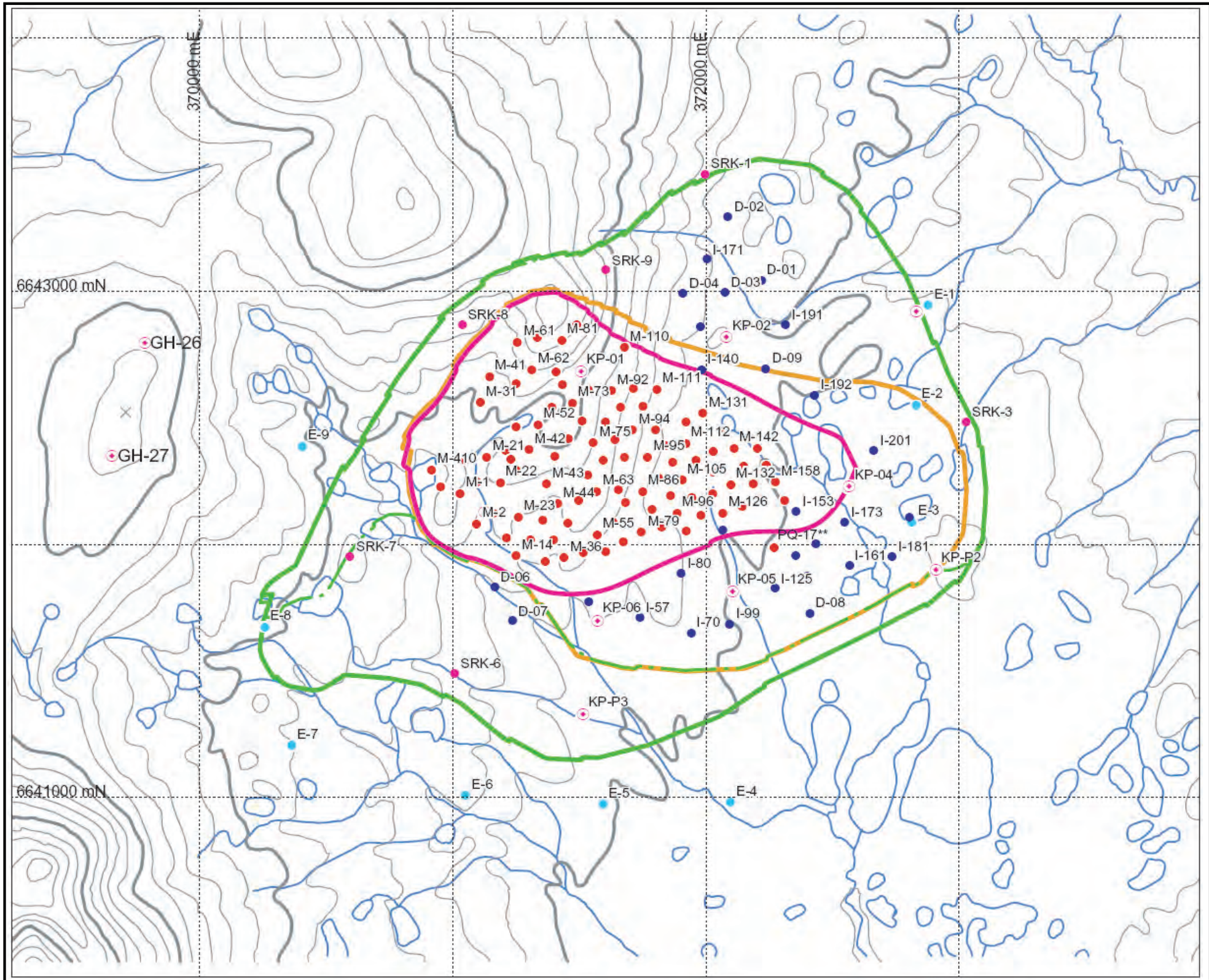
TABLE 8-1
Pebble Project Environmental Baseline Studies
Study Summary for Geochemical Characterization and Metals Leaching/Acid Rock Drainage, Mine Study Area, 2004-2008
Consultant: SRK Consulting

2004 Data Collected or Tasks	2005 Data Collected or Tasks	2006 Data Collected or Tasks	2007 Data Collected or Tasks	2008 Tasks to be Completed	2009 Tasks to be Completed	2010 Tasks to be Completed
Selection of samples for static testing	Initiation of humidity cells on rock samples	Continued kinetic testing on rock samples	Continue kinetic testing on Pebble West rock samples	Continue kinetic testing on Pebble West rock samples	Continue kinetic testing on Pebble West rock samples	Continue kinetic testing on Pebble West rock samples
Static testing	Initiation of humidity cells on representative tailings samples	Continued kinetic testing on representative tailings samples	Continue kinetic testing on Pebble West representative tailings samples	Continue kinetic testing on Pebble West representative tailings samples	Continue kinetic testing on Pebble West representative tailings samples	Continue kinetic testing on Pebble West tailings samples
Selection of samples for kinetic testing	Initiation of column tests on rock samples	Additional static testing on rock	Mineralogical characterization of element occurrence in Tertiary rock	Mineralogical characterization of element occurrence in Tertiary rock	Continue field weathering (barrel) tests and parallel laboratory studies	Continue field weathering (barrel) tests and parallel laboratory studies
Visit to site to review logging practices	Initiation of column tests on representative tailings samples		Mineralogical characterization of carbonate in Tertiary rock	Mineralogical characterization of carbonate in Tertiary rock	Continue kinetic testing on Pebble East rock samples	Continue kinetic testing on Pebble East rock samples
Selection of drill-holes for mine walls	Additional static testing on mine-wall drillholes		Commence field weathering (barrel) tests	Continue field weathering (barrel) tests and parallel laboratory studies		Characterization of Pebble East tailings
	Specific characterization of Tertiary rock samples		Select samples for ABA and kinetics for Pebble East	Continue kinetic testing on Pebble East rock samples		Characterization of pyritic tailings
	2004 progress report		Characterization of Pebble East representative tailings	Characterization of Pebble East representative tailings		
			Characterization of pyritic representative tailings	Characterization of pyritic representative tailings		

TABLE 8-2.
Number of Samples of Each Rock Type Selected for Geochemical Characterization in 2004

Stratigraphic Section	Rock Type	Unit Designation	Number of Samples
Quaternary Deposits	Ferricrete	Fc	2
	Overburden	Ob	8
Tertiary Rocks	Sedimentary Units	TC/TW/TY	24
	Volcanic Units	TA/TB/TD	17
Pre-Tertiary Rocks:	Diorite/Gabbro	D	45
Cretaceous Stratiform and Cross-cutting Plutonic Rocks	Granodiorite-Quartz-Monzodiorite	G (Gp and Gs)	70
	Monzodiorite	N	39
	Monzonite	F (and X2)	17
	Monzonite (near Stock A)	M	12
	Intrusion Breccia	X	23
	Porphyritic Monzodiorte to Quartz Monzodiorite	P	13
	Skarn	K	5
Pre-Tertiary Rocks:	Andesitic Bedded Rocks (Argillite, Siltstone)	Y	90
Jurassic to Cretaceous Sedimentary and Volcano-sedimentary Rocks	Andesitic Bedded Rocks (Volcaniclastic Sandstone, Wacke)	W	8
Other		R	17
		Z	9

FIGURES



THE pebble PARTNERSHIP

Figure 8-1
Consolidated Study Program 2004-2008
Geochemical Characterization and ML/ARD
Existing and Proposed Drill Holes (2004)
Mine Study Area

Legend

Proposed Drill Holes
- Measured
- Indicated
- Geotechnical
- Geochemical
- Exploration

Pit Outlines
- Stage 1 (Payback Pit)
- Stage 2 (Feasibility Pit)
- Stage 3
- Stage 4 (Ultimate Pit)

N

200 0 200 400 600
Datum NAD27 - Zn5 (Alaska) Meters

File: NA	Date: April 14, 2009
Version: 1.0, Rev.	Author: NDM / EVW

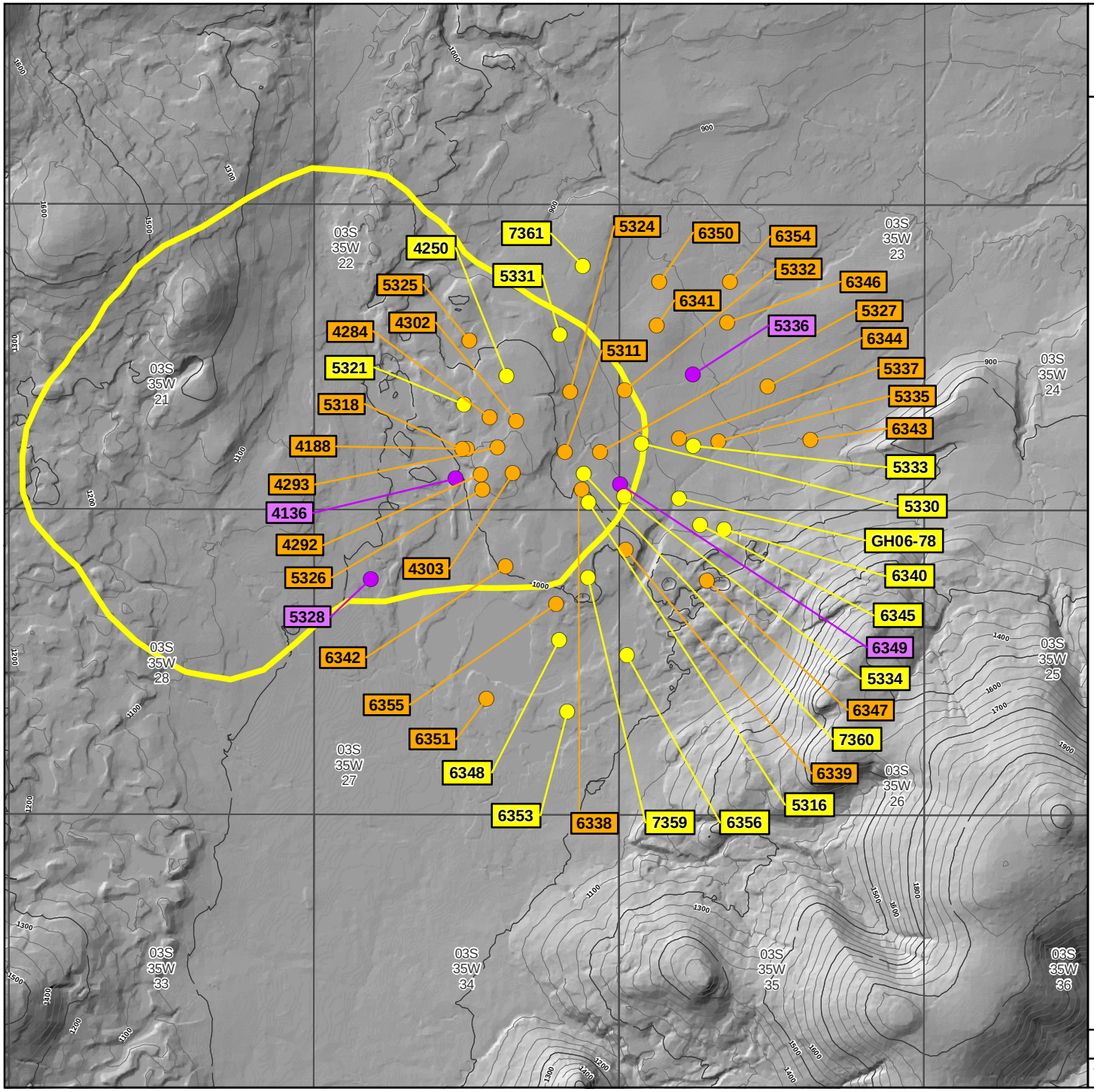


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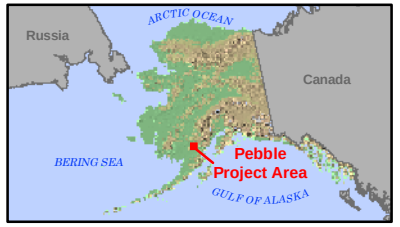
Figure 8-y
Consolidated Study Program;
2004-2008
Geochemical Characterization and ML/ARD
Location of Existing Diamond Drill Holes Proposed for Sampling and Testing (2007)
Mine Study Area

Legend

- Tertiary Rock Characterization
- Cretaceous Rock Characterization
- Tertiary and Cretaceous Rock Characterization
- General Deposit Location
- 6341 Example Drill Hole Identification Label

Note: Contours derived from Eagle/Kodiak 1:4800 mapping. Interval 50'.



Miles
0 0.25 0.5 0.75 1
Kilometers
0 0.25 0.5 0.75 1
N

Scale 1:30,000
Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: RDI_SRK_Drillholes_Fig8-3_8x11L_D03.mxd	Date: April 15, 2009
Version: 3	Author: RDI-LS

1400000 1405000 1410000

2160000

2155000

6350 6354 6341 6346 5331 7365 5325 4250 5324 7364 6344 4284 5337 5335 5311 5327 5326 7363 6378 6342 5328 7359 6347 6351

N

0 1,000 2,000
feet

THE pebble PARTNERSHIP

Figure 8-3
Consolidated Study Program;
2004-2008
Collars of Diamond Drill-holes
Sampled for Humidity Cell and
Subaqueous Column Testwork, 2008
Mine Study Area

DRILL HOLES SAMPLED FOR

- HUMIDITY CELL TESTWORK
- SUBAQUEOUS COLUMN TESTWORK
- 6346 EXAMPLE DRILL HOLE IDENTIFICATION LABEL
- OTHER DRILL HOLES
- GENERAL DEPOSIT LOCATION

Scale as shown

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: PEB_DrillPlan_SRK_Humidity_Subaqueous_Samples_2008.WOR

Date: Aug. 28, 2008 | Drawn by: YL, HDSI

Pebble Project
Environmental Baseline Studies
2004 through 2008
(with updates through 2010)

CONSOLIDATED STUDY PROGRAM

9. TERRESTRIAL WILDLIFE AND HABITAT

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ACRONYMS AND ABBREVIATIONS

ABR	ABR, Inc.—Environmental Research & Services
ADF&G	Alaska Department of Fish and Game
agl	above ground level
AKNHP	Alaska Natural Heritage Program
BONAP	The Biota of North America Program
CSP	consolidated study program
CIR	color infrared
GIS	geographic information system
GPS	global positioning system
MCHTWG	Mulchatna Caribou Herd Technical Working Group
NASA	National Aeronautics and Space Administration
NPS	National Park Service
SOP	standard operating procedure
3PP	Three Parameters Plus
USFWS	U.S. Fish and Wildlife Service
USGS	United States Geological Survey

9. TERRESTRIAL WILDLIFE AND HABITAT

The terrestrial wildlife and habitat component of the environmental baseline description for the Pebble Project includes existing data review, reconnaissance surveys, habitat mapping, and sampling/analysis of select tissues from species that are harvested by local peoples for subsistence use.

ABR, Inc.—Environmental Research & Services (ABR) is conducting the work in collaboration with the Pebble Partnership, staff from federal and state agencies, and some of the consultants working on other disciplines (e.g., trace elements, laboratory services, and fish and aquatic invertebrates).

The work is being carried out in several study areas: (1) the mine study area and surrounding regions, (2) the transportation corridor/Cook Inlet study areas, and (3) portions of Iliamna Lake. Seven elements of study, corresponding to different species assemblages, are included in each area. The work in this consolidated study program (CSP) is discussed separately according to study area and species group.

9.1 Mine Study Area

9.1.1 Study Objectives

The wildlife and habitat study is designed to determine the species assemblages and the abundance of, distribution of, and habitat use by terrestrial wildlife in the Pebble Deposit area and surrounding regions. In addition, an assessment of rare-plant occurrence potential at the deposit area is being conducted. The objectives are as follows:

- Document baseline conditions for wildlife populations and habitats.
- Collect data for use in baseline studies by other disciplines.

9.1.2 Mammals

The mammal study is designed to supplement existing information from previously published and unpublished work in the region and from telemetry data previously collected by management agencies for use in impact analyses. This information is being compiled and analyzed, and field surveys are being conducted of sufficient quality and quantity to provide site-specific information on mammal species to supplement the information gained from the literature review, thereby augmenting and strengthening the existing baseline data.

9.1.2.1 Study Area/Scope

The wildlife and habitat study work for the mine study areas is summarized in Table 9.1-1, according to species group.

The area of study encompasses the deposit area and surrounding drainages (Figure 9.1-1).

Several lines of inquiry are being pursued in this study:

- Field surveys, emphasizing aerial survey by fixed-wing airplane and, to a lesser extent, by helicopter.
- Radio-telemetry surveys and analysis of regional telemetry data for caribou, under the terms of cooperative agreements with agencies.
- Analysis of regional harvest data for big game and furbearers.
- Solicitation of mammal sightings in the study area by other personnel working on the baseline studies program.

The principal mammal species of interest is caribou—it is the most abundant large mammal in the region and one that is important both for subsistence use and sport hunting. The deposit area is located within the annual range of the Mulchatna Herd. One of the hallmarks of the Mulchatna Herd has been the unusual and substantial variation it has shown in range use in the last 15 years. In previous years, the deposit area was thought to host a small number of resident caribou and to provide locally important calving habitat and occasionally winter range. More recently, the herd has used the area during the post-calving aggregation period and the rut. Field information regarding use of the deposit area by caribou is being obtained for the following seasons: late winter/spring, calving, post-calving aggregation (early summer), fall migration/rut, and early winter.

Other large mammal species also are important residents of the region. Brown bears are abundant in southwestern Alaska, and black bears also occur in the project region. Winter concentrations of moose have been noted previously in the Upper Talarik Creek drainage (as described in the Alaska Department of Fish and Game Habitat Management Guide [ADF&G, 1985]). These species are included in the wildlife surveys for this study, as are others (e.g., furbearers) encountered incidentally during surveys for mammals and other species.

9.1.2.2 Methods/Approach

The general approach of the mammal surveys is to supplement existing information gained from a literature review of previously published and unpublished work in the region, and to compile and analyze telemetry and harvest data previously collected by management agencies. In addition, field survey data (aerial surveys and wildlife observation logs) provide site-specific information on large mammal species (primarily caribou and brown bears) to supplement the information gained from the literature review.

The methods used are described in the following sections.

Aerial Surveys

The primary method used to survey large mammal species in the mine study area is systematic aerial surveys of strip transects (spaced at 1-mile intervals on United States Geological Survey [USGS] section lines; Figure 9.1-1) from a Cessna 206 or similar fixed-wing airplane. The size of the transect survey area in 2004 was chosen to encompass the deposit area and surrounding drainages. These transects were extended slightly in 2005. The primary species of interest are caribou, brown bear, and moose, but all species of large mammals (e.g., furbearers) are recorded and mapped opportunistically whenever encountered on each survey.

All transect surveys use a double-count approach employing two observers viewing the same 875-yard-wide transect strip on the right side of the airplane to quantify "sightability" of animals in the transect strip (defined as "the probability that an animal within the observer's field of search will be seen by that observer"; Caughley, 1974). Data are recorded by a third observer (preferably a local resident, e.g., from a subsistence council or panel) sitting on the left side of the airplane. Complete coverage of the survey area is obtained. The airplane is flown at airspeed of approximately 85 knots and altitude of 500 feet above ground level (agl) (occasionally higher or lower, as dictated by terrain) for all surveys. All mammal locations are recorded using a global positioning system (GPS) receiver for portrayal on maps created in a geographical information system (GIS). Standard data (number, sex/age [when possible], activity, direction of movement) are noted.

Field-survey data provide site-specific information on terrestrial mammal species to supplement the habitat-use information gained from a literature review. Analysis focuses on enumerating and mapping species seen on the surveys for a general assessment of distribution and relative abundance in the survey area, rather than deriving statistically rigorous estimates of regional populations and densities. ADF&G has some regional density estimates of caribou and brown bear populations.

Telemetry Data Analysis

An important element of the mammal study is to analyze existing telemetry data for caribou, bears, and moose. Extensive caribou data have been obtained previously in the project region by state and federal resource agencies (bear and moose data in the area are less available). These data constitute an important base of information for use in the environmental baseline report. The intent is to work cooperatively with ADF&G and U.S. Fish and Wildlife Service (USFWS) to perform these types of project-specific analyses, using fixed kernels and other methods of GIS analysis to summarize and depict seasonal distribution patterns of various species.

Harvest Data Analysis

ABR investigators request from ADF&G its annual harvest data on mammal species in the project region to provide background on human use of mammal species. Furbearer harvest data and trapper reports from specific stream drainages (Uniform Coding Units [UCUs]) also provide important background information on the distribution and abundance of these species, which can be difficult to enumerate using field methods. This effort is coordinated with the subsistence component of environmental baseline description for the Pebble Project to further document harvest levels and locations in the study areas.

Wildlife Observation Logs

To take advantage of and solicit input from other contractors working on the project, wildlife observation log sheets are posted prominently in common locations at camps for workers to record miscellaneous sightings of wildlife encountered anywhere in the study area. This approach, which greatly expands the number of potential observers, was used successfully at the Pogo Mine in interior Alaska and produced useful information for the environmental baseline report and environmental impact statement for that project by taking advantage of the presence of other observers when survey biologists were not present. The effectiveness of this system is increased by having wildlife survey crews give informal talks while at work camps to explain the research program to other workers. Observation log sheets are distributed in electronic form to other contractors to solicit their input as well.

9.1.2.3 Major Tasks and Activities

Tasks and Activities for 2004

Specific tasks and activities of the mammal study in 2004 were as follows:

- Conduct six field surveys, emphasizing aerial survey by fixed-wing airplane and, to a lesser extent, by helicopter.
- Analyze regional telemetry data.
- Analyze regional harvest data.
- Solicit mammal sightings in the study area by other personnel working on the baseline studies program.

Two of the six fixed-wing surveys focused primarily on other species (bears in late July/early August and moose in late November), but recorded caribou at the same time.

In addition to the six seasonal fixed-wing surveys, at least one additional survey by helicopter was proposed specifically to search for and examine bear dens in the mine area and to look for seasonal concentrations of bears along anadromous fish streams in the mine study area. It was also planned to solicit from other project personnel their observations of locations of suspected bear dens for examination during this survey.

A helicopter survey dedicated to locating and examining bear dens was not done in 2004. Rather, incidental observations of bear emergence (i.e., identifying and following bear tracks across spring snow fields to locate dens) were recorded during spring fixed-wing surveys. These recordings were then followed up on August 18 and 19, 2004, with specific helicopter visits to the dens located.

Tasks and Activities for 2005

The tasks and activities for 2005 were the same as those for 2004:

- Field surveys, emphasizing aerial survey by fixed-wing airplane and, to a lesser extent, by helicopter.
- Radio-telemetry surveys and analysis of regional telemetry data for caribou, under the terms of cooperative agreements with agencies.
- Analysis of regional harvest data for big game and furbearers.
- Soliciting other personnel working on the baseline studies program for their mammal sightings in the study area.

The same methods were used as in 2004, with some minor changes as described below.

Aerial Transect Surveys. The size of the transect survey area was extended slightly in 2005. The primary species of interest continued to be caribou, brown bear, and moose, but all species of large mammals were recorded and mapped opportunistically whenever encountered on each survey. The following list details the seasonal timing and primary purpose of each survey window:

- Early March: late winter moose and caribou distribution.
- Early May: spring bears (after den emergence and before leaf-out).
- Late May: caribou and moose calving.
- Late June or early July: caribou post-calving.
- Mid-July: caribou post-calving and bears along salmon-spawning streams (mine study area emphasis).
- Mid-August: bears along salmon-spawning streams (transportation corridor/Cook Inlet study areas emphasis).
- Mid-October: Caribou breeding season (rut).
- Late November or early December: Early winter moose and caribou.

Radio-telemetry surveys by fixed-wing airplane were planned in 2005 under the terms of cooperative agreements to be worked out with ADF&G, as discussed and agreed to at a meeting of the Mulchatna Caribou Herd Technical Working Group (MCHTWG) in January 2005. By Alaska state regulation (5 AAC 92.047, Permit for Using Radio Telemetry Equipment), telemetry surveys by private contractors require a permit from ADF&G. It was planned to fly telemetry surveys to search for VHF-radio-collared caribou in the region surrounding the mine within 2 days of each scheduled transect survey, and to fully share the data obtained with the MCHTWG.

In addition to fixed-wing-aircraft surveys, an additional survey by helicopter was proposed specifically to search for and examine bear dens in the mine study area in early May, and two other helicopter surveys were proposed to look for seasonal concentrations of bears along anadromous fish streams in the mine study area in mid-July and mid-August. In addition to specific surveys, the locations of suspected bear dens were solicited from other project personnel for examination during these surveys.

Telemetry Data Analysis. A continuing important element of the mammal study was analysis of existing telemetry data for caribou, bear, and moose collected previously in the region by state and federal resource agencies. In a meeting with MCHTWG in January 2005, it was recognized that the successful application of these methods depend on cooperation with agency biologists to identify and work with existing data sets. ABR investigators acknowledged the potential sensitivities regarding access to such data. Memoranda of understanding were established regarding which data would be used and for what purpose, as well as how they would be analyzed and presented.

Harvest Data Analysis. As in 2004, ABR investigators requested harvest data on big game and furbearer species in the project region from ADF&G to provide background on human use of mammal species, according to the methods described above.

Wildlife Observation Logs. Also as in 2004, ABR investigators continued to solicit input from other contractors working on the project on their miscellaneous sightings of wildlife encountered anywhere in the study area. Observation log sheets were distributed in electronic form to other contractors to solicit their input as well. For instance, the fisheries research team recorded bears observed during their spawning-stream surveys, adding to the information gathered in the ABR surveys of those important seasonal-use areas.

Tasks and Activities for 2006

Specific tasks and activities for 2006 were the same as those for 2005, with the following changes or additions:

- Map the distribution and quantify the abundance and density of large mammals in the mine study area during important seasonal periods for caribou and brown bears, using aerial transect surveys in the mine study area during early and late May, late June, and July 2006.
- In cooperation with state and federal agencies, complete retrospective analyses of the extensive radio telemetry database for the Mulchatna Caribou Herd to provide a comprehensive assessment of the use of the study area by caribou. Where data existed, brown bear and moose telemetry information was also provided.
- Cooperate with state and federal agencies to obtain existing population and harvest survey data for moose, bears, wolves, other furbearers, and other mammal species in the study area for use in baseline characterization and impact assessment.
- Collect information on mammals from incidental sightings by other personnel working on the project.
- Begin survey planning for moose and brown bears studies, in cooperation with the ADF&G and the National Park Service (NPS).
- Compile and summarize the mammal information from 2004 and 2005 in the environmental baseline document.

Tasks and Activities for 2007

Specific tasks and activities for 2007 were similar to those conducted in previous years, and included the following:

- Map the distribution and record the abundance of large mammals in the mine study area during the post-calving period for caribou, using aerial-transect surveys in late June and mid-July 2007.
- In consultation with the MCHTWG, supplement the analysis of caribou movements in the preliminary environmental baseline document using telemetry data collected since the previous data transmittal in mid-2005.
- Collect information on mammals from incidental sightings by other personnel working on the Pebble Project.
- Supplement the mammal information in the environmental baseline document using data collected since 2004.

Aerial Transect Surveys. The 2007 aerial surveys for large mammals in the mine study area built on research begun in 2004. Baseline data were collected during important seasonal periods for selected species for characterization and for project design purposes for the Pebble Project.

Based on historical evidence and data collected to date, caribou are considered to be the most abundant large mammals in the region and are important for both subsistence and sport hunting. One of the

hallmarks of the Mulchatna Caribou Herd has been its substantial and unpredictable variation in range use during the last 15 years. In view of that variability, baseline information on use of the mine study area by caribou during post-calving aggregation is important. The post-calving period from late June to mid-July is when the greatest use of the mine study area by the largest numbers of caribou occurs, as documented both by field surveys and by analysis of radio-telemetry data obtained from the MCHTWG.

As in 2004 through 2006, the primary method used to survey large mammal species in the mine study area in 2007 was systematic aerial surveys in a fixed-wing airplane. Two surveys (one day each in late June and in mid-July) were proposed to follow established systematic strip transects to provide complete coverage of the mine study area. The primary species of interest for the surveys in 2007 was caribou, but all species of mammals were recorded and mapped opportunistically whenever encountered on surveys.

Wildlife Observation Logs. To solicit input from the Pebble Partnership staff and contractors working on the Pebble Project, wildlife observation log sheets were posted in common locations at camps for workers to record miscellaneous sightings of large, medium, or small mammals encountered anywhere in the vicinity of the project. This approach, which increases the number of potential observers, was used successfully in 2004 through 2006 at the Pebble Project base in Iliamna and has yielded useful information by taking advantage of the presence of other observers when survey biologists were not present.

Tasks and Activities for 2008

No field surveys for mammals were conducted in the mine study area in 2008. Although no field surveys were conducted in 2008, the following tasks were accomplished:

- Cooperated with state and federal agencies to obtain existing population and harvest survey data for moose, bears, wolves, other furbearers, and other mammal species in mine study area for use in baseline characterization.
- In consultation with the MCHTWG, the analysis of caribou movements in the preliminary environmental baseline document was supplemented using updated telemetry data.
- Compiled and summarized the mammal information collected from 2004 through 2007 for the environmental baseline document.
- Collected information on mammals from incidental sightings by other personnel working on the Pebble Project.

Tasks and Activities for 2009

The following tasks were accomplished in 2009:

- In consultation with the MCHTWG, the analysis of caribou movements in the preliminary environmental baseline document was supplemented using updated telemetry data.
- A brown bear survey was designed and implemented by ADF&G with help from ABR (Figure 9.1-7)

Tasks and Activities for 2010

- In consultation with the MCHTWG, the analysis of caribou movements in the preliminary environmental baseline document was supplemented using updated telemetry data.
- A moose population survey was conducted that closely followed the methods outlined in Kellie and DeLong (2006), which were designed by ADFG for regional-scale large mammal surveys. The study will be conducted in a broad region surrounding the deposit area and in the region north of Iliamna Lake and south of Lake Clark National Park (Figure 9.1-7).

9.1.3 Raptors

The goals of the raptor surveys for the mine study area are to determine the distribution, abundance, and productivity of nesting raptors in the deposit area and surrounding drainages. Special emphasis has been placed on protected or sensitive species, such as Bald and Golden Eagles, Peregrine Falcons, and Northern Goshawk. The specific goals are listed as follows:

- Identify and map raptor nest sites and determine occupancy and productivity of these sites.
- Delineate important tree- and cliff-nesting raptor habitats in the region of the Pebble Deposit.
- Compile a comprehensive list of raptor species nesting in and using the region of the Pebble Deposit.
- Develop strategies to avoid or minimize effects on raptors in the area, including avoidance guidelines for helicopter and fixed-wing-aircraft pilots.

9.1.3.1 Study Area/Scope

In 2004, the study area included all suitable woodland and cliff habitat available for nesting raptors located in the mine study area (Figure 9.1-2). Suitable habitat within a 1-mile buffer outside the outer boundaries of these areas also was surveyed. Large, suitable habitat features (such as large cliffs or drainages) more than 1 mile outside the outer boundaries also were surveyed when they appeared to provide raptor nesting habitat.

In 2005, ABR investigators increased the size of the survey area for raptors in the mine study area (Figure 9.1-2). This increase was largely in response to initial agency comments on ABR's 2004 study plan calling for broader study regions for most wildlife surveys.

The scope of the raptor survey for baseline study emphasizes species that have special legal or conservation status. Bald Eagles and Golden Eagles are emphasized because they are afforded special protection under the Bald and Golden Eagle Protection Act (U.S. Congress, 1940). The American Peregrine Falcon subspecies, although delisted as an endangered species in 1999, is included in our baseline studies, along with other cliff-nesting raptors, because of continued agency interest in its populations and sensitivity to disturbance. All cliff-nesting raptors (including the coastal subspecies of Peregrine Falcon, whose range may include the Lake Clark/Iliamna region) will be identified during the cliff-nesting surveys for Golden Eagles. Other tree-nesting species (e.g., Northern Goshawk) may be identified during pre-leaf-out surveys for Bald Eagles.

A subspecies of the Northern Goshawk is a State of Alaska Species of Special Concern (ADF&G, 1998) in southeast Alaska. Although nests of Northern Goshawks may be discovered during surveys for Bald Eagles, more intensive coverage of woodland nest sites is often necessary to locate nests of the former species. In 2004, an aerial survey was conducted to search for Northern Goshawk nests within the mine study area. However, because nests in coniferous woodlands are difficult to detect from aircraft, this survey provided only a conservative estimate of sites. An alternative was to conduct play-back recordings of goshawk calls. Play-back recordings in such a large area, however, would have been cost-prohibitive and premature. Moreover, these are intensive survey techniques designed to help locate specific nest sites, which were not considered necessary because suitable habitat in the deposit area appeared to be limited.

9.1.3.2 Methods/Approach

This work will be accomplished through a combination of:

- Aerial surveys in the mine study area.
- Literature and agency file review to collect information on raptors in the region and other known nest sites.

9.1.3.3 Major Tasks and Activities

Tasks and Activities for 2004

Two aerial surveys of suitable nesting habitats were conducted by helicopter in the mine study area to identify large raptors nesting sites. Suitable nesting habitats included cliffs for Peregrine Falcons, Gyrfalcons, and Golden Eagles, and trees for Bald Eagles and other woodland raptors, including Osprey, Northern Goshawks, *Buteo* hawks, and Great-horned Owls. The activities were as follows:

- Surveys were conducted during the arrival and early nesting (incubation) stages for these species (late April to late May). The first survey was conducted before deciduous tree leaf-out (late April-early May) and was used to identify the nests of tree-nesting species, particularly the Northern Goshawk and Bald Eagle. The second survey was planned to occur at least 2 weeks later and was used to identify cliff-nesting raptors, particularly Gyrfalcons, Peregrine Falcons, and Golden Eagles.
- Low level (~150 feet agl) helicopter surveys of suitable forest stands, cliffs, banks, and islets were undertaken with two observers seated on the same side of the aircraft searching woodlands and cliffs for signs of use by nesting raptors (stick nests, ledges, aggressive or perched birds). Multiple passes of some habitats (cliffs) were necessary. Standard operating procedures (SOPs) included flying shorelines of the ocean, lakes, streams, and areas of substantial topographical relief.
- SOPs for Goshawks, Bald Eagles, and other tree-nesting raptors included flying above good woodland stands, and along creeks, hillsides, and lake edges. All islets and islands were also searched. Flights included appropriate angles to look into stick nests.
- SOPs for habitat searches for cliff-nesting species included angling toward the cliff or bank area at least one-half mile from the site and slowly approaching the cliff area. Observers searched for all incidences of whitewash, stick nests, perched and flying birds, and areas of orange-crustose

lichen. When a nest or suggestions of nesting occurred (e.g., aggressive pair), observers identified the location and took a digital picture of the site. Sites were enumerated chronologically as they were found.

- All observations of raptors were recorded on USGS topographic maps (scale 1:63,360) or on aerial photos. Locations also were recorded using an onboard GPS receiver.
- Information recorded at each site included the species present, physical characteristics of the nest site, a brief habitat description, occupied status, and numbers of birds (adults and nestlings) observed.

Tasks and Activities for 2005

In 2005, ABR investigators continued surveys to locate nests and determine occupancy, but added productivity surveys and a mid-winter Bald Eagle survey. These consisted for two helicopter surveys each in suitable habitats for tree- and cliff-nesting raptors to identify and assess the occupancy of raptor nests (Occupancy Survey) and to assess productivity (Productivity Survey) in the mine study area. A separate fixed-wing-aircraft survey was undertaken in mid-winter to determine if any Bald Eagles winter in the area.

As in 2004, suitable nesting habitats included cliffs for Peregrine Falcons, Gyrfalcons, and Golden Eagles, and forested areas for Bald Eagles and other woodland raptors, including Osprey, Northern Goshawks, *Buteo* hawks, and Great-horned Owls. Common Raven nests also were recorded. The activities were as follows:

- Occupancy Surveys were conducted during the arrival and early-to-mid-incubation stages for raptors in the region (late April to late May). The first survey occurred before deciduous tree leaf-out in early May and was used to identify the nests of tree-nesting species, particularly the Northern Goshawk and Bald Eagle. The second survey was planned to occur at least 2 weeks later and was used to identify cliff-nesting raptors, particularly Gyrfalcons, Peregrine Falcons, and Golden Eagles.
- Productivity Surveys were undertaken during the mid-to-late-nestling period for raptors in the region (between late June and late July). These surveys also allowed ABR investigators to identify active nests missed during occupancy surveys and to help determine the status of ambiguous nests.
- Low-level (approximately 150 feet agl) helicopter surveys of suitable forest stands, cliffs, banks, and islets were undertaken according the same SOPs employed in 2004 (see above).
- SOPs for Goshawks, Bald Eagles, and other tree-nesting raptors included flying to good woodland stands, along creeks, on hillsides, and along lake edges. All islets and islands were also searched, using the same SOPs employed in 2004.
- Habitat searches for cliff-nesting species were conducted in 2005, according to the SOPs employed in 2004.
- All observations of raptors were recorded on USGS topographic maps (scale 1:63,360) or aerial photos. Locations also were recorded using an onboard GPS receiver.

- Information recorded at each site included the species present, physical characteristics of the nest site, a brief habitat description, occupied status, and numbers of birds (adults and nestlings) observed.
- Finally, a fixed-wing-aircraft survey was conducted to determine if Bald Eagles overwinter in the region. Two observers searched open-water areas in November and mid-February for Bald Eagles. The SOP for this survey included low-level flights in all areas of open water.

Tasks and Activities for 2006

No field surveys for raptors were conducted in 2006, other than one fixed-wing aircraft survey in November to further assess if Bald Eagles overwinter in the region.

Tasks and Activities for 2007-2010

No field surveys for raptors were conducted in 2007 through 2010. Data compilation, analysis and reporting continued for the data collected from 2004 through 2006.

9.1.4 Waterbirds

The goal of the waterbird study is to determine the distribution, status, and relative abundance of waterbirds in the deposit area and surrounding drainages. Emphasis is placed on waterfowl and waterbirds of special concern, including two species of swans, Harlequin Ducks, loons, and gulls. The major goals are as follows:

- Determine the timing, distribution, and abundance of staging waterbird groups during spring and fall migration, and of molting groups during mid-summer.
- Determine the distribution and abundance of waterbirds—including ducks, swans and gulls—during the nesting and brood-rearing seasons.

9.1.4.1 Study Area/Scope

In 2004, the study area for waterbirds included all suitable wetland habitats available for migrating, staging, nesting, and brood-rearing waterbirds in the deposit area and surrounding drainages (Figure 9.1-3).

In 2005, the study area was expanded to include additional areas to the north and south of the mine study area that were observed to be used by waterbirds in 2004 (Figure 9.1-3). The added survey areas included Nikabuna and Long lakes (important fall staging areas for swans and ducks in the north end of the study area), Lower and Upper Talarik creeks, and all waterbodies from Lower Talarik Creek to the Newhalen River.

The scope of the waterbird study emphasizes documenting important migration routes, breeding grounds, and bird species. The Alaska Peninsula and the Iliamna Lake region are important migration routes for many bird species moving to and from breeding areas in western and northern Alaska and eastern Asia. Important waterbird species in the area include Tundra Swans and, possibly, Trumpeter Swans, and a diverse assemblage of dabbling and diving ducks. River deltas in Iliamna Lake and the Cook Inlet study

area (see Section 9.2) have been found to serve as migration stopovers in spring before region-wide breakup.

Harlequin Ducks breed in the study area and over-winter on nearshore waters in the Kamishak Bay region. The Harlequin Duck was formerly listed as a species of concern by USFWS (Federal Candidate Species Category 2, Endangered Species Act [U.S. Congress, 1973]). Although its current conservation status is unclear, it has received recent attention by resource agencies, particularly because it has been identified as a species not fully recovered from the *Exxon Valdez* oil spill.

9.1.4.2 Methods/Approach

The study was accomplished as follows:

- Surveying all waterbodies for waterfowl and waterbirds during spring and fall migration (Migration Surveys), nesting and brood-rearing (Breeding Pair Surveys), and molting (Pacific Waterbird Molting Surveys). Surveys consisted of a combination of fixed-wing airplane, helicopter, and ground surveys to determine the distribution, composition, and abundance of breeding waterbirds in the area and to identify areas of high use during nesting, brood-rearing, molting, and migration/staging in the mine study area.
- Reviewing literature and agency files to collect information on waterbirds in the region.
- Describing species composition and the selected use of lakes, rivers, and wetland areas in the general deposit location and surrounding areas.

9.1.4.3 Major Tasks and Activities

Tasks and Activities for 2004

During each survey, the ABR field team counted and mapped the distribution and abundance of waterbirds seen on lakes, rivers, and wetland areas. The activities were as follows:

- For Migration Surveys, low-level, fixed-wing aerial surveys were flown every 8 to 10 days during spring (four surveys between April 21 and May 23) and fall (five surveys between September 2 and October 21), along a pre-selected route covering upland lakes in the mine study area. Lakes were grouped as survey units based on relative closeness and other topographic features. One or two observers (depending which aircraft [Cessna 206 or Piper Cub] proved the better survey platform) gathered information on habitat conditions, flock size, and species composition. The surveys were flown lake-to-lake and the route was tracked using an onboard GPS receiver.
- For the Breeding Pair Survey, a fixed-wing aircraft was flown in early June similar to the annual breeding pair surveys flown near Bristol Bay by the USFWS. A series of transects were flown guided by GPS in the most dense lake areas in the Upper Talarik Creek and Koktuli River basins. Data gathered included species, estimated numbers, and observation type (e.g., male, pair, flock). In addition, a helicopter was used to detect pre-breeding pairs of Harlequin Ducks along streams in the mine study area. Observations were located on topographic maps and with an onboard GPS receiver. Surveys occurred in concert with cliff-nesting raptor surveys in late May/early June.

- A follow-up survey of brood-rearing was undertaken in mid-July. A helicopter was used to visit a sample of lakes in the mine study area. Observations were made from the helicopter. At some larger lakes, the helicopter dropped off two observers who then circumnavigated the lake on foot and counted broods. Data collected included species, numbers, brood size, and age.

Tasks and Activities for 2005

The tasks and activities for 2005 built on the surveys conducted in 2004. During each survey, the field team counted and mapped the distribution and abundance of waterbirds seen on lakes, rivers, and wetland areas. The activities were as follows:

- First, low-level, fixed-wing aerial Migration Surveys were flown during the spring (five surveys between April 21 and May 23) and fall (seven surveys between August 17 and October 12) migration periods.
- For the Breeding Pair Survey, a fixed-wing aircraft was flown in early June in a manner similar to that used in 2004 and for the annual breeding pair surveys flown near Bristol Bay by the USFWS. A series of transects were flown using GPS navigation in the most dense lake areas in the Upper Talarik Creek and Koktuli River basins. Data gathered included species, estimated numbers, and observation type (e.g., male, pair, flock).
- Two Pacific Waterbird Molting Surveys were flown on July 26 and August 11 during the molting period.
- These two sets of surveys were flown along most of the same pre-selected routes as flown in 2004, covering upland lakes in the mine study area (some of routes were eliminated in 2005 because of changes in mine development concepts). As in 2004, lakes and connecting streams and rivers were grouped as survey units based on relative closeness and other topographic features. One observer gathered information on habitat conditions, flock size, and species composition. The surveys were flown lake-to-lake, and the route was tracked using an onboard GPS receiver.
- Two additional surveys to locate nesting gulls and swans were conducted in the mine study area in early June. Both surveys were conducted by two observers: the gull survey in a helicopter at a relatively low elevation; the swan survey in a fixed-wing aircraft at a higher elevation and faster (because they are easier to see than gulls). A series of transects were flown over lake and tundra habitats in the mine study area to search for nesting gulls and swans and between Lower Talarik Creek and the Newhalen River for swans. Nest sites were located on topographic maps and recorded with an onboard GPS receiver.
- Three low-level helicopter surveys were conducted to detect pre-nesting pairs of Harlequin Ducks along streams in open tundra and near waterbodies in the mine study area. Observations were located on topographic maps and with an onboard GPS receiver. Surveys occurred in conjunction with other aerial surveys in mid-May to mid-June to reduce personnel and helicopter costs.
- Similar to 2004, a brood-rearing survey was conducted in mid-July. Two observers circumnavigated lakes and traversed wetlands within selected sample units in the mine study area to identify, count, and age broods. A helicopter was used to transport observers between survey areas as well as to conduct aerial surveys of clusters of small lakes.

Tasks and Activities for 2006 through 2010

No field surveys for waterbirds were conducted in 2006 through 2010. Data compilation, analysis, and reporting continued for the data collected in 2004 and 2005.

9.1.5 Landbirds and Shorebirds

The primary goal of this study is to determine the distribution, abundance, and habitat use of breeding landbirds and shorebirds in the region of the mine study area Specifically, the study is designed to accomplish the following goals:

- Determine which landbird and shorebird species breed in the mine study area.
- Determine the distribution and abundance of those species in the mine study area.
- Quantify the level of habitat use by each species during the breeding season.

9.1.5.1 Study Area/Scope

The study area for landbirds and shorebirds in 2004 (Figure 9.1-4) encompassed the deposit area and surrounding drainages. Surveys focused on the use of habitats by landbirds and shorebirds in this area.

In 2005, the study area was expanded to encompass additional areas (Figure 9.1-4) to coincide with the larger area being mapped for wildlife habitats near the mine study area and with the core areas being surveyed for mammals, raptors, and waterbirds.

At the beginning of the study, information was limited on the bird species that breed and nest in the area, but several species of passerines that are considered conservation priority species for Alaska were recognized as likely to occur. These included Northern Shrike, Gray-cheeked Thrush, Varied Thrush, Blackpoll Warbler, Golden-crowned Sparrow, and possibly others. Breeding information also was sparse for shorebirds, but likely species of conservation concern were thought to include Wandering Tattler, and perhaps Hudsonian Godwit and Short-billed Dowitcher.

At the end of the 2004 field season, a total of 64 bird species had been observed in the study area, and many of those were confirmed as nesting in the area. Thirteen of those 64 species are considered conservation priority species for Alaska by at least one statewide, regional, or national working group focused on bird conservation (ADF&G, 1998; BPIFWG, 1999; ASWG, 2000; Audubon Alaska, 2002; USFWS, 2002). Ten of those 13 species of conservation concern were confirmed as nesting in the area (American Golden-Plover, Pacific Golden-Plover, Whimbrel, Hudsonian Godwit, Surfbird, Short-billed Dowitcher, Arctic Warbler, Gray-cheeked Thrush, Blackpoll Warbler, and Golden-crowned Sparrow).

Thus, in 2005, ABR investigators continued the habitat-based surveys. Designed for a range of species, including the species of conservation concern noted above, the surveys yielded data to enable accurate assessments of habitat preferences for landbirds and shorebirds in the study area. These habitat-association data were intended to be incorporated into GIS overlays to determine acreages of breeding bird habitats.

9.1.5.2 Methods/Approach

To support this scope of work, the following methods and approaches were used:

- Identify species occurrence, distribution, and abundance of breeding landbirds and shorebirds in the mine study area using point count and circular study plot techniques.
- Determine the habitat associations of landbirds and shorebirds in the study area, based on ground observations in pre-identified locations in each habitat type.

Point counts are used to detect singing male passerine birds defending territories. They consist of recording all species seen or heard within standard 10-minute intervals at a select sample point location (Ralph et al., 1995). The location of point-count plots are determined by habitat type identified in the study area. Observations include categorizing estimated distance categories to allow density calculations, thus yielding the number of species and individual birds found in a particular habitat type at each point-count location (Laake et al., 1994; Rosenstock et al., 2002). Because of the high variability inherent in landbird and shorebird point-count data (patchiness in bird presence on the landscape), it is necessary to collect multiple data points in each habitat type. ABR investigators attempted to survey at least 30 point count locations in each habitat (as recommended by Ralph et al. [1995] for habitat-association data). The data are presented as densities, if the data are sufficient to allow density estimates; otherwise, the data are presented as birds per point. In addition, the locations of all nests discovered opportunistically were recorded with a GPS receiver; dedicated nest searching was not planned.

Circular study plots were initially proposed in 2004 to be used in open habitats where cryptic ground-nesting shorebirds may occur. Plots of 1.57 acres (1,476-foot radius) were proposed, where two observers would record all species seen or heard as the observers, working simultaneously, would walk the plot in concentric circles around the plot center. These circular plot studies yield data for species present and for densities of birds. No specific attempt is made to locate nests of any species because this requires a much more substantial effort. After preliminary efforts in 2004 and interviews with other researchers and investigators conducting bird surveys, it was decided that this methodology unnecessarily duplicated and did not yield better results than the point-count surveys. The methodology was dropped from the study plans for subsequent years.

Habitat information was collected at each survey location to allow accurate determinations of habitat use for a range of breeding bird species. It was also assumed that this effort could be ongoing with additional data collected in subsequent years, as needed, to increase sample sizes. This protocol of assembling habitat-use data across years is an accepted practice in studies of habitat relationships of landbirds and shorebirds and does not depend on using random methods to locate sample points (Hutto and Young, 2002). With sufficient data for each habitat type, it is understood that ABR will be able to make more robust estimates of habitat association information for landbirds and shorebirds in the Pebble Project area.

9.1.5.3 Major Tasks and Activities

Tasks and Activities for 2004

Breeding landbirds and shorebirds in the mine study area were surveyed in June 2004, using a combination of point counts to locate singing or calling birds. Wildlife habitats for each observation were recorded in the field to determine the habitat associations of landbirds and shorebirds in the area.

The locations of survey points were determined based on habitat types as identified from existing land-cover data for Lake Clark National Park (which covers a portion of the mine site) and from 1970s and 1980s high-altitude color infrared (CIR) aerial photography from the National Aeronautics and Space Administration (NASA).

The field team conducted point counts at several locations in each major habitat type in the mine study area to quantify the natural variability in bird species and numbers occurring in each habitat type. At the beginning of the study in 2004, it was unclear how many habitat types occurred in this area, but 80-point counts were assumed sufficient at that time. Point counts focused in those areas in proximity to the deposit area. Point counts were conducted to record all species seen or heard at each sample point location, using the techniques described above.

Tasks and Activities for 2005

In 2005, the survey area was expanded. ABR investigators used point counts for the breeding bird surveys in the mine study area. These surveys were scheduled for late May/early June 2005, to occur during the peak of breeding for shorebirds and landbirds. Point counts were conducted in order to record all species seen or heard, according to the methodology described above. All observations were categorized in estimated-distance categories to allow density calculations.

To allocate plots for sampling, ABR investigators first evaluated new high-resolution, true-color aerial photographs for the study area that were captured in 2004. Based on that evaluation, they then selectively surveyed particular habitats that were not sampled or were under-sampled during the 2004 breeding bird surveys (missed habitats and under-sampling occurred in 2004 because the survey locations at that time were allocated using much older, lower resolution NASA aerial photography).

ABR field crew conducted habitat-based point counts at 160 locations in 2005. These point-count data yielded the number of species and individual birds found in each habitat type at each point-count location. These data were presented as densities, if the data were sufficient to allow density estimates. Otherwise, the data were presented as birds per point.

Tasks and Activities for 2006 through 2010

No field surveys for landbirds and shorebirds were conducted in 2006 through 2010. Data compilation, analysis and reporting continued for the data collected in 2004 and 2005.

9.1.6 Wildlife Habitat Mapping

The goal of this study is to classify and map wildlife habitats in a broad region surrounding the Pebble Project.

9.1.6.1 Study Area/Scope

Habitat mapping and evaluation are conducted in a contiguous area surrounding the deposit area (Figure 9.1-5). The area proposed for mapping in 2004 was approximately 60,300 acres.

The actual area mapped increased in 2005, and study areas for the various components of the wildlife study were refined as necessary. In 2005, the planned mapping area was adjusted to approximately 72,500 acres to cover the core areas being surveyed for mammals, raptors, waterbirds, and landbirds and shorebirds in the mine study area (Figure 9.1-5). ABR also integrated the mapping of wildlife habitats with the mapping of wetlands by Three Parameters Plus (3PP) to produce an integrated habitat map for the Pebble Project.

The scope of work for the habitat mapping study includes the following:

- Classifying, mapping, and quantifying the areas covered by various habitat types.
- Identifying the importance of these habitats to wildlife species (using survey data specific to the mine—see individual wildlife survey sections above).
- Quantitatively assessing the area of each mapped wildlife habitat using GIS.

9.1.6.2 Methods/Approach

The approach to mapping wildlife habitats is to determine the high-value habitat(s) for a number of wildlife in the study area (including mammals, raptors, waterbirds, landbirds and shorebirds, and amphibians, as noted in this document). Using data from wildlife surveys in the study area, and from a literature review, the most important habitats for these species are determined. Following this, area figures are calculated for the high-value habitats of mammals, raptors, waterbirds, landbirds and shorebirds, and amphibians that are within the study area. Additionally, existing land-cover data for Lake Clark National Park and Preserve (NPS, 2001) are used for mapping wildlife habitats on a broader scale. These public-domain data are coarse-scale (99-foot pixels) and the land-cover classes are general, but the data do cover a broad region surrounding and including the mine study area.

The method for mapping and classifying wildlife habitats involves a series of steps. Habitats are initially identified by stereoscopic interpretation of true-color aerial photography (provided by the Pebble Partnership in early 2005). As necessary, photo interpretations are augmented with NASA high-altitude CIR photography, primarily to verify scrub habitats and partially vegetated areas, both of which are common in the study area. Individual habitat polygon boundaries are then mapped digitally with ArcGIS software onto digital orthophoto mosaics for the area. Each mapped polygon is coded with a vegetation (land-cover) type, a physiography type, a surface-form type, and a provisional wildlife-habitat type. Wildlife habitats are eventually formally derived by combining land-cover types, physiography types, and surface-form types using wildlife-habitat classification systems developed by ABR biologists for similar forest and tundra regions in Alaska. These mapping classification systems have been effectively used in mountainous and lowland terrain similar to that of the Pebble Project study area, at Fort Richardson in southcentral Alaska (Jorgenson et al., 1989, 2003).

All wildlife habitat mapping is supported by ground reference data for the area. Field surveys to collect ground reference data were conducted in the study area in August 2004 and August 2005. The goal of these surveys was to collect vegetation, physiography, and surface-form information for several sample sites representing each photosignature or identified polygon (up to five sites per photo-signature), and to carefully examine, on the ground, those photosignatures that were difficult to interpret during mapping.

Sites are accessed by helicopter and on foot, and located by navigating to pre-determined GPS locations. At a minimum, the dominant plant species are assessed visually and vegetation and surface form types recorded at each site visited. Soil information is collected at the ground reference sites. Wildlife observations, including wildlife sign, are recorded at each site. Starting in 2005, it was intended that rare plants identified during ground surveys would be recorded with photo documentation and voucher specimen collections as part of the rare-plant occurrence-potential study (see Section 9.1.7, below). Documentary photos were taken at each survey location.

It is planned that in subsequent years and once draft habitat maps have been generated, polygon-verification surveys will be conducted to verify those portions of the wildlife habitat maps that have been completed. Map polygons will be corrected as needed following analysis of the field data.

9.1.6.3 Major Tasks and Activities

Tasks and Activities for 2004

The following specific tasks and activities were included for the wildlife habitat study in 2004:

- Photo interpretation of landscape features on CIR photography of the study area.
- Preliminary digital mapping of landscape polygons.
- First-round field surveys to collect ground reference data to aid in identifying photo signatures from photo interpretations.
- Preliminary digital mapping of wildlife habitats.

Tasks and Activities for 2005

The tasks and activities for the wildlife habitat study included the following:

- Confirming early CIR photo interpretations with 2005 true-color aerial photography.
- Second-round field surveys to collect new ground reference data and ground verification data to aid in identifying photosignatures and to use in correcting mapped polygons as needed.
- Continued digital mapping of wildlife habitats.
- An updated evaluation of wildlife use of the mapped habitats.

Tasks and Activities for 2006 through 2010

No field surveys for the wildlife habitat mapping work were conducted in 2006 through 2010. Work focused on digital mapping using the field data collected in 2004 and 2005. ABR investigators also prepared to incorporate data from the wetland and vegetation mapping conducted by 3PP, adding information on physiography and surface form to the vegetation data to yield a multivariate map of wildlife habitats for the mine study area.

9.1.7 Rare-Plant Occurrence Potential

The rare-plant occurrence study was first conducted in 2005. The goals of this work are to determine whether any of the rare plant taxa in Alaska (as listed on the Alaska Natural Heritage Program (AKNHP) Vascular Plant Tracking List [AKNHP, 2004]) have the potential to occur in the Pebble Project area. This work is conducted using existing data on rare plant distributions and habitats, and comparing those to the habitat information collected as part of wildlife habitat study. The desired outcome of the study is to identify those habitats within the Pebble Project area likely to support populations of rare plants.

9.1.7.1 Study Area/Scope

ABR investigators did not conduct actual surveys of rare plants, but instead proposed an office-only study. The area studied was the same as that for the wildlife habitat study (see Figure 9.1-5).

9.1.7.2 Methods and Approach

The approach to the study was to identify the rare plant species that have the potential to occur in the mine study area by reviewing the available literature and by contacting botanists who have conducted surveys near the Pebble Project area. Investigators focused efforts on only those species listed by AKNHP as S1 (i.e., critically imperiled in the state and representing 172 taxa).

The distributions of the S1 species listed by the AKNHP were evaluated for ranges that overlap with the Pebble Project area and for habitats that occur in the area. ABR investigators used distribution and habitat information for rare plant taxa found in several resources (Hultén, 1968; Welsh, 1974; Lipkin and Murray, 1997). In addition, a formal data request to the AKNHP was made for specific collection-location and habitat information for species that have ranges overlapping the study area. Any synonymies in nomenclature and/or taxonomic changes were reconciled using the references above, plus Kartesz (1994) and BONAP (1998). No field surveys were planned for this study.

Based on a preliminary review of plant distributions in the Pebble Project area, ABR investigators expected this study to yield a list of perhaps 10 to 15 rare plant taxa that have the potential to occur in the area because their current ranges overlap the area and because suitable habitat is present broadly in the area. After determining this list of potential rare plant taxa for the area, ABR investigators sought to identify those taxa for which suitable habitats exist within the mine study area.

9.1.7.3 Major Tasks and Activities

The following major tasks and activities for this work were conducted in 2005:

- The literature review, as described above, and consultation with AKNHP personnel to determine the potential for rare plant taxa to occur in the mine study area.
- Identification of habitats in the mine study area that could support populations of rare plants.

It was intended that the remaining work to map and discuss the significance of identified habitats would be completed during compilation of the chapter on threatened and endangered species for the preliminary environmental baseline document.

9.1.8 Wood Frogs

The wood frog study was conducted in 2007, in part to develop a baseline population occupancy database, but also to compare to studies conducted elsewhere on declining amphibian populations worldwide.

Declines in amphibian populations have been occurring worldwide for several decades, due in part to alterations in their development from water-born contaminants and increases in surface water acidity from industrial activities (Blaustein and Wake, 1990; Wyman, 1990), and possibly also due to increases in ultraviolet radiation from reductions in the earth's ozone layer (Blaustein et al., 1994). There is general consensus that such declines have not occurred to a great degree in the wood frog populations in Alaska (the only amphibian species ranging north of southeast Alaska; Hodge, 1976), because water quality and amphibian habitats in the state are generally in pristine condition (note that global effects, such as a thinning ozone layer and global warming, may still present a problem for Alaskan frogs).

Monitoring efforts for wood frog (*Rana sylvatica*) populations in Alaska, however, have been initiated only recently, and there is growing interest in determining population levels, if only to serve as controls in evaluating the declines occurring in other amphibian species in more developed regions of the world. In the first wide-ranging study of wood frogs in southcentral Alaska, Gotthardt (2004) found the species to be "widespread and abundant" in the more developed portions of the Cook Inlet region. Indications are that the species is less common farther west in Alaska, but few surveys have been conducted there.

9.1.8.1 Study Area/Scope

The scope of this study is as follows:

- To assess habitat suitability for wood frogs in the Pebble Project study area.
- To determine the presence/absence (occupancy) of wood frogs in a range of waterbody types in the project study area.

The 2007 wood frog study consisted of an office-based assessment of wood frog habitat in the vicinity of the Pebble Project coupled with occupancy field surveys to evaluate the occurrence of the species in the area.

The mine study area for wood frogs (Figure 9.1-6) is the same as that used for wildlife habitat mapping (Figure 9.1-5).

9.1.8.2 Methods/Approach

A literature search was first conducted to determine habitat use by wood frogs in Alaska and also to compile occurrence data for Pebble Project region (some data already exist on wood frog occurrence from wildlife and fisheries surveys in the area). Based on the results of this search, field surveys were conducted to determine the occupancy of the species in a range of suitable habitats. The results of this study will be integrated with the wildlife habitat mapping study to allow an evaluation of the potential for the species to occur across the study area based on the presence of suitable habitat.

9.1.8.3 Major Tasks and Activities

The major tasks and activities for the wood frog study were conducted in 2007. In the spring, a literature review was conducted specifically for evaluation of habitat use by wood frogs in Alaska and in other boreal forest environments in North America. A summary of habitat use was compiled, and habitats used by wood frogs in other studies were equated to those habitats known to occur (from the wildlife habitat mapping study) in the Pebble Project study area.

Using the true color aerial photography provided by the Pebble Partnership in 2005 and the mapped hydrology for the area, scientists identified waterbody habitats to sample in the study area. Sample locations were randomly located according to waterbody type. The actual survey points were at the edge of each randomly located waterbody and were determined by stratified, random methods using a GIS. Sample sites were accessed by helicopter and on foot by navigating to pre-determined GPS coordinates for each survey point.

The timing of the field surveys for calling male frogs were finalized in late April when an assessment of snowmelt and waterbody-ice conditions in the study area could be made. Surveys were conducted from mid- to late-May 2007.

The surveys focused on determining the presence of the species and followed the protocol of the North American Amphibian Monitoring Program (NAAMP, 2004), with modifications in timing for the long afternoon and dusk periods in Alaska. No systematic sampling efforts were made to quantify the number of frogs present, although qualitative indexes of abundance were made using the Wisconsin calling index (NAAMP, 2004; Gotthardt, 2004). Occupancy sampling involved either a double-sampling scheme or a removal-sampling scheme following the methods for occupancy studies outlined in MacKenzie and Royle (2005) and MacKenzie et al. (2006). A final decision on the specific occupancy study design to be used was made following an evaluation of the number and dispersion of waterbodies throughout the study area. Surveys were kept short (5 minutes) to enable a greater number of habitats to be surveyed in a given day.

Data analysis to determine probability of occupancy in the waterbody types in the study area was conducted using the program Presence, Version 2.0. The use of co-variates (such as air temperature and cloud cover) was considered in the analysis to improve the estimates of occupancy rate.

When the wildlife habitat mapping is complete (not expected until after 2008), researchers will evaluate the potential for wood frogs to occur in appropriate habitats across the Pebble Project study area. Using these mapped habitats and the occupancy data for the study area from 2007, it should be reasonable to extrapolate and predict the occurrence of the species in a range of habitats throughout the study area. With this information, the acreage of suitable wood frog habitat in the study area can be determined.

9.2 Transportation Corridor/Cook Inlet Study Areas

9.2.1 Study Objectives

The objectives of the wildlife studies in the transportation corridor/Cook Inlet study areas are similar to the objectives described above for the mine study area (Section 9.1.1). They include the following:

- Document baseline conditions of wildlife and habitat.

- Collect data for input into other environmental baseline studies by other disciplines.

9.2.2 Study Area

The transportation corridor/Cook Inlet study areas encompass a 2,000-foot wide corridor within portions of the Bristol Bay drainages from the Pebble Deposit to Williamsport and within portions of the area surrounding Iliamna and Iniskin bays.

The study area described above applies to almost all the wildlife studies in the transportation corridor/Cook Inlet study areas as illustrated on Figure 9.2-1 (the study for mammals). The wildlife and habitat study work completed for the transportation corridor/Cook Inlet study areas is summarized in Table 9.2-1, according to species group.

9.2.3 Mammals

The goals, scope, and methods for the mammal surveys and studies to be conducted in this study area are identical to those described for the mine study area (Sections 9.1.2.1 and 9.1.2.2).

The timing of the aerial transect surveys was identical to and used the same aircraft, flight crew, and procedures as in the mine study area (Section 9.1.2.2). Instead of systematically spaced transects, however, the flight line followed a GPS track of a representative road alignment within the corridor, with observations recorded in 875-yard-wide strips on each side of the airplane at a survey altitude of 500 feet agl. The helicopter survey for bears extended a half-mile upstream and downstream of all fish-spawning streams crossed by the representative road route.

In 2005, the scope of work for the mammal study was expanded to include marine mammal surveys. The survey area thus increased into regions surrounding Iliamna and Iniskin bays in the Cook Inlet area. The timing and equipment for the aerial transect surveys was the same as in 2004 and as also described for the mine study area. Different than in 2004, however, transect lines were allocated throughout the transportation corridor to obtain estimates of sightability and density within areas of differing vegetative cover along the corridor.

The study area for the field surveys in 2004 and 2005 is shown on Figure 9.2-1.

Tasks and Activities for 2004

The tasks and activities for 2004 were the same as those described for the mine study area (Section 9.1.2.3). They included aerial surveys, telemetry data analysis, harvest data analysis, and gathering incidental wildlife-sighting data with wildlife observation logs. Refer to Section 9.1.2.2 for the methods employed.

A helicopter survey for bears (conducted in late July/early August) extended beyond the study area corridor to one-half mile upstream and downstream of all fish-spawning streams within this portion of the study area.

Tasks and Activities for 2005

The tasks and activities for 2005 were the same as in 2004 and as those described for the mine study area (Section 9.1.2.3), with the addition of a marine mammal survey (Section 9.3, below).

Reconnaissance-only surveys were conducted in three areas: (1) along the west side of the Newhalen River from Iliamna Lake up to just south of the community of Nondalton, (2) from Seal Spit (at the north end of Iniskin Peninsula) to Iniskin Bay, and (3) at Seal Spit (Figure 9.2-1). These surveys entailed single reconnaissance flights over the areas to visually inspect the potential presence of mammal habitats instead of intensive transect coverage, which is focused on surveying animals directly. ABR investigators recorded observations and took digital photographs of the habitats observed. Investigators supplemented the records from these surveys with existing aerial photography for the area (where available) and information from the literature.

The potential addition of radio-tracking surveys and GIS analyses of agency telemetry data on caribou (as contemplated for the mine study area) applied to the transportation corridor area as well. Agency data sets from past population surveys of bears and moose in the transportation corridor were also sought for inclusion in baseline analyses. Wildlife-observation log sheets posted at camp locations included incidental sightings made at locations along the transportation corridor alternatives.

Tasks and Activities for 2006

No field surveys for mammals in the transportation corridor or for harbor seals in Iliamna Lake were conducted in 2006. Although no field surveys were conducted in 2006, the following tasks were accomplished:

- Cooperated with state and federal agencies to obtain existing population and harvest survey data for moose, bears, wolves, other furbearers, and other mammal species in the transportation corridor for use in baseline characterization and impact assessment.
- Collected information on mammals from incidental sightings by other personnel working on the project.
- Began planning for intensive moose and brown bear surveys, in cooperation with ADF&G and the NPS.
- Compiled and summarized the mammal information from 2004 and 2005 in the preliminary environmental baseline document.

Tasks and Activities for 2007 and 2008

No field surveys of terrestrial mammals in the transportation corridor/Cook Inlet study areas were conducted in 2007 or 2008, but aerial surveys of harbor seal haul-out sites in Iliamna Lake were conducted, as described in Section 9.3, below.

Tasks and Activities for 2009

The following tasks were accomplished in 2009: a brown bear survey was designed and implemented by ADF&G with help from ABR (Figure 9.1-7).

Tasks and Activities for 2010

A moose population survey was conducted that closely followed the methods outlined in Kellie and DeLong (2006), which were designed by ADFG for regional-scale large mammal surveys. The study will be conducted in a broad region surrounding the deposit area and in the region north of Iliamna Lake and south of Lake Clark National Park (Figure 9.1-7).

9.2.4 Raptors

The goals, scope of work, and methods for the raptor surveys in the transportation corridor/Cook Inlet study areas are identical to those described for the mine study area (Sections 9.1.3.1 and 9.1.3.2, above). The study area in 2004 was a representative road corridor of at least 1 mile on either side of a centerline including the Y-valley area between Iliamna and Iniskin bays and the coastal area of each bay (Figure 9.1-2).

In 2005, the study area was revised. Reconnaissance-only surveys were conducted in two areas: (1) from Seal Spit to Iniskin Bay and (2) along the southeast shoreline of eastern Iliamna Lake (Figure 9.1-2). These surveys entailed single flights over the areas to visually inspect the nesting-raptor habitats present during May (nest occupancy period). ABR investigators described cliff and woodland habitat in these corridors and documented any nest sites located during the survey flights. Along Iliamna Lake, reconnaissance surveys were confined to areas generally extending from the shorelines of islands and the main coast of Iliamna Lake along the route and inland approximately one-half mile (Figure 9.1-2). These included the south shoreline of Pile Pay from Pile Bay Village to a point approximately 6 miles west of Squirrel Point and the shorelines of Porcupine, Flat, Seal, Triangle, Rabbit, Twomile, and Tenmile islands. ABR investigators supplemented the records from these surveys with existing aerial photography for the area (where available) and information from the literature.

Field surveys were only conducted in 2004 and 2005. No field surveys for raptors were conducted in 2006 through 2010. Instead, data gathered during 2004 and 2005 were compiled, analyzed and summarized.

9.2.5 Waterbirds

The goals, scope and methods for the waterbird surveys to be conducted are identical to those described for the mine study area (Sections 9.1.4.1 and 9.1.4.2). The study area in this case was within a corridor of at least 1 mile on either side of the centerline of a representative road alignment including the Y-valley area, as shown on Figure 9.1-3. During spring and fall migration, the outlets of rivers flowing into Iliamna Lake were also surveyed for staging waterbirds.

In 2005, the study area was expanded beyond the initial corridor, and reconnaissance-only surveys were conducted in two areas: from Seal Spit to Iniskin Bay and the southeast shore of eastern Iliamna Lake (Figure 9.1-3). These surveys entailed single flights over the areas to visually inspect the waterbird habitats present. ABR investigators recorded their observations and took digital photographs of the habitats observed. They supplemented the records from these surveys with existing aerial photography for the area (if available) and information from the literature.

No field surveys for waterbirds were conducted in 2006 through 2010. Instead data gathered during 2004 and 2005 were compiled, analyzed and summarized.

9.2.6 Landbirds and Shorebirds

Field surveys for landbirds and shorebirds were not conducted in 2004 in the transportation corridor/Cook Inlet study areas. Instead of field surveys, bird occurrence and habitat use information from areas nearby (primarily in Lake Clark National Park and Preserve) were analyzed.

Field surveys were conducted in 2005. The goals, scope and methods for the landbird and shorebird surveys in the transportation corridor/Cook Inlet study areas are identical to those described for the mine study area (Sections 9.1.5.1 and 9.1.5.2). The study area in this case, however, was a 2,000-foot-wide corridor centered on a representative road alignment (including the Y-valley area) and Iliamna and Iniskin bays (Figure 9.2-2).

Reconnaissance-only surveys were conducted in three areas: (1) west of the Newhalen River from the deposit area to Iliamna Lake, (2) along a representative road corridor above the north shore of Iliamna Lake to Williamsport and out to Knoll Head, and (3) a corridor across Iniskin Peninsula from Sea Otter Point to Iniskin Bay (Figure 9.2-2). These surveys entailed single flights over the areas to visually inspect the landbird and shorebird habitats present. ABR investigators recorded their observations and took digital photographs of the habitats observed. They supplemented the records from these surveys with existing aerial photography for the area (where available) and information from the literature.

No field surveys for breeding landbirds and shorebirds were conducted in 2006 through 2010. Data gathered during 2004 were compiled, analyzed, and summarized for the environmental baseline document.

9.2.7 Wildlife Habitat Mapping

The goals, scope, and methods for the habitat mapping to be conducted in the region of the transportation corridor/Cook Inlet study areas are identical to those described for the mine study area (Sections 9.1.6.1 and 9.1.6.2). The study area in this case, however, centered on a representative road alignment as well as in areas of Iliamna and Iniskin bays.

In 2004, the area to be mapped was approximately 18,700 acres, consisting primarily of a 1,312-foot wide representative road corridor from Iniskin Bay to the deposit area, including the Y-valley (Figure 9.2-3).

In 2005, the study area was expanded to approximately 23,800 acres to accommodate a 2,000-foot-wide corridor centered on an additional representative road alignment. Reconnaissance-only surveys were conducted in three of these areas: (1) along a corridor west of the Newhalen River from the deposit area to Iliamna Lake, (2) along a representative road alignment that runs above the north shore of Iliamna Lake to Williamsport and on to Knoll Head, and (3) a corridor across Iniskin Peninsula from Sea Otter Point to Iniskin Bay (Figure 9.2-3). All other areas were surveyed according to the detailed methodology described in Section 9.1.6.2, above.

ABR investigators proposed to use existing (1998) land-cover mapping for Lake Clark National Park and Preserve (NPS, 2001). These land-cover data, derived from Landsat imagery, are coarse-scale (99-foot pixels) and habitat types are general in nature, but they cover a substantial portion of the study area. Investigators proposed to aggregate their fine-scale map classes and map polygons, derived from aerial

photography interpretations, to create the same habitat classes as mapped for Lake Clark National Park from Landsat imagery.

The reconnaissance surveys entailed single flights over the areas to visually inspect the vegetation, physiography, and landforms present (the three primary landscape elements used in the ABR classification of wildlife habitats). Investigators recorded their observations and took digital photographs of the landscape elements observed. They supplemented the records from these surveys with existing aerial photography for the area (if available) and information from the literature.

No field surveys for the wildlife habitats were conducted in 2006 through 2010.

The final step of the study in the transportation corridor/Cook Inlet study areas was to integrate the ABR mapping of wildlife habitats with the mapping of wetlands by HDR Alaska, Inc. and 3PP. This involved combining the ABR physiography and surface form information with the HDR Alaska, Inc. and 3PP vegetation and wetland maps to produce an integrated, mulitvariate map for the Pebble Project for the transportation corridor/Cook Inlet study areas.

9.2.8 Rare Plant Occurrence

The study for assessing the potential for rare-plant occurrence was first conducted in 2005. The goals, scope, and methods for the study in the region of the transportation corridor/Cook Inlet study areas are identical to those described for the mine study area (Sections 9.1.7.1 and 9.1.7.2). The study area in this case, however, is the 2,000-foot-wide corridor centered on a representative road alignment (including the Y-valley area) and locations along the shores of Iliamna and Iniskin bays (same as the study area for landbirds and shorebirds and habitat mapping, as depicted on Figures 9.2-2 and 9.2-3).

No field surveys were conducted for the rare-plant occurrence study. Most of the work was office-based and was conducted in 2005.

9.3 Iliamna Lake Study – Harbor Seals

The wildlife study in Iliamna Lake focuses on marine mammals—most notably harbor seals. The study objectives are similar to those for the wildlife and habitat studies conducted in the mine study area and the transportation corridor/Cook Inlet study areas. Details on the study areas, methods, and work completed are described below. The study work is summarized in Table 9.3-1.

A new aerial survey element was added to the wildlife baseline study in 2005. It used visual counts and photographic coverage of harbor seal haulouts in Iliamna Lake and in Chinitna, Iniskin, Iliamna, and Cottonwood bays (Figure 9.2-1). The survey coverage included the coastal bays to provide more information on seals and other marine mammals (seen incidentally). It therefore complements the boat-based wildlife surveys conducted by the marine study team (CSP 12). The aerial surveys did not include cetacean surveys offshore.

Harbor seal haulouts documented previously in Iliamna Lake (1991, 1998-1999) were photographed using the same methods as in past surveys (Small, 2001). The harbor seal surveys were flown at higher altitudes (800 to 1,000 feet, weather permitting) to minimize disturbance of seals and employed oblique aerial photography with a 35-millimeter camera and zoom lens to facilitate accurate counts of seals using

haulouts. Surveys were timed to coincide with low tide stages and times of day when use of seal haulouts increases and followed techniques used in other recent surveys in the region (Bennett, 1996; Small, 2001). Local observers were consulted about their knowledge of seal haulout locations and use.

Aerial surveys for harbor seals were not conducted in 2006 through 2010.

In 2007, the work in Iliamna Lake was continued. Known haul-out sites reported by previous researchers and confirmed in 2005 were surveyed in 2007 (see Figure 9.3-1 for the location of the 2007 seal surveys). This effort was coordinated with similar aerial surveys of harbor seals using marine haul-out sites in the coastal bays near the Knoll Head (conducted by the marine study team). The same survey methods were used for harbor seals in Iliamna Lake as for harbor seals in the coastal. A pilot and two observers counted seals between May and October from a Cessna 206 airplane (or suitable substitute) flying at an altitude of 1,000 feet agl. Observers used photography to record groups of more than 20 seals for later correction of counts, if necessary. Fewer surveys (12 instead of 22) were flown of the lake haul-out sites than of the marine haul-outs. The period of greatest interest is the month of August, which available data indicate is the peak haul-out period.

The study of Iliamna Lake seals continued in 2007 and 2008 with field studies to provide 3 years of survey data for this high-profile but poorly documented population of harbor seals, which is one of very few populations of lake seals known in the world.

9.4 References

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TABLES

TABLE 9.1-1
Pebble Project Environmental Baseline Studies
Study Summary for Terrestrial Wildlife and Habitat, 2004-2010, Mine Study Area
Consultant: ABR, Inc.

Discipline	2004 Data Collected or Tasks	2005 Data Collected or Tasks	2006 Data Collected or Tasks	2007 Data Collected or Tasks	2008 Data Collected or Tasks	2009 Data Collected or Tasks	2010 Tasks to be Completed
Mammals	**Mine Study Area**						
	Information Gathering / Literature Search	Information Gathering / Literature Search & Review	Information Gathering / Literature Search & Review	Information Gathering / Literature Search & Review	Information Gathering / Literature Search & Review	Information Gathering / Literature Search & Review	Information Gathering / Literature Search & Review
	Scope and Schedule	Scope and Schedule	Scope and Schedule	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan	Scope and Schedule	Scope and Schedule
	2004 Study Plan	2005 Study Plan	2006 Study Plan Summary	2007 Study Plan Summary	2008 Study Plan Summary	2009 Study Plan Summary	2010 Study Plan Summary
	Aerial Transect Surveys (1 each in April, May, July, August, October, November)	Aerial Transect Surveys (1 in March, 2 in May, 1 in June, 1 in July, 1 in August, 1 in October, 1 in December)	Aerial Transect Surveys (2 in May, 1 in June, 1 in July)	Aerial Transect Surveys (1 in June, 1 in July)			
	Bear Den Survey (August)	Bear Den Surveys (1 each in May and July)	Bear Den Surveys (1 each in May and July)				
		Beaver Cache Survey in mine area (1 in October)					
		Mulchatna Caribou Herd Telemetry Data Analysis	Mulchatna Caribou Herd Telemetry Data Analysis	Mulchatna Caribou Herd Telemetry Data Analysis	Mulchatna Caribou Herd Telemetry Data Analysis	Mulchatna Caribou Herd Telemetry Data Analysis	Mulchatna Caribou Herd Telemetry Data Analysis
		Initial Environmental Analysis of Mine Development Concepts and Mitigation Planning	Input to Preliminary Environmental Evaluation Document				
				Plan Brown Bear GPS Telemetry Study	Plan Brown Bear GPS Telemetry Study		
				Develop Plan for Baseline Trace Elements Analysis of Tissues from Terrestrial Mammals	Develop Plan for Baseline Trace Elements Analysis of Tissues from Brown Bears		
					Plan Brown Bear Population Survey	Brown Bear Population Survey	
							Moose Population Survey
	Data Entry and Analysis	Data Entry and Analysis	Data Entry and Analysis	Data Entry and Analysis	Data Entry and Analysis	Data Entry and Analysis	Data Entry and Analysis
	Communication and Data Management	Communication and Data Management	Communication and Data Management	Communication and Data Management	Communication and Data Management	Communication and Data Management	Communication and Data Management
	Coordination with NDM, Agency Meetings	Coordination with NDM, Agency Meetings, and Monthly Reporting	Coordination with NDM, Agency Meetings, and Monthly Reporting	Coordination with PLP, Agency Meetings, and Monthly Reporting	Coordination with PLP, Agency Meetings, and Monthly Reporting	Coordination with PLP, Agency Meetings, and Monthly Reporting	Coordination with PLP and Monthly Reporting
		2004 Progress Report	Draft Environmental Baseline Document	Draft Environmental Baseline Document	Draft Environmental Baseline Document	Draft Environmental Baseline Document	Finalize Draft 2004-2008 Environmental Baseline Document
Raptors	**Mine Study Area**						
	Information Gathering / Literature Search	Information Gathering / Literature Search & Review	Information Gathering / Literature Search & Review				
	Scope and Schedule	Scope and Schedule	Scope and Schedule	Scope and Schedule	Scope and Schedule		
	2004 Study Plan	2005 Study Plan	2006 Study Plan Summary	2007 Study Plan Summary			
	Aerial Surveys for Tree-nesting Raptors (April)	Aerial Surveys to Determine Occupancy (May)					
	Aerial Surveys for Cliff-nesting Raptors (May-June)	Aerial Surveys to Determine Nesting Success and Productivity (June-August)					
		Aerial Surveys for Wintering Bald Eagles (November and February)					
		Initial Environmental Analysis of Mine Development Concepts and Mitigation Planning	Input to Preliminary Environmental Evaluation Document				
	Data Entry and Analysis	Data Entry and Analysis	Data Analysis				
	Communication and Data Management	Communication and Data Management	Communication and Data Management	Communication and Data Management			
	Coordination with NDM, Agency Meetings	Coordination with NDM, agency meetings, and monthly reporting	Coordination with NDM, agency meetings, and monthly reporting	Coordination with PLP, Agency Meetings, and Monthly Reporting			
		2004 Progress Report	Draft Environmental Baseline Document	Draft Environmental Baseline Document	Draft Environmental Baseline Document		Finalize Draft 2004-2008 Environmental Baseline Document

Discipline	2004 Data Collected or Tasks	2005 Data Collected or Tasks	2006 Data Collected or Tasks	2007 Data Collected or Tasks	2008 Data Collected or Tasks	2009 Data Collected or Tasks	2010 Tasks to be Completed
Waterfowl	**Mine Study Area**						
	Information Gathering / Literature Search	Information Gathering / Literature Search & Review	Information Gathering / Literature Search & Review				
	Scope and Schedule	Scope and Schedule	Scope and Schedule	Scope and Schedule	Scope and Schedule		
	2004 Study Plan	2005 Study Plan	2006 Study Plan Summary	2007 Study Plan Summary			
	Spring and Fall Waterfowl Migration Surveys (April, May, Sept, Oct)	Spring and Fall Migration Surveys (April, May, August, Sept, Oct)					
	Breeding Waterfowl Surveys (early June)	Breeding Waterfowl Surveys (late May)					
	Breeding Swan Surveys (early June)	Breeding Swan Surveys (late May)					
	Breeding Harlequin Duck Surveys (May)	Breeding Harlequin Duck Surveys (May)					
	Brood-rearing Harlequin Duck Surveys (July)	Brood-rearing Harlequin Duck Surveys (July, August)					
	Brood-rearing Waterfowl Surveys (July)	Brood-rearing Waterfowl Surveys (July)					
		Breeding Gull Surveys (June)					
		Molting Waterfowl Surveys (July, August)					
		Initial Environmental Analysis of Mine Development Concepts and Mitigation Planning	Input to Preliminary Environmental Evaluation Document				
	Data Entry and Analysis	Data Entry and Analysis	Data Analysis				
	Communication and Data Management	Communication and Data Management	Communication and Data Management	Communication and Data Management			
	Coordination with NDM, Agency Meetings	Coordination with NDM, Agency Meetings, and Monthly Reporting	Coordination with NDM, Agency Meetings, and Monthly Reporting	Coordination with PLP, Agency Meetings, and Monthly Reporting			
		2004 Progress Report	Draft Environmental Baseline Document	Draft Environmental Baseline Document	Draft Environmental Baseline Document		Finalize Draft 2004-2008 Environmental Baseline Document
Breeding Birds	**Mine Study Area**						
	Information Gathering / Literature Search	Information Gathering / Literature Search & Review	Information Gathering / Literature Search & Review				
	Scope and Schedule	Scope and Schedule	Scope and Schedule	Scope and Schedule	Scope and Schedule		
	2004 Study Plan	2005 Study Plan	2006 Study Plan Summary	2007 Study Plan Summary			
	Breeding Bird Point-Count Surveys (June)	Breeding Bird Point-Count Surveys (June)					
	Data Entry and Analysis	Data Entry and Analysis	Data Analysis	Data Analysis			
	Communication and Data Management	Communication and Data Management	Communication and Data Management	Communication and Data Management			
	Coordination with NDM, Agency Meetings	Coordination with NDM, Agency Meetings, and Monthly Reporting	Coordination with NDM, Agency Meetings, and Monthly Reporting	Coordination with PLP, Agency Meetings, and Monthly Reporting			
		2004 Progress Report	Draft Environmental Baseline Document	Draft Environmental Baseline Document	Draft Environmental Baseline Document		Finalize Draft 2004-2008 Environmental Baseline Document
Habitat Mapping	**Mine Study Area**						
	Information Gathering / Literature Search	Information Gathering / Literature Search	Information Gathering / Literature Search				Information Gathering / Literature Search
	Scope and Schedule	Scope and Schedule	Scope and Schedule	Scope and Schedule	Scope and Schedule	Scope and Schedule	Scope and Schedule
	2004 Study Plan	2005 Study Plan	2006 Study Plan Summary	2007 Study Plan Summary	2008 Study Plan Summary	2009 Study Plan Summary	2010 Study Plan Summary
	Habitat Surveys to Ground Truth Aerial Photography (August)	Habitat Surveys to Ground Truth Aerial Photography (August)					
	Map Coordination with 3PP	Map Coordination with 3PP	Map Coordination with 3PP	Map Coordination with 3PP	Map Coordination with 3PP	Map Coordination with 3PP	Map Coordination with 3PP
	Data Entry and Analysis	Data Entry and Analysis	Data Analysis and Digital Habitat Mapping	Data Analysis and Digital Habitat Mapping	Data Analysis and Digital Habitat Mapping	Data Analysis and Digital Habitat Mapping	Data Analysis and Digital Habitat Mapping
							Wildlife Habitat-use Evaluations
	Communication and Data Management	Communication and Data Management	Communication and Data Management	Communication and Data Management	Communication and Data Management	Communication and Data Management	Communication and Data Management
	Coordination with NDM, Agency Meetings	Coordination with NDM, Agency Meetings, and Monthly Reporting	Coordination with NDM, Agency Meetings, and Monthly Reporting	Coordination with PLP, Agency Meetings, and Monthly Reporting	Coordination with PLP and Monthly Reporting	Coordination with PLP and Monthly Reporting	Coordination with PLP and Monthly Reporting
		2004 Progress Report					Finalize Draft 2004-2008 Environmental Baseline Document

Discipline	2004 Data Collected or Tasks	2005 Data Collected or Tasks	2006 Data Collected or Tasks	2007 Data Collected or Tasks	2008 Data Collected or Tasks	2009 Data Collected or Tasks	2010 Tasks to be Completed
Threatened and Engangered Species				**Mine Study Area**			
				Information Gathering			
				Scope and Schedule	Scope and Schedule		
				2007 Study Plan Summary			
				Data Compilation and Analysis			
				Draft Environmental Baseline Document	Draft Environmental Baseline Document		Finalize Draft 2004-2008 Environmental Baseline Document
Wood Frogs				**Mine Study Area**			
				Information Gathering / Literature Search & Review			
				Scope and Schedule	Scope and Schedule		
				2007 Study Plan Summary			
				Presence/absence Surveys (mid-May)			
				Data Analysis			
				Communication and Data Management			
				Coordination with PLP, Agency Meetings, and Monthly Reporting			
				Draft Environmental Baseline Document	Draft Environmental Baseline Document		Finalize Draft 2004-2008 Environmental Baseline Document

TABLE 9.2-1
Pebble Project Environmental Baseline Studies
Study Summary for Terrestrial Wildlife and Habitat, 2004-2010, Transportation Corridor/Cook Inlet Study Areas
Consultant: ABR, Inc.

Discipline	2004 Data Collected or Tasks Completed	2005 Data Collected or Tasks Completed	2006 Data Collected or Tasks Completed	2007 Data Collected or Tasks Completed	2008 Data Collected or Tasks Completed	2009 Data Collected or Tasks Completed	2010 Data Collected or Tasks Completed
Mammals	**Transportation Corridor/Cook Inlet Study Areas**						
	Information Gathering / Literature Search	Information Gathering / Literature Search & Review	Information Gathering / Literature Search & Review	harbor seal surveys in Iliamna Lake	harbor seal surveys in Iliamna Lake	Brown Bear Survey in cooperation with ADF&G	Moose Population Survey
	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Recommendations				
	2004 Study Plan	2005 Study Plan	2006 Study Plan Summary				
	Aerial Reconnaissance Surveys (1 each in April, May, July, August, October, November)	Aerial Transect Surveys (1 in March, 2 in May, 1 in June, 1 in July, 1 in August, 1 in October, 1 in December)					
	Aerial Survey of Bears on Salmon Spawning Streams (1 in August)						
			Beaver Cache Survey (1 in October)				
	Data Entry and Analysis	Data Entry and Analysis	Data Analysis	Data Analysis	Data Analysis		
	Communication and Data Management	Communication and Data Management	Communication and Data Management	Communication and Data Management	Communication and Data Management		
	Coordination with NDM, Agency Meetings	Coordination with NDM, Agency Meetings, and Monthly Reporting	Coordination with NDM, Agency Meetings, and Monthly Reporting	Coordination with PLP, Agency Meetings, and Monthly Reporting	Coordination with PLP, Agency Meetings, and Monthly Reporting		
		2004 Progress Report	Draft Environmental Baseline Document	Draft Environmental Baseline Document	Draft Environmental Baseline Document		
			Planning for Cooperative Survey Efforts with Agencies	Planning for Cooperative Survey Efforts with Agencies	Planning for Cooperative Survey Efforts with Agencies		
Raptors	**Transportation Corridor/Cook Inlet Study Areas**						
	Information Gathering / Literature Search	Information Gathering / Literature Search & Review	Information Gathering / Literature Search & Review				
	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Recommendations	Scope and Schedule	Scope and Schedule	Scope and Schedule	Scope and Schedule
	2004 Study Plan	2005 Study Plan	2006 Study Plan Summary				
	Aerial Surveys for Tree-nesting Raptors (April)	Aerial Surveys to Determine Occupancy (May)					
	Aerial Surveys for Cliff-nesting Raptors (May-June)	Aerial Surveys to Determine Nesting Success and Productivity (June-August)					
		Aerial Surveys for Wintering Bald Eagles (November and February)					
	Data Entry and Analysis	Data Entry and Analysis	Data Analysis				
	Communication and Data Management	Communication and Data Management	Communication and Data Management				
	Coordination with NDM, Agency Meetings	Coordination with NDM, Agency Meetings, and Monthly Reporting	Coordination with NDM, Agency Meetings, and Monthly Reporting				
		2004 Progress Report	Draft Environmental Baseline Document	Draft Environmental Baseline Document	Draft Environmental Baseline Document	Draft Environmental Baseline Document	Draft Environmental Baseline Document

TABLE 9.2-1
Pebble Project Environmental Baseline Studies
Study Summary for Terrestrial Wildlife and Habitat, 2004-2010, Transportation Corridor/Cook Inlet Study Areas
Consultant: ABR, Inc.

Discipline	2004 Data Collected or Tasks Completed	2005 Data Collected or Tasks Completed	2006 Data Collected or Tasks Completed	2007 Data Collected or Tasks Completed	2008 Data Collected or Tasks Completed	2009 Data Collected or Tasks Completed	2010 Data Collected or Tasks Completed
Waterfowl	**Transportation Corridor/Cook Inlet Study Areas**						
	Information Gathering / Literature Search	Information Gathering / Literature Search & Review	Information Gathering / Literature Search & Review				
	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Recommendations	Scope and Schedule	Scope and Schedule	Scope and Schedule	Scope and Schedule
	2004 Study Plan	2005 Study Plan	2006 Study Plan Summary				
	Spring and Fall Waterfowl Migration Surveys (April, May, Sept, Oct)	Spring and Fall Migration Surveys (April, May, August, Sept, Oct)					
	Breeding Waterfowl Surveys (early June)	Breeding Waterfowl Surveys (late May)					
	Breeding Swan Surveys (early June)	Breeding Swan Surveys (late May)					
	Breeding Harlequin Duck Surveys (May)	Breeding Harlequin Duck Surveys (May)					
		Brood-rearing Harlequin Duck Surveys (July, August)					
	Data Entry and Analysis	Data Entry and Analysis	Data Analysis				
	Communication and Data Management	Communication and Data Management	Communication and Data Management				
	Coordination with NDM, Agency Meetings	Coordination with NDM, Agency Meetings, and Monthly Reporting	Coordination with NDM, Agency Meetings, and Monthly Reporting				
		2004 Progress Report	Draft Environmental Baseline Document	Draft Environmental Baseline Document	Draft Environmental Baseline Document	Draft Environmental Baseline Document	Draft Environmental Baseline Document
Breeding Birds	**Transportation Corridor/Cook Inlet Study Areas**						
	Information Gathering / Literature Search	Information Gathering / Literature Search & Review	Information Gathering / Literature Search & Review				
	Scope, Schedule	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Recommendations	Scope and Schedule			Scope and Schedule
	2004 Study Plan	2005 Study Plan	2006 Study Plan Summary				
		Breeding Bird Point-Count Surveys (June)					
		Data Entry and Analysis	Data Analysis				
	Communication and Data Management	Communication and Data Management	Communication and Data Management				
	Coordination with NDM, Agency Meetings	Coordination with NDM, Agency Meetings, and Monthly Reporting	Coordination with NDM, Agency Meetings, and Monthly Reporting				
		2004 Progress Report	Draft Environmental Baseline Document	Draft Environmental Baseline Document	Draft Environmental Baseline Document	Draft Environmental Baseline Document	Draft Environmental Baseline Document

TABLE 9.2-1
Pebble Project Environmental Baseline Studies
Study Summary for Terrestrial Wildlife and Habitat, 2004-2010, Transportation Corridor/Cook Inlet Study Areas
Consultant: ABR, Inc.

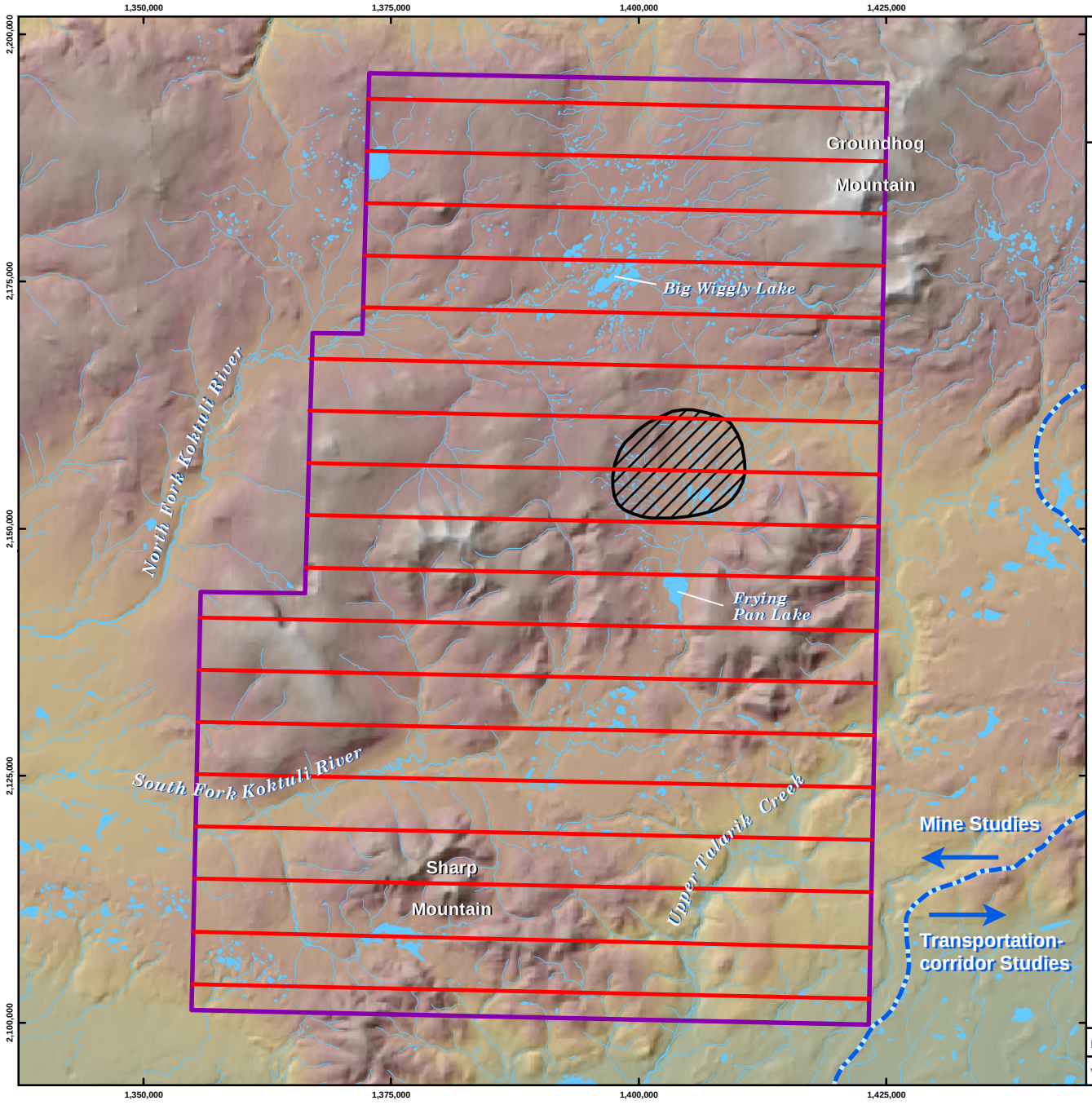
Discipline	2004 Data Collected or Tasks Completed	2005 Data Collected or Tasks Completed	2006 Data Collected or Tasks Completed	2007 Data Collected or Tasks Completed	2008 Data Collected or Tasks Completed	2009 Data Collected or Tasks Completed	2010 Data Collected or Tasks Completed
Habitat Mapping	**Transportation Corridor/Cook Inlet Study Areas**						
	Information Gathering / Literature Search	Information Gathering / Literature Search	Information Gathering / Literature Search				
	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan	Scope and Schedule	Scope and Schedule			Scope and Schedule
	2004 Study Plan	2005 Study Plan	2006 Study Plan Summary				
	Habitat Surveys to Ground Truth Aerial Photography (August)	Habitat Surveys to Ground Truth Aerial Photography (August)					
	Map Coordination with HDR	Map Coordination with HDR	Map Coordination with HDR	Map Coordination with HDR	Map Coordination with HDR	Map Coordination with HDR	Map Coordination with HDR
	Data Entry and Analysis	Data Entry and Analysis	Data Analysis and Digital Habitat Mapping	Data Analysis and Digital Habitat Mapping	Data Analysis and Digital Habitat Mapping	Data Analysis and Digital Habitat Mapping	Data Analysis and Digital Habitat Mapping
	Communication and Data Management	Communication and Data Management	Communication and Data Management	Communication and Data Management	Communication and Data Management	Communication and Data Management	Communication and Data Management
	Coordination with NDM, Agency Meetings	Coordination with NDM, Agency Meetings, and Monthly Reporting	Coordination with NDM, Agency Meetings, and Monthly Reporting	Coordination with PLP, Agency Meetings, and Monthly Reporting	Coordination with PLP and Monthly Reporting	Coordination with PLP and Monthly Reporting	Coordination with PLP and Monthly Reporting
		2004 Progress Report					
Threatened and Engangered Species	**Transportation Corridor/Cook Inlet Study Areas**						
				Information Gathering			
				Scope and Schedule	Scope and Schedule	Scope and Schedule	Scope and Schedule
				2007 Study Plan Summary			
				Data Compilation and Analysis			
				Draft Environmental Baseline Document	Draft Environmental Baseline Document	Draft Environmental Baseline Document	Draft Environmental Baseline Document

TABLE 9.3-1
Pebble Project Environmental Baseline Studies
Study Summary for Terrestrial Wildlife and Habitat, 2004-2008, Iliamna Lake Harbor Seals
Consultant: ABR, Inc.

2004 Data Collected or Tasks Completed	2005 Data Collected or Tasks Completed	2006 Data Collected or Tasks Completed	2007 Data Collected or Tasks Completed	2008 Data Collected or Tasks Completed
	Information Gathering / Literature Search & Review	Information Gathering / Literature Search & Review	Information Gathering / Literature Search & Review	Information Gathering / Literature Search & Review
	Scope, Schedule, Field Sampling Plan		Scope, Schedule, Field Sampling Plan	Scope and Schedule
	2005 Study Plan		2007 Study Plan	
	Aerial Transect Surveys (May-October)		Aerial Surveys of Harbor Seal Haul-outs in Iliamna Lake (12 total; May-October)	Aerial Surveys of Harbor Seal Haul-outs in Iliamna Lake (12 total; May-October)
	Communication and Data Management	Communication and Data Management	Communication and Data Management	Communication and Data Management
	Coordination with NDM, Agency Meetings, and Monthly Reporting	Coordination with NDM, Agency Meetings, and Monthly Reporting	Coordination with PLP, Agency Meetings, and Monthly Reporting	Coordination with PLP, Agency Meetings, and Monthly Reporting
	Draft Environmental Baseline Document	Draft Environmental Baseline Document	Draft Environmental Baseline Document	Draft Environmental Baseline Document

Note: No further work continued in 2009 or 2010.

FIGURES



THE pebble PARTNERSHIP

Figure 9.1-1
Consolidated Study Program 2004–2008, Terrestrial Wildlife and Habitats, Aerial-Survey Transects for Large Mammals (2004–2007), Mine Study Area

Legend

- Aerial-survey Transect
- Mine Transect Survey Area
- General Deposit Location

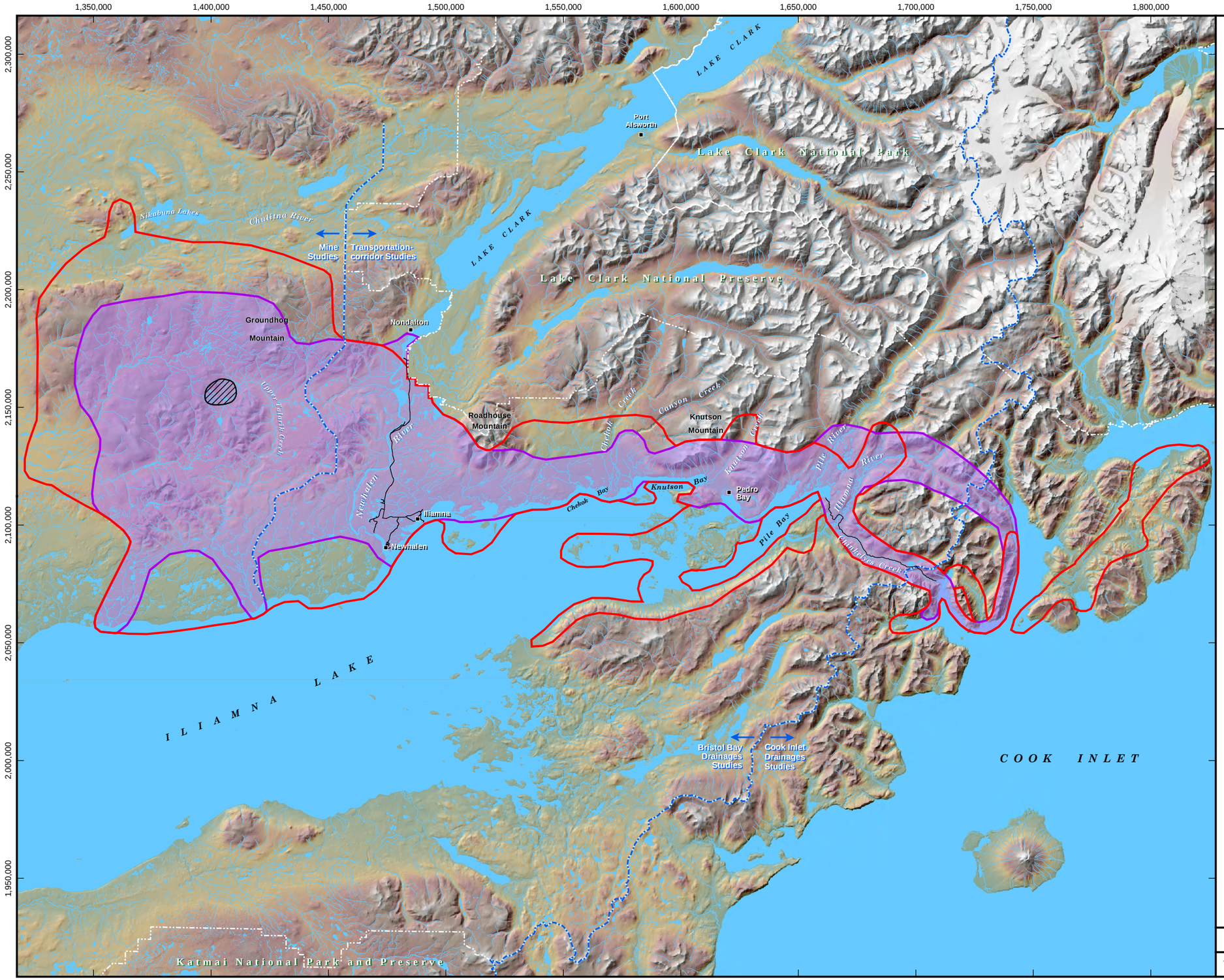
Miles
0 1 2 3 4
Kilometers
0 2 4 6

N

Scale 1:190,000

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: 9-1-1_MammalTransects_Mine_PLP_CSP_v01.mxd	Date: July 11, 2011
Version: 1	Author: ABR-AZC



THE pebble PARTNERSHIP

Figure 9.1-2
Consolidated Study Program 2004–2008, Terrestrial Wildlife and Habitats, Survey Areas for Raptors (2004–2005), Mine and Transportation Corridor Study Areas

Legend

- 2004 Survey Area
- 2005 Survey Area
- General Deposit Location
- Existing Road

Miles
0 5 10 15

Kilometers
0 5 10 15 20 25

N

Scale 1:505,000

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: 9-1-2_RaptorSA_MineTC_PLP_CSP_v01.mxd	Date: July 15, 2011
Version: 1	Author: ABR-AZC

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2,300,000 2,250,000 2,200,000 2,150,000 2,100,000 2,050,000 2,000,000 1,950,000

LAKE CLARK

Port Alsworth

Lake Clark National Park

Nikabuna Lakes

Chulitna River

Mine Studies

Transportation-corridor Studies

LAKE CLARK

Lake Clark National Preserve

Groundhog Mountain

Nondalton

Upper Talarik Creek

Roadhouse Mountain

Chekok Creek

Canyon Creek

Knutson Mountain

Knutson Creek

Pile River

Illiamna River

Newhalen River

Knutson Bay

Pedro Bay

Chekok Bay

Pile Bay

Chinkelyes Creek

Iliamna

Newhalen

ILIAMNA LAKE

Bristol Bay Drainages Studies

Cook Inlet Drainages Studies

COOK INLET

Katmai National Park and Preserve

THE pebble PARTNERSHIP

Figure 9.1-3
Consolidated Study Program 2004–2008, Terrestrial Wildlife and Habitats, Survey Areas for Waterbirds (2004–2005), Mine and Transportation Corridor Study Areas

Legend

- 2004 Study Area
- 2005 Study Area
- 2004 and 2005 Study Area
- General Deposit Location
- Existing Road

0 5 10 15 Miles

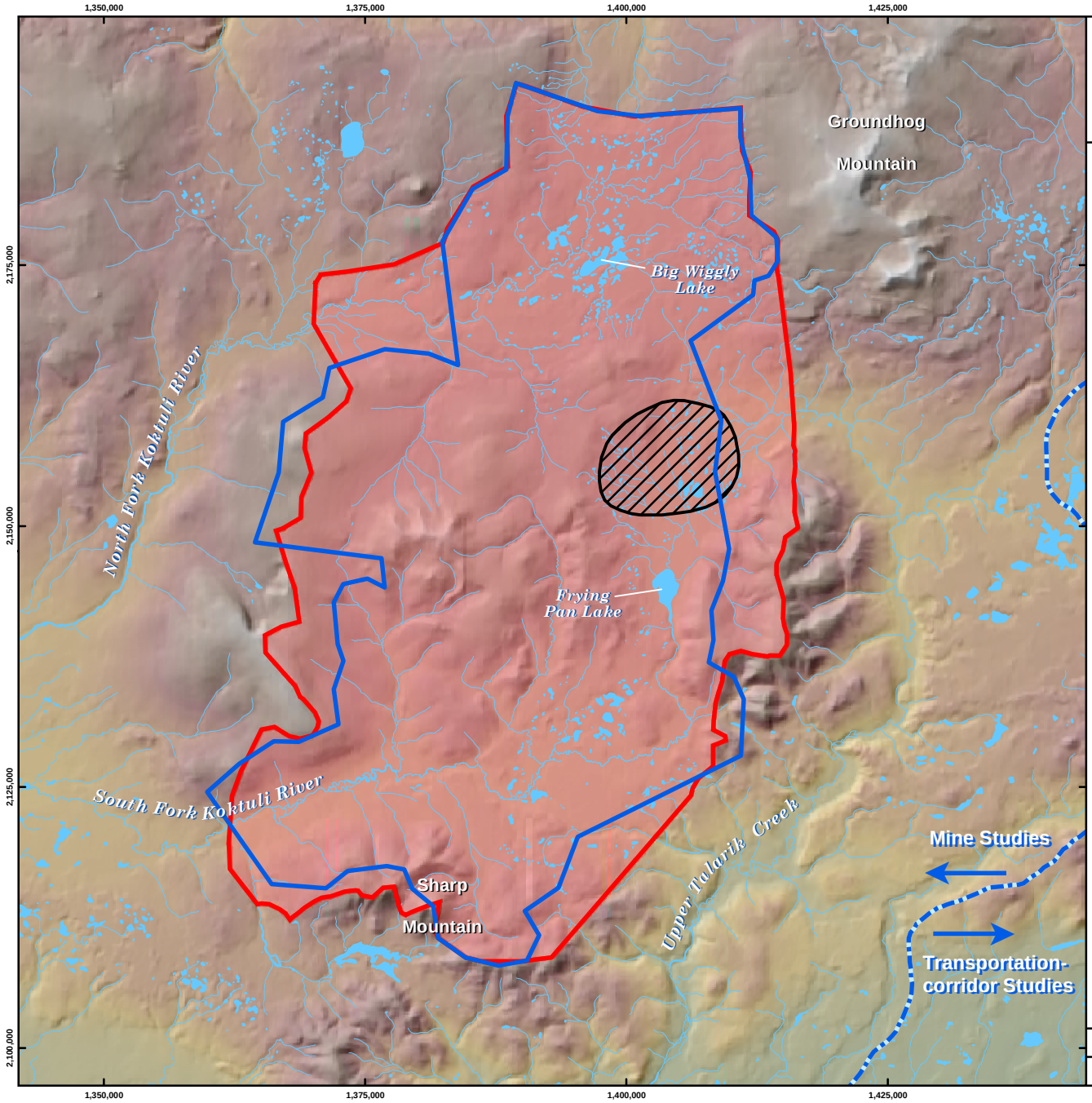
0 5 10 15 20 25 Kilometers

N

Scale 1:500,000

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: 9-1-3_WaterbirdSA_MineTC_PLP_CSP_v01.mxd	Date: July 15, 2011
Version: 1	Author: ABR-AZC



THE pebble PARTNERSHIP

Figure 9.1-4
Consolidated Study Program 2004–2008, Terrestrial Wildlife and Habitats, Survey Areas for Landbirds and Shorebirds (2004–2005), Mine Study Area

Legend

- 2004 Survey Area
- 2005 Survey Area
- General Deposit Location

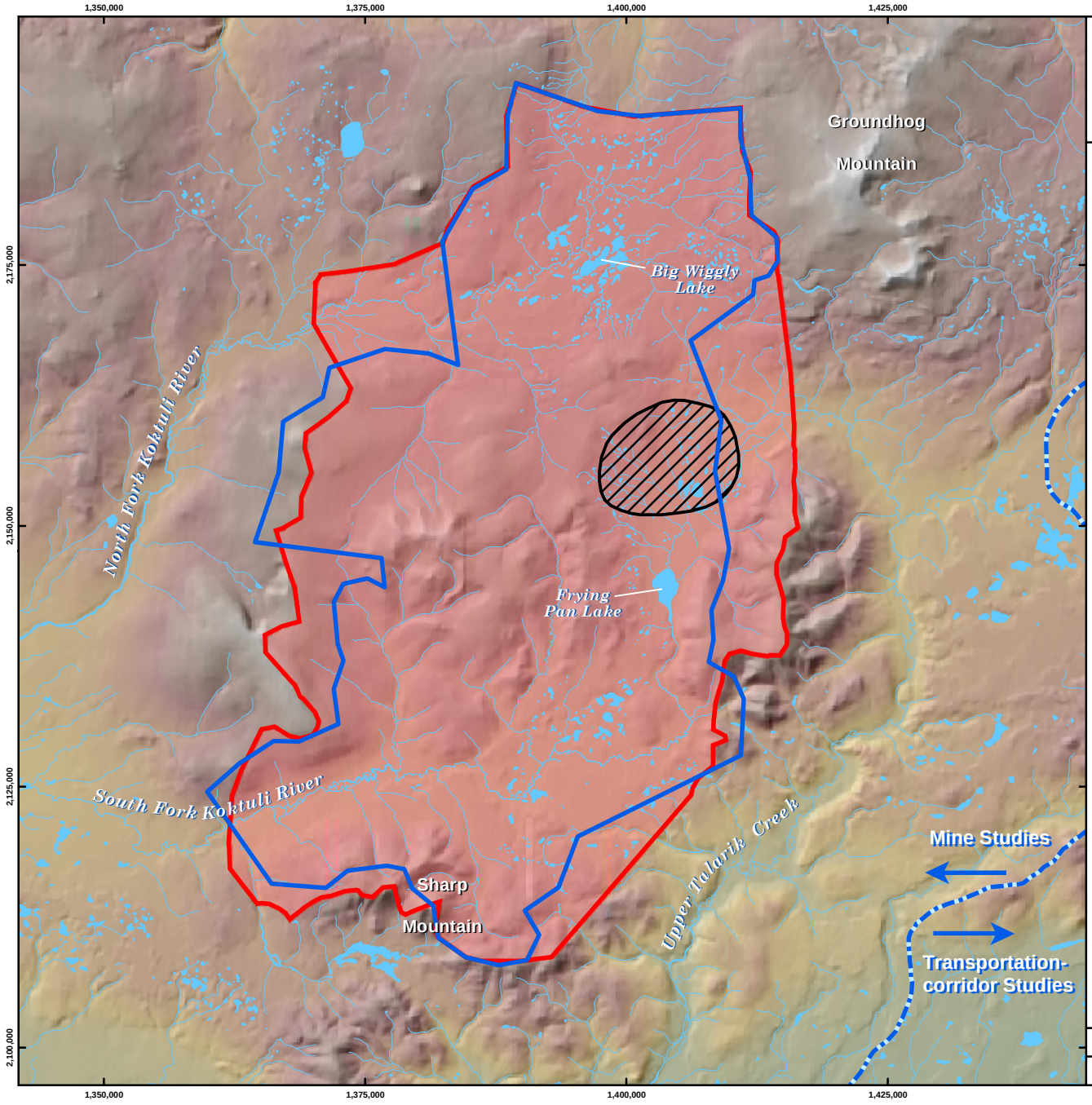
Miles
0 1 2 3 4
Kilometers
0 2 4 6

Scale 1:180,000

N

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: 9-1-4_BreedingBirds_Mine_PLP_CSP_v01.mxd	Date: July 15, 2011
Version: 1	Author: ABR-AZC



THE pebble PARTNERSHIP

Figure 9.1-5
Consolidated Study Program 2004–2008,
Terrestrial Wildlife and Habitats,
Habitat Survey Areas (2004–2005) and Mapping Areas (2006–2008),
Mine Study Area

Legend

- 2004 Survey Area
- 2005 Survey Area and 2006–2008 Mapping Area
- General Deposit Location

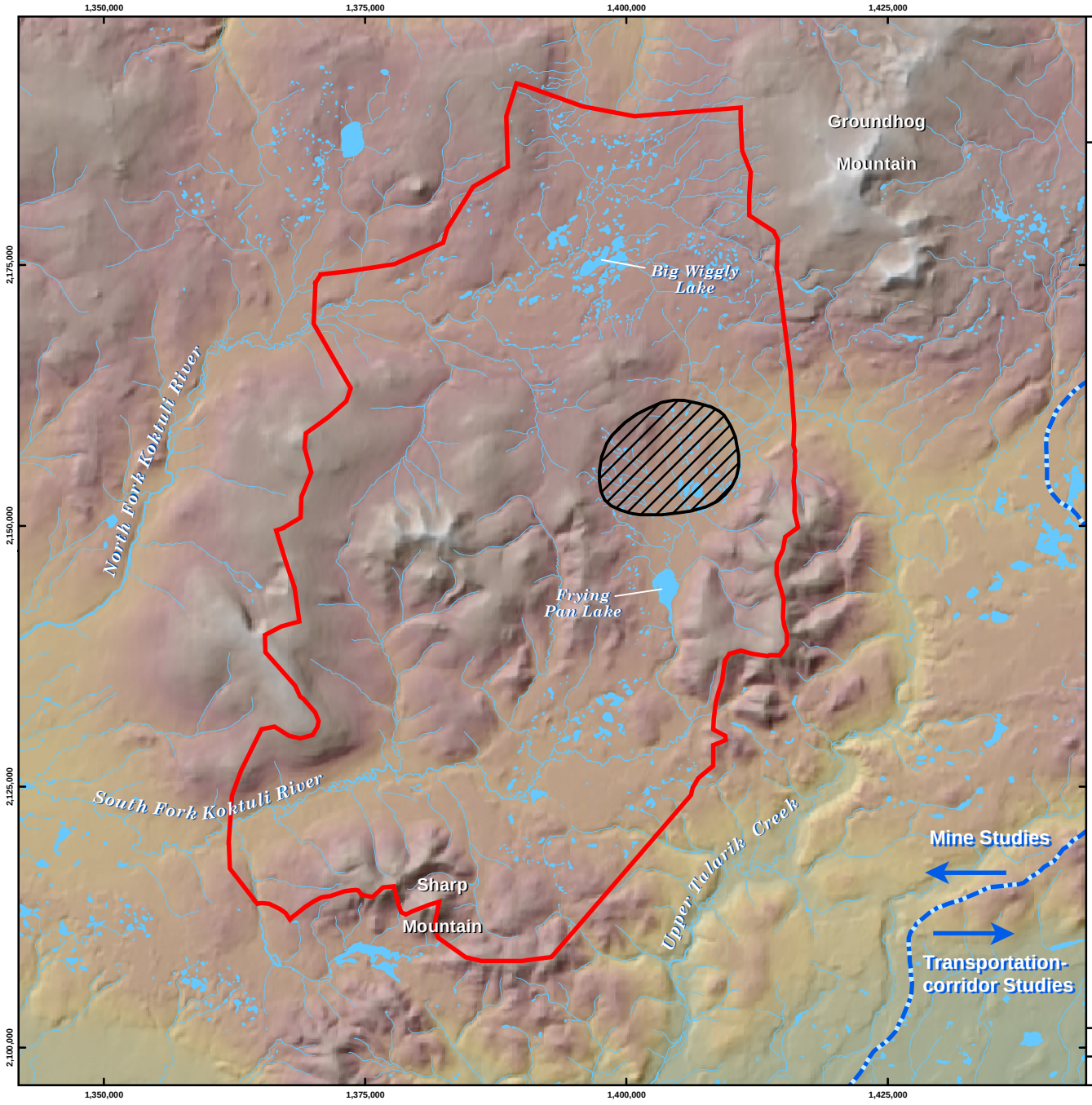
Miles
0 1 2 3 4
Kilometers
0 2 4 6

N

Scale 1:180,000

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: 9-1-5_HabMapping_Mine_PLP_CSP_v01.mxd	Date: July 15, 2011
Version: 1	Author: ABR-AZC



THE pebble PARTNERSHIP

Figure 9.1-6
Consolidated Study Program
2004–2008,
Terrestrial Wildlife and Habitats,
Study Area for Wood Frogs (2007),
Mine Study Area

Legend

- 2007 Mapping Area for Wood Frogs
- General Deposit Location

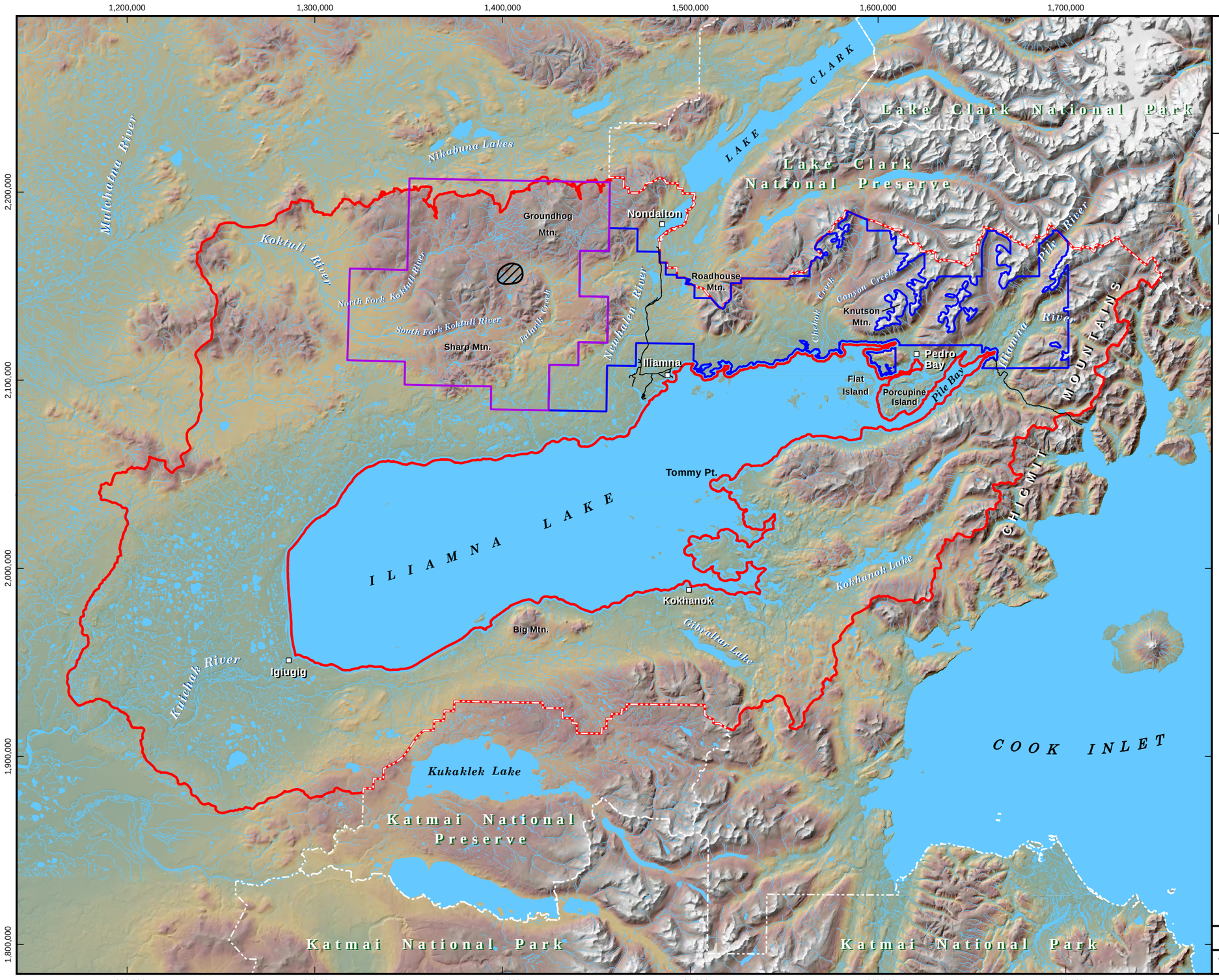
Miles
0 1 2 3 4
Kilometers
0 2 4 6

N

Scale 1:180,000

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: 9-1-6_WoodFrogSA_Mine_PLP_CSP_v01.mxd	Date: July 15, 2011
Version: 1	Author: ABR-AZC



THE pebble PARTNERSHIP

Figure 9.1-7
Consolidated Study Program 2004-2008
Bear (2009) and Moose (2010)
Population Surveys Areas,
Mine and Transportation Corridor Study Area

Legend

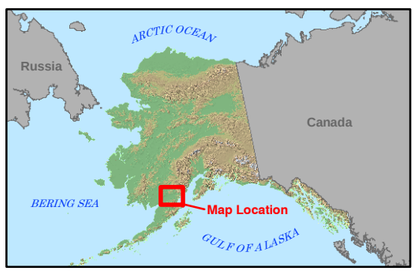
- May 2009 Bear Density Survey Area

April 2010 Moose Density Survey Area

- Mine Study Area
- Transportation-Corridor Study Area

Data source: Bear survey data used with permission of E. Becker, ADF&G.

- General Deposit Location
- Existing Road



0 5 10 15 20 Miles

0 5 10 15 20 25 30 Kilometers

N

Scale 1:630,000

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: 16-2-1B_BearMoosePopSAs_PLP_EBD_v02.mxd	Date: March 8, 2011
Version: 2	Author: ABR-AZC

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2,300,000 2,250,000 2,200,000 2,150,000 2,100,000 2,050,000 2,000,000 1,950,000

Nikabuna Lakes
Chulitna River
Mine Studies
Transportation-corridor Studies
LAKE CLARK
Port Alsworth
Lake Clark National Park
Lake Clark National Preserve
Groundhog Mountain
Nondalton
Roadhouse Mountain
Chekok Creek
Canyon Creek
Knutson Mountain
Knutson Creek
Pile River
Chinitna Bay
Iliamna River
Knutson Bay
Pedro Bay
Chekok Bay
Pile Bay
Iliamna
Newhalen
Chinitnyes Creek
Iniskin Bay
Iliamna Bay
ILIAMNA LAKE
Bristol Bay Drainages Studies
Cook Inlet Drainages Studies
COOK INLET

Figure 9.2-1
Consolidated Study Program 2004–2008, Terrestrial Wildlife and Habitats, Survey Areas for Large Mammals and Harbor Seals (2004–2005), Mine and Transportation Corridor Study Areas

Legend

- 2004 and 2005 Mine Survey Transects
- 2004 and 2005 Mine Transect Survey Area
- 2004 Survey Area
- 2005 Transportation Corridor Survey Area
- 2005 Iliamna Lake Seal Survey
- 2005 Coastal Bay Seal Survey
- General Deposit Location
- Existing Road

Miles
0 5 10 15

Kilometers
0 5 10 15 20 25

N

Scale 1:480,000

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

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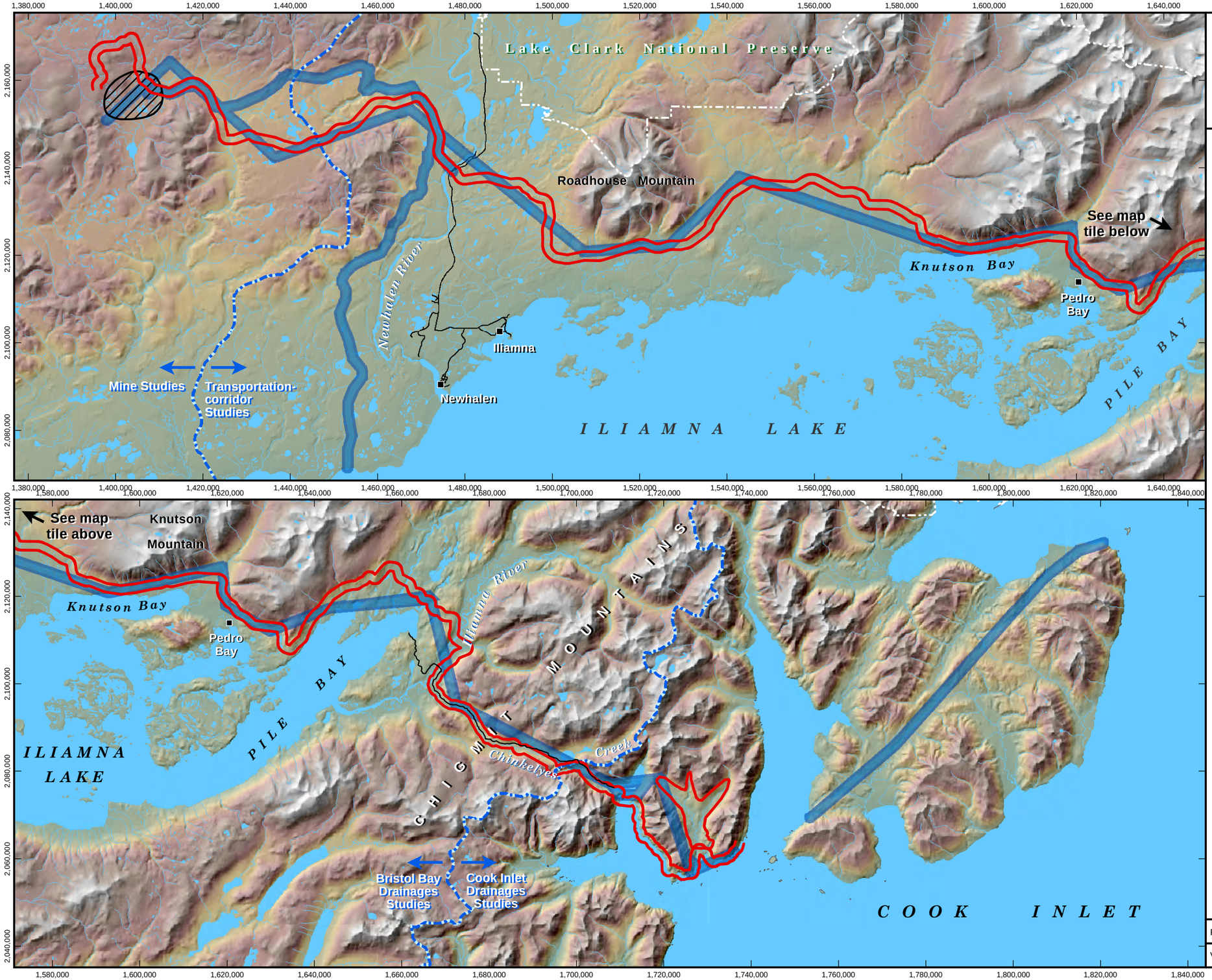


THE pebble PARTNERSHIP

Figure 9.2-2
Consolidated Study Program 2004–2008, Terrestrial Wildlife and Habitats, Survey Areas for Landbirds and Shorebirds (2005), Transportation Corridor Study Area

Legend

- 2005 Survey Area (2000-ft road corridor and Y-valley)
- 2005 Reconnaisance Survey
- General Deposit Location
- Existing Road

Miles
0 1 2 3 4 5 6 7 8

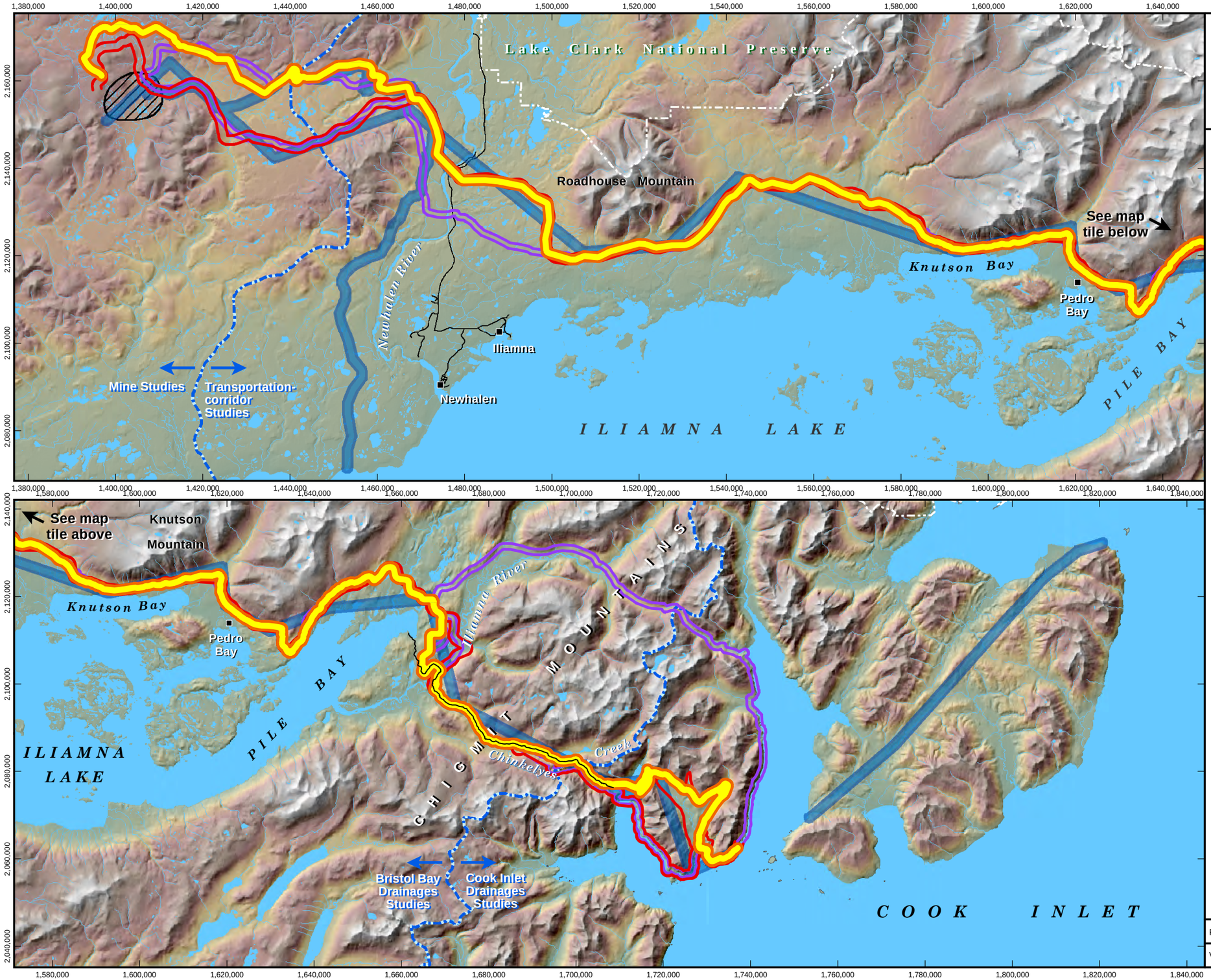
Kilometers
0 2 4 6 8 10 12

N

Scale 1:270,000

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: 9-2-2_BreedingBirds_MineTC_PLP_CSP_v01.mxd	Date: July 15, 2011
Version: 1	Author: ABR-AZC



THE pebble PARTNERSHIP

Figure 9.2-3
Consolidated Study Program 2004–2008, Terrestrial Wildlife and Habitats, Habitat Survey Areas (2004–2005) and Mapping Areas (2006–2008), Transportation Corridor Study Area

Legend

- 2004 Survey Area (1312-ft road corridor)
- 2005 Survey Area (2000-ft road corridor and Y-valley)
- 2005 Reconnaisance Survey
- 2006–2008 Mapping Area (2000-ft road corridor)
- General Deposit Location
- Existing Road

Miles
0 1 2 3 4 5 6 7 8

Kilometers
0 2 4 6 8 10 12

N

Scale 1:270,000

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: 9-2-3_HabMapping_MineTC_PLP_CSP_v01.mxd	Date: July 15, 2011
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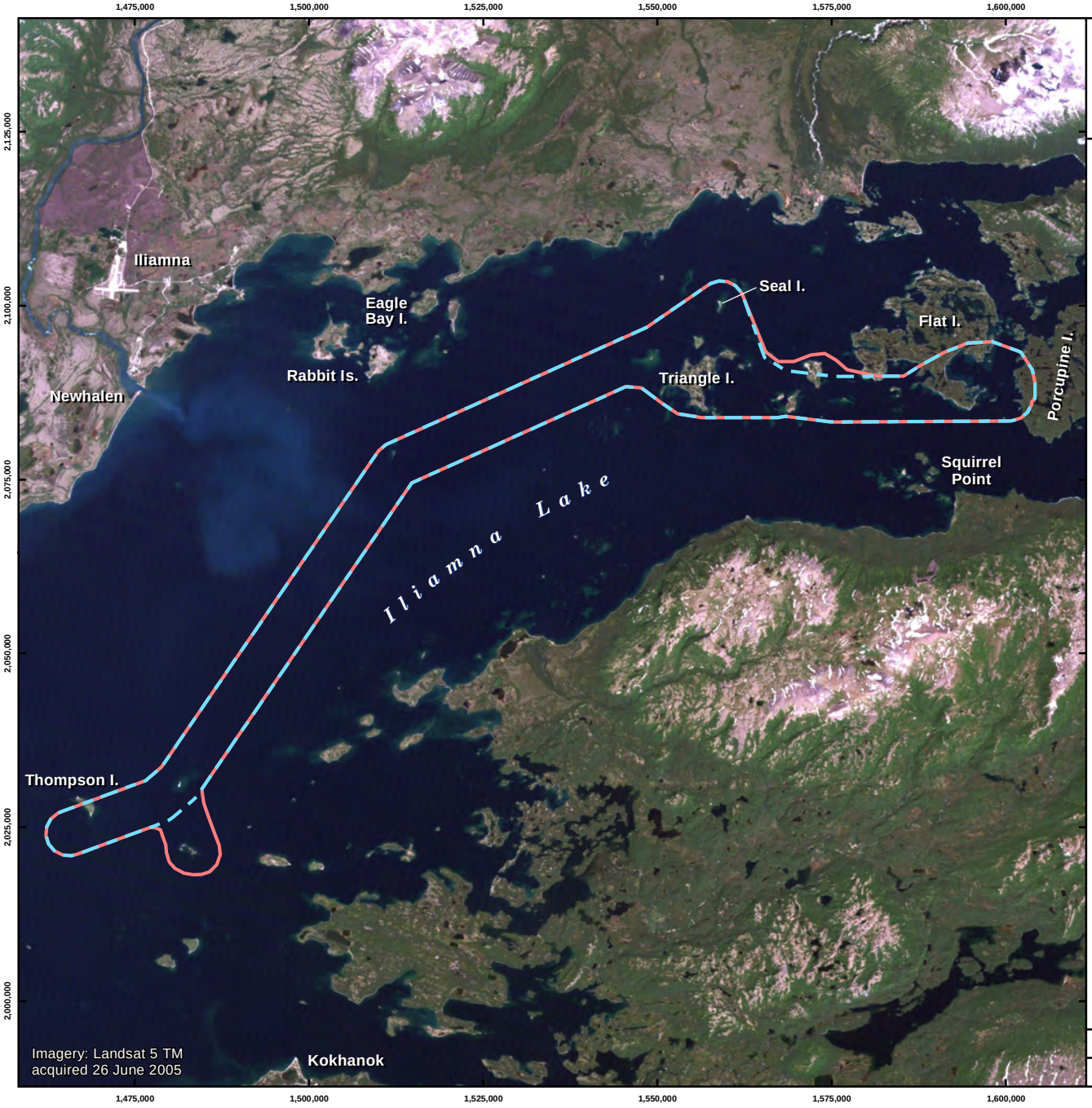

THE pebble PARTNERSHIP

Figure 9.3-1
Consolidated Study Program 2004–2008, Terrestrial Wildlife and Habitats, Survey Areas for Harbor Seals (2005, 2007–2008), Mine Study Area

Legend

- 2005 Iliamna Lake Seal Survey Area
- 2007–2008 Iliamna Lake Seal Survey Area

Miles
0 1 2 3 4 5

Kilometers
0 2 4 6 8

N

Scale 1:270,000

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: 9-3-1_HarborSeals_IlLake_PLP_CSP_v01.mxd	Date: July 15, 2011
Version: 1	Author: ABR-AZC

Pebble Project
Environmental Baseline Studies
2004 through 2008

CONSOLIDATED STUDY PROGRAM

10. WETLANDS

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Figure 10-2, Consolidated Study Program, 2004-2008, Wetlands Field Verification Areas (2004-2005) and Mapping Area (2006), Transportation Corridor/Cook Inlet Study Areas

ACRONYMS

AKNHP	Alaska Natural Heritage Program
CSP	consolidated study program
GIS	geographic information system
HDR	HDR Alaska, Inc.
HGM	hydrogeomorphic0
NWI	National Wetlands Inventory
3PP	Three Parameters Plus
USACE	United States Army Corp of Engineers
USGS	United States Geological Survey

10. WETLANDS

The wetlands component of the environmental baseline description for the Pebble Project includes information review, field inventories, and digital mapping of wetland resources in the study areas. The objectives, approach, and activities are the same for the mine study area and the transportation corridor/Cook Inlet study areas.

There are three consultants for the wetlands study. From 2004 through 2006, Three Parameters Plus (3PP) led the wetlands work in the mine study area and provided oversight to HDR Alaska, Inc. (HDR), which was responsible for the wetlands work for most of the transportation corridor/Cook Inlet study areas. Since 2007, 3PP has led the wetlands study in both areas

Work for the wetlands study from 2004 through 2008 is summarized in Table 10-1.

10.1 Objectives of Study

The objectives of the wetland study are as follows:

- Document baseline hydrologic conditions in and near to wetlands.
- Collect data for input into studies by other disciplines.

It is expected that the wetlands study, as described in this consolidated study program (CSP), will collect the appropriate baseline data necessary to characterize the wetlands in the study areas.

10.2 Study Area/Scope

The general area for the wetlands study consists of approximately 750,000 acres located between the Iniskin Bay and the North Fork Koktuli River watershed and includes the watersheds of the Upper Talarik Creek and the South Fork Koktuli River. The specific areas studied, however, evolved over time.

The proposed study area for 2004 was approximately 72,000 acres and was designated for initial photo mapping and for field evaluations.

The actual wetland locations and field verification areas evaluated during the 2004 field season are shown on Figures 10-1and 10-2. Minor modifications to the original proposed area were made as the 2004 field season progressed. Most of it (approximately 73,000 acres) was located in watersheds in the immediate vicinity of the deposit and in the portion of the transportation corridor between the deposit and the Newhalen River. Additional area east of the deposit (representing approximately 40,000 acres) was also evaluated. This area consisted of an approximately 3,300-foot-wide transportation corridor from the Newhalen River to Iniskin and Iliamna bays on Cook Inlet, including some minor variants.

The study area was refined in 2005, particularly along the transportation corridor and through the inclusion of the “y-Valley” between Iniskin and Iliamna bays (Figure 10-2).

In 2006, the study area near the deposit (Figure 10-1) increased substantially to approximately 105,441 acres, including the following:

- A larger area for the segment of transportation corridor from the deposit to the Newhalen River.
- The addition of a large portion of the Upper Talarik Creek watershed.
- The addition of a small area in the North Fork Koktuli River watershed, near Wiggly Lake.

The study area for the transportation corridor was reduced to approximately 30,000 acres because the imagery used for final digital mapping was limited to a corridor that was approximately 2,000 feet wide (narrower than the original 3,300-foot-wide area field-verified in 2004 and 2005) (Figure 10-2).

In 2007, the mine study area for mapping and field data collection expanded to approximately 248,766 acres in size, as shown on Figure 10-1. The expanded areas included the following:

- The lower and upper reaches of the Upper Talarik Creek watershed (to now encompass the entire watershed).
- Most of the North Fork Koktuli River watershed to its confluence with the South Fork Koktuli River.
- The lower reach of the South Fork Koktuli River watershed to its confluence with the North Fork Koktuli River.

In 61,202 acres of the expanded study area, typically only those wetlands and waters within recognized floodplains were delineated.

In 2008, the mine study area for mapping and field data collection expanded to approximately 249,407 acres in size, as shown on Figure 10-1. The expanded areas included additional transportation corridor study area for crossing of the Newhalen River.

The general scope of work for the wetland study includes compiling existing and field-mapped information for the areas described above into the project geographic information system (GIS) and preparing digital maps. CSP 19 (Data Management and GIS) provides additional information on this latter effort.

10.3 Methods/Approach

The approach to mapping wetlands and vegetation for the Pebble Project is relatively simple, but involves several steps:

- Collecting and reviewing data from existing sources, including the use of GIS to track, analyze, and evaluate a variety of data sources and to prepare high-quality map products.
- Preliminary mapping of wetlands and waterbodies on aerial photographs (where available) or in the GIS.
- Identifying (in the GIS and on field maps or photos) prospective locations for sampling representative sites in the field, focusing on complex wetland/upland boundary areas, areas with questionable boundary locations, and areas where multiple sample points can be easily accessed.

- Field-verifying preliminary mapping, sampling representative sites using criteria and indicators described in the 1987 U.S. Army Corps of Engineers (USACE) *Wetland Delineation Manual* (USACE, 1987), and subsequent regulatory guidance related to wetland determinations.
- Collecting wetland-function assessment data according to the Magee method (Magee, 1998).
- Photographing any incidental observations of important habitat features, streams, cultural resources, new or existing disturbances, etc.
- Photographing and recording the locations of any rare or sensitive plant species encountered during field evaluations.
- Entering wetland determination data and wetland functional assessment data into a web-based/accessible relational database. This allows the data to be analyzed and evaluated quickly and with built-in quality control measures/options. These data are integrated into the overall data management system for the environmental baseline studies and will provide baseline data on conditions in the study areas.
- Preparing final maps of wetlands and waterbodies on digital, true-color, ortho-rectified photography in the GIS. Final mapping is expected to include designation of mosaics of wetland types (with respect to hydrogeomorphic [HGM] classes and vegetation types) and wetlands and uplands.
- Preparing documentation to support the Pebble Project environmental baseline document.

10.4 Major Tasks/Activities

The wetlands team performed the following tasks and activities as the study progressed:

- Determine the extent of existing soil/vegetation disturbance in the project.
- Describe the predominant vegetation types found in the study area, and determine the normal prevalence of hydrophytic vegetation species in each. Vegetation types are also correlated with the terrestrial wildlife study habitat types, and where appropriate, fisheries habitat data.
- Describe the predominant soil types found in the study area and their hydric characteristics/status.
- Determine the predominant HGM class of wetlands identified in the study area, and describe the primary functions associated with each.

10.4.1 Tasks and Activities for 2004

Work specifically under way in 2004 to support the wetlands program included digital presentation of the following mapping attributes:

- Existing National Wetlands Inventory (NWI) mapping.
- United States Geological Survey (USGS) Earth Resources Observation and Science (EROS) land cover mapping and vegetation/land cover types associated with the Bristol Bay Land Management Plan.
- Vegetation mapping/cover classes found on the Lake Clark National Park website.

- Orthophoto mosaic coverage of the 1978 color infrared (CIR) photography from the National Aeronautics and Space Administration (NASA).
- True color orthophotography and associated contour data (2 to 10 feet, depending on the complexity of the terrain) for the mine area.
- Watershed boundaries as previously determined by the Bristol Bay Native Corporation.
- Exploratory soil survey data and other data sources related to soil types and parent materials.

To prepare for field work, 3PP staff proposed preliminary mapping directly onto aerial photographic prints, if such prints were available prior to the 2004 field season. Satellite images could also be used where true color photography did not currently exist.

It was planned that field crews would use new true color aerial photography and orthophotography as soon as it became available. Alaska Department of Transportation and Public Facilities staff planned to complete their aerial survey of the preferred transportation corridor(s) and provide the orthophotography and topographic mapping to the Pebble Partnership team to be incorporated into the Pebble Partnership GIS database; this was not expected to occur, however, until the 2004 field season was nearly complete.

The 2004 preliminary mapping and field verification area for the mine study area focused on the following:

- The Pebble Deposit.
- The North Fork Koktuli River, South Fork Koktuli River, and Upper Talarik Creek.

The mapping and field verification area for the transportation corridor/Cook Inlet study areas focused on a 3,300-foot-wide transportation corridor extending from the Newhalen River to the Bristol Bay/Cook Inlet drainages divide and beyond down to Iliamna and Iniskin bays.

It was understood that field verification could extend into the 2005 field season.

10.4.2 Tasks and Activities for 2005

In 2005, work completed or under way to support the wetlands study included digital presentation of the same map attributes as described for 2004, with the following three additions:

- USGS topographic mapping.
- IKONOS-satellite imagery of portions of the transportation corridor.
- Land ownership information.

In 2004, multiple crews of wetland scientists collected data from hundreds of representative sites in the mine and transportation corridor/Cook Inlet study areas. Because of the timing of project start-up, field work was done before any preliminary digital mapping of wetlands or vegetation types had been completed. By 2005, however, digital mapping for areas visited in 2004 was under way. It was also proposed at that time to conduct digital mapping of field areas to be investigated in 2005 before the summer field season began, to the extent possible.

For field data collection, it was proposed to focus on the following in the mine study area:

- Collecting additional field verification data for wetland determinations and functional assessment in vegetation types that were not consistently wetland or upland during the 2004 field season.
- Collecting additional functional-assessment data in small wetlands that had not been identified during the 2004 field season.
- Reviewing digital mapping completed after the 2004 field season.

The work in the transportation corridor/Cook Inlet study areas included reconnaissance surveys, as well as field verifications. The activities are noted below:

- Fly-over reconnaissance of an approximately 3,300-foot-wide corridor along the west side of the Newhalen River, stretching north from Lake Iliamna towards the deposit (which had been sampled in 2004 by 3PP).
- Extension of digital data compilation eastward to include the Iniskin Peninsula, specifically, georeferencing and rectifying existing NWI mapping for that area.
- Fly-over reconnaissance of an approximately 3,300-foot-wide corridor from Chinitna Bay to the upper Iliamna River drainage or Iliamna Bay.

Field work to be done in 2005 also included the following:

- Limited re-visit of areas visited in 2004 to observe wetland hydrologic conditions in a wetter year.
- Limited additional sampling within the corridor sampled in 2004 to fill data gaps.

10.4.3 Tasks and Activities for 2006

With the exception of expanding the mine study area, the overall scope of the wetland study did not change significantly in 2006. Digital mapping of areas visited in 2004 and 2005 was under way. Final wetland and vegetation mapping for many evaluation areas was expected to be completed in late 2006.

As in 2004 and 2005, field data collected during the 2006 field season used criteria found in the *Wetland Delineation Manual* (USACE, 1987); however, 2006 data collection also used the new indicators outlined in the *Interim Regional Supplement to the Corps of Engineers Wetland Delineation Manual*: *Alaska Region* (USACE, 2006), and the results of the two methods were directly compared.

Field data forms, which had previously used the 1995 Supplement to the wetland indicator plant list for Alaska were also re-evaluated in 2006. References to this list were removed as requested by the Alaska District of the USACE in early May 2006.

The 2004 and 2005 field verification area for the transportation corridor/Cook Inlet study areas was approximately 40,000 acres in size. However, the 2006 mapping area was approximately 10,000 acres smaller because the digital imagery used for mapping now covered a corridor that was approximately 2,000 feet wide (narrower than the 3,300-foot-wide field verification area). No field work was planned for the transportation corridor in 2006.

10.4.4 Tasks and Activities for 2007

With the exception of adding more area to the mine study area (Figure 10-1), the overall scope of the wetland study did not change substantially in 2007. Digital mapping of areas visited in 2004, 2005, and 2006 was under way.

Field-based studies concentrated on the mine study area and included the following minor changes in scope: reviewing prior plant-species observation data and flagging species of interest to the Alaska Natural Heritage Program (AKNHP) for review and, where appropriate, for revisits. If species of interest were found at the time of the revisit, voucher specimens were collected, mounted, and submitted to the University of Alaska Fairbanks herbarium for concurrence.

Field-based studies were not planned in the transportation corridor/Cook Inlet study areas in 2007, other than to follow-up on plant-species of interest to the AKNHP, as described above.

10.4.5 Tasks and Activities for 2008

With the exception of adding slightly more area to the mine study area (Figure 10-1), the overall scope of the wetland study did not change substantially in 2008. Digital mapping of areas visited in 2004, 2005, 2006, and 2007 is still under way. The mine study area for 2008 has changed only slightly from 2007 and is described in Figure 10-1.

Field-based studies concentrated on the mine study area, and included the tasks and activities for 2007 as well as expanding the survey to incorporate the 2008 study area.

10.5 References

Magee, D. 1998. Rapid Procedure for Assessing Wetland Functional Capacity, Based on Hydrogeomorphic Classification. Prepared for U.S. Army Corps of Engineers.

U.S. Army Corps of Engineers (USACE). 1987. Corps of Engineers Wetlands Delineation Manual. Wetlands Research Program Technical Report Y-87-1. Department of the Army Waterways Experiment Station. January 1987.

———. 2006. Interim Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Alaska Region. U.S. Army Engineer Research and Development Center. Document ERDC/EL TR-06-3. February 2006. 106 pp.

TABLES

TABLE 10-1
Pebble Project Environmental Baseline Studies
Study Summary for Wetlands, 2004-2008
Consultants: Three Parameters Plus, Inc., and HDR Alaska, Inc.

2004 Data Collected or Tasks	2005 Data Collected or Tasks	2006 Data Collected or Tasks	2007 Data Collected or Tasks	2008 Data Collected or Tasks
Mine Study Area				
Information Gathering				
Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan
2004 Study Plan	2005 Study Plan	2006 Study Plan Summary	2007 Study Plan Summary	
With RDI, Initial Design and Testing of Wetlands Application in the NDM Database	With RDI, Design and Testing of Reports and QC Tools in Wetlands Application of the NDM Database.	With RDI, Design New Forms Related to New Alaska Delineation Manual, and Test Wetland Application in the NDM Database		
With RDI, Initial Design and Layout of Project GIS and Data Management Procedures	GIS and Data Management Coordination	GIS and Data Management Coordination	GIS and Data Management Coordination	GIS and Data Management Coordination
Preliminary Wetland Impact Analysis Using Historical Data Sources and NDM Mine Development Concept Footprints	Preliminary Wetland Impact Analysis Using Historical Data Sources and NDM Mine Development Concept Footprints	Preliminary Wetland Impact Analysis Using Historical Data Sources and NDM Mine Development Concept Footprints		
Jurisdictional Wetland Determinations Using the 1987 Corps of Engineers Manual (Portions of the South Fork Koktuli, North Fork Koktuli, Upper Talarik, and Newhalen Watersheds)	Jurisdictional Wetland Determinations Using the 1987 Corps Manual (Same Area as 2004)	Jurisdictional Wetland Determinations Using the 1987 Corps Manual and the 2006 Alaska Delineation Manual (Upper Talarik Watershed)	Jurisdictional Wetland Determinations Using the 1987 Corps Manual and the 2006 Alaska Delineation Manual or Equivalent (Predominantly Upper Talarik & North Fork Koktuli Watersheds)	Jurisdictional Wetland Determinations Using the 1987 Corps Manual and the 2006 Alaska Delineation Manual or Equivalent
Rapid Wetland Functional Assessments Using the Magee/Hollands Method				
Photo Documentation of Streams, Various Habitat Features, Representative Wetlands and Uplands	Photo Documentation of Streams, Various Habitat Features, Representative Wetlands and Uplands	Photo Documentation of Streams, Various Habitat Features, Representative Wetlands and Uplands	Photo Documentation of Streams, Various Habitat Features, Representative Wetlands and Uplands	Photo Documentation of Streams, Various Habitat Features, Representative Wetlands and Uplands
	Two-Day Work Plan/Database Overview with Corps and EPA Project Staff			
	Small Pools Study Design & Piezometer Installation (Dr. Mark Rains)			
	Water Body Evaluations with Photos and pH and EC Data to Support Small Pools Study.	Water Body Evaluations with Photos and pH and EC Data to Support Small Pools Study.	Water Body Evaluations with Photos and pH and EC Data to Support Small Pools Study.	Water Body Evaluations with Photos and pH and EC Data to Support Small Pools Study.
	Rapid Evaluations of Willow and Mixed Willow/Alder Shrub Thickets to Support Jurisdictional Mapping Work	Rapid Evaluations of Willow and Mixed Willow/Alder Shrub Thickets to Support Jurisdictional Mapping Work	Rapid Evaluations of Willow and Mixed Willow/Alder Shrub Thickets to Support Jurisdictional Mapping Work	Rapid Evaluations of Willow and Mixed Willow/Alder Shrub Thickets to Support Jurisdictional Mapping Work
Data Entry and QC	Data Entry and QC	Data Entry and QC	Data Entry and QC	Data Entry and QC
Digital Mapping of Jurisdictional Wetland Boundaries, HGM Type, Vegetation Type, and Existing Disturbance	Digital Mapping of Jurisdictional Wetland Boundaries, HGM Type, Vegetation Type, and Existing Disturbance	Digital Mapping of Jurisdictional Wetland Boundaries, HGM Type, Vegetation Type, and Existing Disturbance	Digital Mapping of Jurisdictional Wetland Boundaries, HGM Type, Vegetation Type, and Existing Disturbance	Digital Mapping of Jurisdictional Wetland Boundaries, HGM Type, Vegetation Type, and Existing Disturbance
Coordination with NDM & Agencies	Coordination with NDM & Agencies, Monthly Reporting, Fall Agency Summary Presentation	Coordination with NDM, agency meetings, and monthly reporting	Coordination with NDM, agency meetings, and monthly reporting	Coordination with NDM, agency meetings, and monthly reporting
	2004 Progress Report		Review plant species data collected to date, revisit field sites with potential species of interest to the Alaska Natural Heritage Program. Collect voucher specimens where appropriate.	Review plant species data collected to date, revisit field sites with potential species of interest to the Alaska Natural Heritage Program. Collect voucher specimens where appropriate.
				Write draft EBD background vegetation and wetland sections for early 2009 submittal. Review HDR submittals.

2004 Data Collected or Tasks	2005 Data Collected or Tasks	2006 Data Collected or Tasks	2007 Data Collected or Tasks	2008 Data Collected or Tasks
Transportation Corridor/Cook Inlet Study Areas				
2004 Study Plan	2005 Study Plan	2006 Study Plan Summary	2007 Study Plan Summary	
	Two Day Work Plan/Database Overview with Corps and EPA Project Staff			
Jurisdictional Wetland Determinations Using the 1987 Corps Manual (including work for minor route variations and for two routes from Pile Bay to Cook Inlet)	Jurisdictional Wetland Determinations Using the 1987 Corps Manual (field work, same area as 2004 plus Y Valley)			
		Analysis of Wetland Function Data	Analysis of Wetland Function Data	Analysis of Wetland Function Data
Photo Documentation of Streams, Various Habitat Features, Representative Wetlands and Uplands	Photo Documentation of Streams, Various Habitat Features, Representative Wetlands and Uplands			
Data Entry	Data Entry	Data QC and Update	Data QC and Update	Data QC and Update
Digital Mapping of Jurisdictional Wetland Boundaries, HGM Type, Vegetation Type, and Existing Disturbance	Digital Mapping of Jurisdictional Wetland Boundaries, HGM Type, Vegetation Type, and Existing Disturbance	Digital Mapping of Jurisdictional Wetland Boundaries, HGM Type, Vegetation Type, and Existing Disturbance	Digital Mapping of Jurisdictional Wetland Boundaries, HGM Type, Vegetation Type, and Existing Disturbance	Digital Mapping of Jurisdictional Wetland Boundaries, HGM Type, Vegetation Type, and Existing Disturbance
	Communications w/ Design Team Regarding Constraints			
	2004 Progress Report			
			Review plant species data collected to date, revisit field sites with potential species of interest to the Alaska Natural Heritage Program. Collect voucher specimens where appropriate.	Review plant species data collected to date, revisit field sites with potential species of interest to the Alaska Natural Heritage Program. Collect voucher specimens where appropriate.
				Write draft EBD background vegetation and wetland sections for early 2009 submittal.

RDI = Resource Data, Inc.
EPA = U.S. Environmental Protection Agency
GIS = Geographic Information System
HGM = Hydrogeomorphic
NRCS = Natural Resources Conservation Service
QC = Quality Control
SWANCC = Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers
UAA = University of Alaska, Anchorage
USACE = U.S. Army Corps of Engineers

FIGURES

155°52'0"W 155°44'0"W 155°36'0"W 155°28'0"W 155°20'0"W 155°12'0"W 155°4'0"W 154°56'0"W

60°0'0"N

59°52'0"N

59°44'0"N

Black Lake

Big Wiggly Lake

Frying Pan Lake

Upper Talarik Creek

North Fork Koktuli River

South Fork Koktuli River

Chiquita Lake

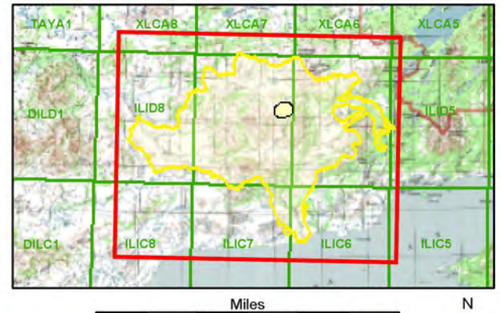
Iliamna Lake

THE pebble PARTNERSHIP

Figure 10-1
Consolidated Study Program, 2004-2008
Wetlands 2004-2008
Field Verification and Mapping,
Mine Study Area

Legend

- General Deposit Location
- 3PPI 2008 Field Study Area
- 3PPI 2007 Field Study Area
- 3PPI 2006 Field Study Area
- 3PPI 2004/2005 Field Study Area



Miles
0 1 2 3 4 5 6

N

Scale 1:190,000
Alaska State Plane Zone 5 (units feet)
1983 North American Datum

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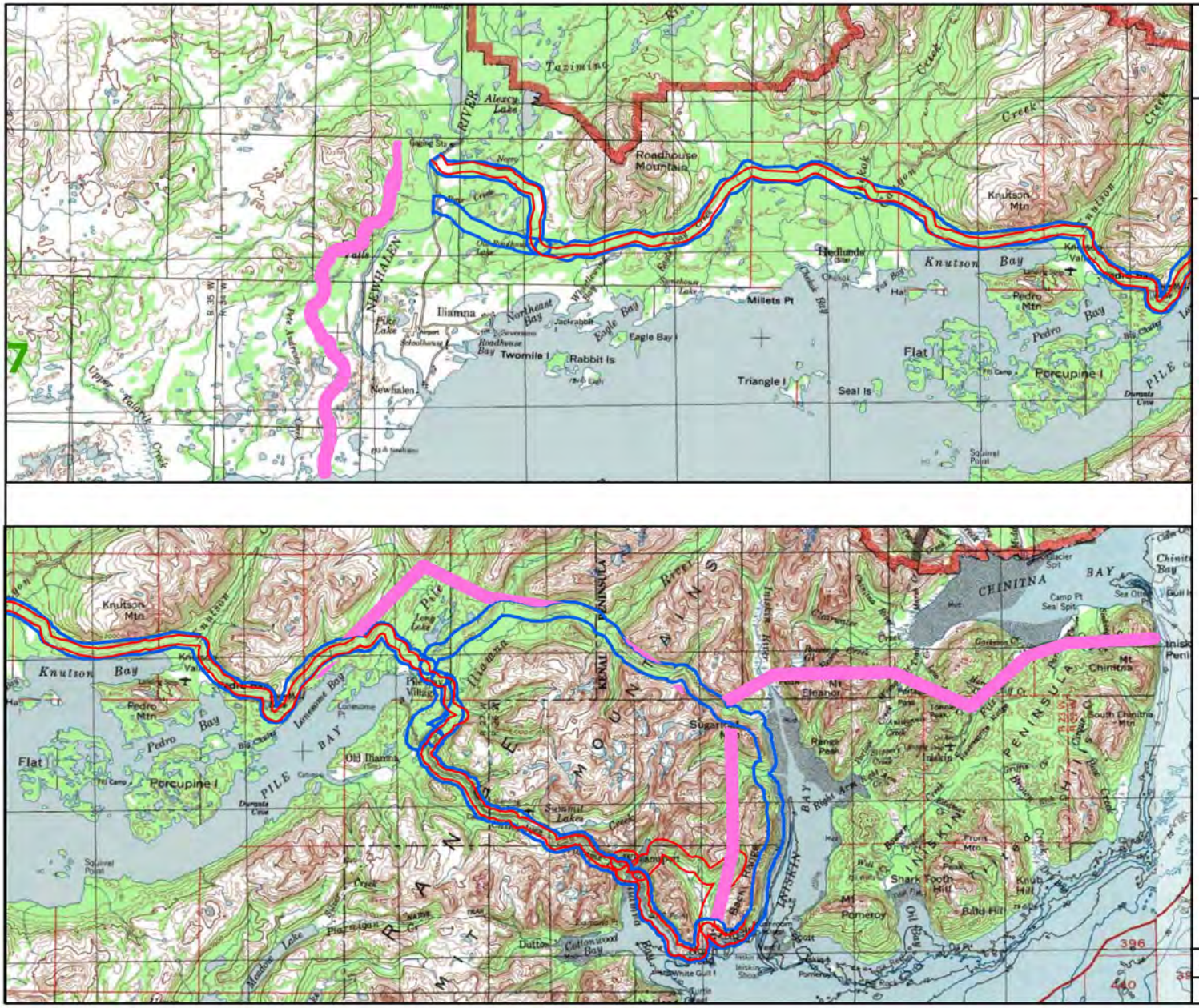

THE pebble PARTNERSHIP

Figure 10-2
Consolidated Study Program, 2004-2008
Wetlands
Field Verification Areas (2004-2005)
and Mapping Area (2006)
Transportation Corridor /
Cook Inlet Study Areas

LEGEND

- 2005 Study Area and 2006 Mapping Area (2,000-ft transportation corridor and Y valley)
- 2004 Study Area (3,300-ft transportation corridor)
- Reconnaissance Only

N

0 1 2 4 6 8 Miles

0 1 2 4 6 8 10 Kilometers

Scale 1:400,000

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: Studyplan\2006_Fig10_1.mxd	**Date: July 5th, 2011**
Version: 7	**Author: HDR - DW, PLP-JG**

Pebble Project
Environmental Baseline Studies
2004 through 2008

CONSOLIDATED STUDY PROGRAM

11. FISH AND AQUATIC RESOURCES

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ACRONYMS AND ABBREVIATIONS

APC	Alaska Peninsula Corporation
APCS	Alaska Peninsula Corporation Services
AUC	Area-Under-the-Curve, Spawning Escapement Model
cm	centimeter
EBD	environmental baseline document
ft	foot
FL	fork length
GIS	geographic information system
GPS	global positioning system
h	hour
HSC	Habitat Suitability Criteria
IFIM	Instream Flow Incremental Methodology
km	kilometer
KR	Mainstem Koktuli River
L	liter
m	meter
mm	millimeter
min	minutes
NMFS	National Marine Fisheries Service
NFK	North Fork Koktuli River
PHABSIM	Physical Habitat Simulation Model
RKm	river kilometer
RM	river mile
RTK DGPS	Real Time Kinematic Differential Global Positioning System
SFK	South Fork Koktuli River
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UT	Upper Talarik Creek
WSE	water surface elevation

11. FISH AND AQUATIC RESOURCES

11.1 Study Area

The study area for fish and aquatic resources encompassed the aquatic habitats associated with the Pebble Deposit, the transportation corridor/Cook Inlet study areas, and Iliamna Lake and its tributaries. The proposed mine study area includes the mainstem and tributary habitats of the North Fork Koktuli River (NFK), South Fork Koktuli River (SFK), and Upper Talarik Creek (UT; Figure 11-1). Additional study areas near the Pebble Deposit include the uppermost reaches of the mainstem Koktuli River (KR) from river kilometer (RKm) 16.55 to the confluence of the NFK and SFK, and Kaskanak Creek. The transportation corridor/Cook Inlet study areas consisted of a 2,000-foot (ft)- (609.6 meter [m]) wide corridor that follows a representative road alignment beginning at the northeastern edge of the deposit and continuing above the north shore of Iliamna Lake east to the Cook Inlet (Figure 11-2). In addition to the studies occurring in the mine and transportation corridor/Cook Inlet study areas, a rainbow trout radio telemetry study was conducted in Iliamna Lake and surrounding streams.

11.2 Studies Conducted

Because limited existing information was available, a broad and diverse field sampling program was conducted from spring 2004 through fall 2008 to describe fish distribution and abundance in relation to various aquatic habitat characteristics and instream flow patterns. To achieve this goal, multiple studies, each with its own specific objectives, were implemented. These studies have been grouped into three main categories:

- Aquatic habitat assessments.
- Fish distribution and relative abundance surveys.
- Instream flow studies.

11.3 Aquatic Habitats

Extensive studies of aquatic habitat conditions were conducted from 2004 through 2008. These studies were designed to describe various aquatic habitat characteristics so that relationships between habitat conditions and fish distribution and abundance could be assessed. Aquatic habitat studies took place in the mine study area and in various streams along the representative road alignment.

11.3.1 Aquatic Habitat Assessments in the Mine Study Area

The aquatic habitat surveys for 2004 through 2008 were conducted in three types of aquatic habitats: mainstem and tributary streams, off-channel aquatic habitats, and lakes. The mainstem and tributary studies focused primarily on the NFK, SFK, and UT watersheds, although some stream habitat assessments were also conducted in the upper reach of the mainstem KR and in Kaskanak Creek. The off-channel aquatic habitat assessments occurred exclusively in the NFK, SFK, and UT watersheds, and the

lake habitat assessments were conducted only in the SFK and UT drainages. Study objectives and methodologies are discussed specific to these aquatic habitat types in the sections that follow.

11.3.1.1 Mainstem and Tributary Aquatic Habitat Assessments

Mainstem and tributary sampling occurred in 2004 through 2008 in the KR, NFK, SFK, UT, and Kaskanak Creek watersheds. The major objectives of the mainstem and tributary aquatic habitat assessments were as follows:

- To characterize mainstem and tributary streams with regard to reach-scale channel processes and characteristics.
- To delineate and describe discrete habitat units (e.g., pools, riffles, glides) with regard to their potential to serve as fish habitat.
- To describe the distribution of aquatic habitat types available for fish use.

Mainstem and tributary habitats were sampled using several methods, including modified Tier 1 and Tier 3 aquatic habitat assessments based on United States Forest Service (USFS) protocols (USFS, 2001), special habitat feature surveys, qualitative habitat sampling, anecdotal habitat data collection, and mesohabitat mapping. Details of each of these survey methods are discussed below.

Modified Tier 1 and Tier 3 Aquatic Habitat Surveys

In 2004, 2005, 2007, and 2008, modified Tier 1 and Tier 3 habitat survey protocols (USFS, 2001) were used to collect mainstem and tributary habitat data in the NFK, SFK, and UT watersheds. The modified Tier 1 and Tier 3 aquatic habitat survey methods for the project were adapted from Chapter 20, Fish and Aquatic Stream Habitat Survey, of the *USFS FSH 2090–Aquatic Habitat Management Handbook* (R-10 Amendment 2090.21-2001-1;USFS 2001). Aquatic habitats were evaluated using a hierarchical system that classifies habitats based on discrete units with measurable criteria. Using this method, habitat data can be collected at multiple tiers (i.e., Tiers 1, 2, and 3) so that Tier 1 represents the broadest level of classification (e.g., reach-scale data) and Tiers 2 and 3 represent finer levels of classification (e.g., meso- and microhabitat units). Habitat nomenclature used in the surveys followed the methodology described in the Fish and Aquatic Stream Habitat Survey chapter (USFS, 2001).

Because the USFS protocols were developed for use in forested wadeable Southeast Alaska streams, the protocols used for this project were modified for use in non-forested streams. Method protocols are described in detail in the *Aquatic Habitat Management Handbook* (USFS, 2001). Specific modifications and variations from the USFS protocols are discussed below.

Depending on the sampling year, either a continuous or subsampling scheme was used for the Tier 1 and Tier 3 aquatic habitat surveys. In 2008, habitat surveys typically began at a predetermined location, which was commonly a tributary confluence. Tier 1 and Tier 3 data were collected concurrently as the survey progressed in an upstream direction. The goal was to collect continuous habitat data to the upper extent of fish distribution in each surveyed stream and its associated tributaries. A sample reach was defined as a section of channel with consistent channel morphology and flow volume. Reaches were delineated during the 2008 aquatic habitat surveys when a major change in the reach-scale geomorphology (e.g., channel type, gradient) was observed or at a tributary confluence if the observed percent flow contribution of the

tributary to the mainstem was greater than 20 percent. In 2008, approximately 149 stream miles (240 kilometers [km]) were surveyed using the modified Tier 1 and Tier 3 approaches; this total survey distance represents 142 different streams and 275 delineated sample reaches (Figure 11-3). Tier 1 data (i.e., reach-scale data) were collected at channel morphology transects established within these delineated reaches; these transects were located in fast-water habitats, because these habitats generally demonstrate channel geometry that has resulted from reach-scale flow volume and geomorphic processes. Among the entire 2008 habitat survey area, 643 channel morphology transects were surveyed.

In 2004, 2005, and 2007, a subsampling scheme was applied for Tier 1 and Tier 3 aquatic habitat surveys and surveys in subsampled reaches were conducted independently of each other. The modified Tier 1 surveys, conducted in 2004 and 2007, occurred at 30 representative channel morphology transects in the NFK, SFK, and UT watersheds. Each transect was sampled on a single occasion in June 2004, August 2004, or July 2007. Three transects were located on the NFK tributary 1.190. The SFK watershed was represented by 12 mainstem transects, with an additional eight transects in selected SFK tributaries. The UT watershed was represented by two mainstem and five tributary transects. The modified Tier 3 subsampling approach was used in 2004, 2005, and 2007. Sixty-one subsample reaches, representing 14 streams, were surveyed in these 3 study years (Figure 11-3). Among these 61 subsample reaches, approximately 27.3 miles (44 km) of stream were sampled; individual subsample reach lengths ranged from approximately 328 to 9,840 ft (100 to 3,000 m) of continuous stream.

Although the sampling scheme Tier 1 and Tier 3 aquatic habitat assessments varied among sampling years, the specific Tier 1 and Tier 3 habitat parameters that were recorded during field surveys were largely similar among years. The reach-scale (i.e., Tier 1) parameters that were recorded include channel type, channel profile, bankfull width, bankfull depth, channel bed width, wetted width, bank incision depth, bank slope length, bank slope angle, discharge, stream gradient, and substrate distribution (Table 11-1). With the exception of channel profile, bank incision, and bank slope data, each of these parameters was recorded in 2004, 2007, and 2008. In 2004 and 2007, detailed channel profile data were collected by spanning a Kevlar tape along the length of each transect and measuring the depth with an incrementally marked wading rod at various intervals along the length of the tape. Approximately 20 intervals were used for each transect. Tape distances associated with the left and right top of bank, bottom of bank, and wetted edges were recorded. Bank incision depth was measured in 2004 and 2007, and bank slope length and angle were measured only in 2004. Channel type was also recorded in 2005, during the modified Tier 3 surveys conducted that year.

Methods used to collect Tier 1 habitat parameters were consistent across all sampling years. Channel type was determined using definitions provided in the USFS *A Channel Type Users Guide for the Tongass National Forest, Southeast Alaska* (Paustian et al., 1992). Bankfull width, bankfull depth, channel bed width, and wetted width were measured using a 164-ft (50-m) Kevlar tape, calibrated laser range finder, stadia rod, and/or an incrementally marked wading rod. Bankfull width measurements were extended to include major side channels present at each channel morphology transect. Bankfull depth was defined and measured as the maximum depth relative to the bankfull flow level. Discharge was calculated using either a Marsh McBirney flow meter or the float method, as described in the *National Handbook of Recommended Methods for Water Data Acquisition* (USGS, 1977). In 2004 and 2007, an auto level and stadia rod were used to calculate stream gradient from differences in water surface elevations (WSEs) across a measured distance upstream and downstream of each transect. In 2008, stream gradient was determined using a clinometer over a distance of 20 bankfull widths, unless the line of sight was obscured

because of sinuosity and vegetation, in which case the greatest visible line of sight was used. Substrate distribution data were acquired using Wolman pebble counts (Wolman, 1954). Selection bias for substrate measurements was minimized by conducting a boot-tip survey, in which the observer selected the first particle encountered at the tip of the boot. One hundred substrate pieces were measured using a gravelometer, or along the intermediate axis using a metric ruler. Pebble count data were used to calculate D50 and D84 particle sizes (USFS, 2001).

Modified Tier 3 habitat surveys (USFS, 2001) were conducted by two-person field crews in June-July 2004, June 2005, July-September 2007, and June-September 2008 to delineate and quantify habitats in the study area. The goal of the modified Tier 3 surveys was to delineate individual habitat units along the length of a mainstem or tributary stream. Recognized habitat types were based on and modified from mesohabitat definitions provided by Moore et al. (2006) and included fast-water habitat types (i.e., cascade, riffle, run/glide), slow-water habitat types (i.e., backwaters/sloughs, pools), and beaver pond complexes (Table 11-2). In 2008, pond, lake, and flowing wetlands were also encountered and classified as such. Secondary habitat units (i.e., subunits) were identified when encountered within the primary habitat units. Tier 3 habitat data were collected specific to each of the primary and secondary habitat units. Within the 27.3 miles (44 km) of stream that were subsampled during the 2004, 2005, and 2007 surveys, 1,781 individual habitat units were delineated. In 2008, 7,602 individual habitat units were delineated and sampled for Tier 3 habitat data.

The following Tier 3 habitat survey parameters were recorded in all sampling years: habitat type, habitat unit length, substrate data, percent undercut bank, riparian vegetation types, large woody debris data, pool wetted width, maximum pool depth, pool tail crest depth; although data collection methods varied among years (Table 11-1). In 2004, 2005, and 2007, habitat unit lengths were determined using a hip chain spool and thread, and length measurements in 2008 were determined using a Kevlar tape or a calibrated laser range finder. Dominant and subdominant substrates were recorded for the first 3 study years, but in 2008, percent substrate composition was visually estimated for each habitat unit. For all 4 years, substrate classes were based on a modified Wentworth scale (Wentworth, 1922) and included organics, sand/silt (<2 millimeters [mm] in diameter), gravel (2 to 64 mm in diameter), cobble (64 to 256 mm in diameter), boulder (>256 mm in diameter), and bedrock. Percent undercut bank was determined as the proportion of the total bank length with significant undercut. Recognized riparian vegetation types included conifer forest, broadleaf forest, willow shrub, alder shrub, other shrub, tundra, bog, fen, and other herbaceous. The number of large wood pieces and clusters were recorded. Pool wetted width, maximum pool depth, and pool tail crest measurements were made for all sampling years using a Kevlar tape, calibrated laser range finder, stadia rod, and/or incrementally marked wading rod. Residual pool depth was calculated as the difference between the maximum pool depth and the depth at the pool tail crest.

Additional Tier 3 survey parameters were collected in 2008 (Table 11-1). These parameters included habitat unit wetted width for all habitat types, habitat unit average depth, percent bank erosion, cover types, percent cover, and pool forming factor. Width and depth measurements were made using a Kevlar tape, calibrated laser range finder, or stadia rod. When survey conditions (e.g., rain, dense riparian vegetation) precluded the use of a measuring tape or laser rangefinder, ocular estimates were made for unit dimensions. For each unit, percent eroding bank, cover type, and percent cover were visually assessed and recorded. In addition to maximum pool depth and pool tail crest depth, the factor responsible for forming the pool (e.g., stream meander, boulder, woody debris) was also recorded in 2008. Digital photos and global positioning system (GPS) waypoints were taken to document and describe the habitat

units that were delineated. In 2008, selected habitat crews also flagged randomly selected habitat units for subsequent fish sampling, so that fish distribution and abundance data could be directly tied to habitat characteristics and fish densities could be calculated by habitat type. Details regarding the selection of the habitat units for fish sampling and the fish sampling protocols are discussed in Section 11.4.2.1.

Modified Tier 3 habitat survey data were also collected for split channels in 2008 and for side channels in 2004, 2005, 2007, and 2008. Split channels were defined as separate flow paths located within the bankfull channel and separated from each other by gravel bars that were barren or supported only annual vegetation. When split flow was encountered, each channel was surveyed in accordance with the modified Tier 3 sampling protocols discussed above; the proportion of flow transmitted by the split was used to classify each channel as primary (i.e., has the majority of the flow) or secondary (i.e., has less flow than the primary channel). Side channels were defined as features with a fluvially sorted bed that were separated from the main channel by an island that was at least as long as the main channel bankfull width and supported permanent vegetation. Each channel was identified as entering from the downstream left or right bank and classified as wet or dry. In 2008, GPS waypoints were recorded to note split and side channel locations, and in 2004, 2005, and 2007, hip chain readings were used to record the relative location of side channels.

Special Feature Surveys. In 2008, special habitat feature surveys were conducted concurrent with the modified Tier 1 and Tier 3 aquatic habitat surveys. The goal was to document the presence and location of special habitat features (i.e., tributaries, springs, seeps, possible barriers to upstream fish migration) encountered during the surveys. Parameters recorded as part of the special feature surveys are shown in Table 11-1. For tributaries, seeps, and springs, the percent flow contribution to the mainstem was visually estimated, and the temperatures of the special feature inflow and of the mainstem water upstream and downstream of the inflow were measured. For possible fish migration barriers, the following data were recorded: barrier type (e.g., beaver dam, falls), barrier height, barrier length, and water depth below barrier. A GPS waypoint and a photograph were taken for each special feature.

Lower UT Habitat Surveys. In 2008, the lower mainstem reaches of the UT, from its confluence with Iliamna Lake to RKm 14.5 (Figure 11-3), received special attention, because these reaches were not previously sampled for aquatic habitat data. These lower reaches pass through land owned by the Alaska Peninsula Corporation (APC), and the survey was conducted in coordination with fisheries staff from Alaska Peninsula Corporation Services (APCS). Generally, the modified Tier 1 and Tier 3 sampling methodologies described above were also used for this lower UT study; variations between the above methodologies and those used for this study component are as follows.

The lower main channel UT aquatic habitat surveys were conducted using an inflatable raft, because flow conditions and channel size precluded the ability to conduct foot surveys. After the main channel UT habitat surveys were completed, foot surveys were conducted in side channels to inventory side channel habitats. For consistency with the main channel boat surveys, side channel foot surveys were conducted in a downstream direction. Because of the extensive network of side channels in the lower 9 miles (14.5 km) of the UT, a subsampling was implemented; a minimum of 25 percent of representative side channel habitat was identified on orthophotographs and subsequently surveyed.

The primary focus of the main channel and side channel surveys in the lower UT was the delineation of individual habitat units and the collection of Tier 3 habitat data. Four hundred two individual main channel, side channel, and split channel habitat units were delineated. All of the parameters that were

collected for the other 2008 modified Tier 3 habitat surveys (Table 11-1) were also measured or recorded for the lower UT study, with the exception of percent undercut bank. Special feature surveys were performed in conjunction with the downstream Tier 3 sampling. The special feature surveys in the lower UT differed from the protocols described above in that side channels and split channels were recognized as feature types, in addition to tributaries, springs, seeps, and fish migration barriers. The decision to recognize side and split channels as feature types was based on the extensive channel network in these lower UT reaches.

Tier 1 habitat data collected during the 2008 lower UT study occurred at channel morphology sites located at 0.3-mile (0.5-km) intervals in the center of the main channel. Each site was flagged during the Tier 3 habitat survey, and a fish assessment team subsequently visited each site for fish distribution and abundance sampling. Channel morphology data was collected at these sites during the fish surveys. Measured channel morphology parameters include bankfull width, bankfull depth, channel bed width, wetted width, and stream gradient. Channel type was recorded by the habitat survey crew during the Tier 3 aquatic habitat surveys. Higher flows and greater depths restricted the number of channel morphology data and fish sampling sites in the lowest reaches of UT.

Mainstem Index Habitat Surveys. From 2004 through 2008, 55 mainstem index sites were surveyed to describe the fish habitat **.** In August 2008, habitat and fish surveys were conducted at 43 index sites in the mainstem NFK, SFK, and UT. Using a geographic information system (GIS) software environment, sites were established at approximately 4.33-km intervals along the entire lengths of the mainstem NFK, SFK, and UT. Primary study objectives and fish sampling protocols are described in Section 11.4.2.4. In 2008, the habitat sampling component of this study used modified Tier 3 aquatic habitat survey protocols (USFS, 2001). At each index site, individual habitat units were delineated over a total stream length of 40 m; among all 43 index sites, 61 individual habitat units were delineated. These modified Tier 3 surveys were abbreviated surveys in that only the following parameters were recorded for each habitat unit: habitat type, habitat unit length, bankfull width, average wetted width, average depth, stream gradient, percent substrate composition, percent undercut bank, percent cover, and number of key wood pieces. These parameters were measured and recorded using the same protocols discussed above. In 2004, qualitative stream habitat surveys were used to collect habitat data at 16 index sites. Methodologies for these surveys are described below.

Qualitative Stream Habitat Surveys

In August 2004, qualitative stream habitat surveys were conducted at 16 pre-established monitoring locations in the NFK, SFK, UT, and Kaskanak Creek (Figure 11-4). These 16 sites were also surveyed for fish abundance and density data as part of the fish mainstem index study (see Section 11.4.2.4). Habitat characteristics at these monitoring sites were described in terms of stream gradient, stream type, bank composition, bank stability, habitat type composition, cover, substrate, beaver dam presence, and overall habitat quality with regard to spawning, rearing, and overwintering habitat conditions (Table 11-1). Stream type classifications were made using Rosgen alpha-level classifications, which are based on stream characteristics that result from relief, landform, and valley morphology (Rosgen, 1996). Although qualitative descriptions were recorded for the majority of these parameters, quantitative data for percent habitat type composition and percent substrate composition were collected by visual assessment. Classified habitat types used to determine percent habitat composition included backwaters, sloughs,

scour pools, glides, riffles, and cascades. Substrate size classes were based on a modified Wentworth Scale (Wentworth, 1922).

Supplemental Habitat Data Collection

During the 2004 through 2007 sampling years, supplemental habitat data were often collected by fish sampling crews concurrent with fish sampling events in the mainstem and tributary habitats of the KR, NFK, SFK, and UT. The parameters that were most often recorded to describe the habitat of the fish sampling site include habitat type, sample length, wetted width, substrate type, and cover type (Table 11-1). The recognized habitat types are the same as those used for the modified Tier 3 aquatic habitat surveys discussed above. Sample length and wetted width measurements were made using a Kevlar tape, and substrate and cover types were visually assessed. The direct linkage between the 2008 modified Tier 3 aquatic habitat surveys and the fish sampling that occurred at the delineated habitat units precluded the need for the collection of anecdotal habitat data during the 2008 fish surveys. Additional details regarding fish sampling efforts and fish-habitat associations are described in Section 11.4.2.1.

Mesohabitat Mapping

Mesohabitat mapping was conducted to provide a quantitative description of the distribution of aquatic habitats available in the mainstem NFK, SFK, and UT. The mesohabitat mapping involved two main types of data collection and processing: field mapping and remote sensing analysis. Field surveys were conducted in the mainstem NFK, SFK, and UT in 2005 and 2007. These field studies focused on the documentation and delineation of mesohabitat types within selected sample reaches. To further build upon field data collection efforts and to extend the map coverage to the entire study area, GIS technology was used for remote mesohabitat mapping. For both components, mesohabitat types were generally based on definitions in Moore et al. (2006; Table 11-2). These mesohabitat types are the same as those used during the modified Tier 3 aquatic habitat surveys, except that cascade, pond, lake, and wetland habitat types were not noted in the mainstem NFK, SFK, and UT reaches that were mapped.

In June 2005, reaches of approximately 1,640 ft (500 m) were walked to describe the distribution of mesohabitat types within each sampled reach. Four reaches were sampled in the mainstem NFK, and six reaches were sampled in both the mainstem SFK and the mainstem UT. Mesohabitat type, habitat unit length, and coordinates describing the upstream and downstream extents of each encountered mesohabitat during the surveys were recorded (Table 11-1).

Additional mesohabitat field surveys were conducted between August and October 2007. The 2007 study area included a continuous section of the mainstem UT from river mile (RM) 9 (RKm 14.8) upstream to the confluence of tributary UT1.450, as well as five study reaches on the NFK and three reaches on the SFK. The 2007 mesohabitat surveys were conducted on foot by trained two-person field teams proceeding downstream. Mesohabitats were surveyed along the full lengths of all channels flowing around island complexes. Surveyors collected data with a handheld GPS/PDA unit using ArcPad® software and a Trimble XB receiver (Archer Field PC, estimated accuracy ± 2.0 ft), a waterproof digital GPS-enabled camera (Ricoh, Caplio 500SE), and a laser rangefinder (Bushnell Yardage Pro, accuracy ± 3.0 ft). Mesohabitat type, habitat unit length, channel bed width, and coordinates describing the upstream and downstream extent of each habitat unit were recorded during these 2007 mesohabitat field surveys (Table 11-1). Habitat unit lengths and channel bed widths were measured using a laser range finder. All field data were recorded and stored in the GPS/PDA unit. A photograph was taken at each

mesohabitat unit. To ensure that recorded locations accurately represented the stream centerline, mesohabitat transition points and photographs were taken in the center of the stream whenever conditions allowed. Field data were downloaded and stored in a secure electronic backup device on a nightly basis.

Mesohabitats also were mapped using remote-sensing data. Data sources used include 2004 ortho-rectified digital imagery of the NFK, SFK, and UT; 2008 ortho-rectified digital imagery of the UT; and 2004 geo-referenced videography from a low-flying helicopter of the SFK and UT. A series of steps were then undertaken in a GIS-software environment to be able to quantify the distribution of mesohabitat types within the NFK, SFK, and UT.

The first step involved using the 2005 and 2007 field data and a digitized channel margin layer to construct a polygon coverage describing mesohabitat units that were field surveyed. Wetted channel margins were digitized on the 2004 orthophotos. Start and end points of each mesohabitat unit identified during the 2005 and 2007 field surveys were plotted, and a polygon coverage was created depicting each mesohabitat unit, so that field GPS points defined the upstream and downstream extent, and wetted channel margins defined lateral habitat unit boundaries. Habitat units delineated during field surveys were overlaid on the 2004 orthophotos and reviewed to calibrate the appearance of habitat types on the 2004 images.

The second step was to expand the coverage of mesohabitat data. For portions of the mainstem channels that were not surveyed, mesohabitat units were classified and delineated based on the 2004 imagery to create a polygon coverage for the remaining area. The mapper's confidence in the classification of each mesohabitat unit identified from the photos was rated high, moderate, or low. Factors impairing the ability to positively identify the unit type (e.g., glare, shadow, poor image quality) were noted in the comments field of the associated attributes table.

The 2004 videography and 2008 orthophotos were utilized to confirm habitat classifications and note temporal changes in habitats and channel locations. Videography was reviewed to improve photo-derived habitat unit classifications for the SFK and UT. After completing the mapping based on the 2004 orthophotos and the videography, the UT mesohabitat map (i.e., the polygon layer) was overlaid on the 2008 orthophotos to confirm habitat classifications and to identify areas where the channel location or habitat has changed since 2004. Lastly, the wetted area of all habitat unit polygons was calculated using a GIS function. The number of units and total area of each type of habitat was calculated for each EBD stream reach.

11.3.1.2 Off-Channel Aquatic Habitat Assessments

From 2005 through 2008, off-channel habitat studies were conducted in the NFK, SFK, and UT watersheds. These off-channel studies consisted of three sampling components. First, instream flow studies were conducted to characterize the distribution of off-channel habitats and to understand flow relationships between main channel and off-channel habitats. The other two components are habitat and fish surveys, which were subsequently conducted at the off-channel habitat sites established during the instream flow component. Collectively, the objectives of the off-channel habitat studies were as follows:

- Characterize the quality and quantity of aquatic habitats within representative off-channel areas adjacent to mainstem rivers.

- Compare fish distribution and abundance patterns between main channel and off-channel habitats.
- Compare fish distribution and abundance patterns among off-channel habitat types.
- Provide fish presence and relative abundance data for use in instream flow model development.
- Understand off-channel habitat function relative to mainstem flow patterns.
- Evaluate mechanisms of off-channel habitat connectivity with mainstem channels.

Sampling protocols that were used for the habitat survey component are discussed below. Fish sampling protocols are described in Section 11.4.2.2. Instream flow methods, including the establishment of the off-channel study transects and the selection of representative off-channel habitat sampling sites, are described in Section 11.5.

The off-channel habitat studies were conducted in the SFK watershed in 2005 through 2007, the UT watershed in 2007, and the NFK watershed in 2008. Aquatic habitat survey methods used in the 2005 through 2007 surveys differed from those used for the 2008 surveys. In 2008, modified Tier 3 aquatic habitat survey protocols (USFS, 2001) were used. For the 2005 through 2007 surveys, habitat data were collected supplemental to fish sampling at the off-channel sites.

Modified Tier 3 Aquatic Habitat Surveys

Modified Tier 3 aquatic habitat surveys (USFS, 2001) were conducted at 17 NFK off-channel habitat sites between late July and mid-August 2008. Sampling at each NFK off-channel habitat site occurred over a distance equivalent to 10 times the off-channel feature width upstream and downstream of each off-channel transect. If the off-channel habitat length was less than 100 m, then the entire habitat was sampled. Habitat units at each off-channel habitat site were delineated by two-person survey crews, and special habitat feature surveys were conducted concurrently. Among the 17 off-channel habitat sites that were surveyed in 2008, 38 individual habitat units were delineated. The parameters recorded during the modified Tier 3 and special feature habitat surveys are shown in Table 11-3. Data collection protocols for these parameters are the same as those discussed in Section 11.3.1.1. Habitat types used for the off-channel surveys were the same as those used for the mainstem and tributary surveys, except isolated pools were distinguished from other types of pools (e.g., scour pools) because of the prevalence of this microhabitat type in off-channel areas. Each off-channel habitat site was walked to determine if there was a surface connection to the mainstem. Site photographs were taken, and approximate off-channel habitat dimensions were sketched on a field copy of orthophotos.

To provide main channel habitat and fish data for comparison with off-channel sampling results, the mainstem NFK adjacent to the off-channel habitat sites was also surveyed in 2008 using the same modified Tier 3 aquatic habitat survey protocols. The mainstem survey began approximately 10 bankfull widths downstream of the downstream-most off-channel transect and progressed upstream to 10 bankfull widths upstream of the upstream-most transect. Within this survey area, 60 mainstem habitat units were delineated.

Supplemental Habitat Data Collection

Off-channel habitat surveys in the SFK and UT were conducted concurrent with fish sampling events. Within the SFK watershed, 75 off-channel habitat sites were positioned along 12 SFK off-channel

transect, and in the UT, 57 off-channel habitat sites were positioned along nine transects. The SFK off-channel sites were sampled in September 2005, June and August 2006, and July 2007, and the UT off-channel sites were sampled in July and October 2007. Habitat data collected during the fish surveys included habitat type, sample length, wetted width, substrate type, and cover type (Table 11-3). Habitat types used for the off-channel habitat surveys in 2005 through 2007 were the same as those used for the 2008 off-channel habitat surveys as discussed above. Sample length and wetted width measurements were made using a Kevlar tape, and substrate and cover types were visually assessed. Groundwater and surface water connections were also noted for each off-channel habitat site.

To provide mainstem habitat and fish data for comparison with off-channel sampling results, study sites were established at the main channel midpoint of each SFK and UT off-channel study transect, as well as at the mainstem instream flow transects. Twelve and nine mainstem sites affiliated with the off-channel transects were surveyed in the SFK and UT, respectively. Additionally, there were 17 and 31 main channel sites affiliated with the mainstem instream flow transects in the SFK and UT, respectively. Habitat and fish surveys were conducted concurrently for each main channel site. Habitat sampling protocols at the mainstem sites were the same as those for the mainstem and tributary anecdotal habitat data collection events (see Section 11.3.1.1).

11.3.1.3 Lake Habitat Assessments

In 2005 and 2007, aquatic habitat assessments were conducted in various lakes in the SFK and UT watersheds. These lake surveys focused on the collection of depth, substrate, and water quality data. Six lakes in the SFK watershed were sampled for depth profile data in August 2005, and 17 lakes in the SFK and UT watersheds were sampled for depth, substrate, and water quality data in July and September 2007. All depth and substrate data were collected along transects that were established to capture a representative lake bottom profile; three to six transects were established for each lake. Substrate size classes were based on a modified Wentworth Scale (Wentworth, 1922). Using a handheld YSI meter, water temperature, pH, specific conductivity, and total dissolved solids were measured at three different surface water locations for each lake sampled in 2007.

11.3.2 Aquatic Habitat Assessments in the Transportation Corridor/Cook Inlet Study Areas

There are numerous drainages within the transportation corridor/Cook Inlet study areas, varying from large rivers (e.g., Newhalen River) to very small seasonally flowing channels that drain water from Roadhouse and Knutsen mountains to the North. Some of these drainages may support fish populations and migratory or anadromous fishes, in particular. Field data on habitat conditions and fish species present in these drainages were collected in 2004, 2005, 2007, and 2008. The fish sampling component is discussed in Section 11.4.3. For the aquatic habitat assessments, the primary objectives were as follows:

- Collect site-specific channel morphology and habitat data to describe existing aquatic habitat conditions at representative stream crossings (primary survey site locations).
- Collect site-specific channel morphology and habitat data to describe existing aquatic habitat conditions upstream and/or downstream of the primary survey sites, or on nearby tributaries (support survey sites).

- Identify aquatic resources (e.g., anadromous fish presence, fish migration barriers, water quality) present at sample sites.

One hundred sixteen sites were initially surveyed in 2004, with 27, 11, and 26 additional site surveys added in 2005, 2007, and 2008, respectively (Figure 11-2). The length of stream surveyed at each stream was 656 ft (200 m) or 40 times the average channel bed width. The lesser of the two values was chosen as the sample length.

Among all sampling years, parameters describing channel morphology, aquatic habitat characteristics, special habitat features, and water quality were recorded at each site location (Table 11-4). There was variation across years as to what specific parameters recorded, a result of the different study methods that were employed. In 2004, 2005, and 2007, all parameters were recorded specific to each survey site. In 2008, modified USFS Tier 1 and Tier 3 aquatic habitat survey protocols guided the approach. Consequently, channel morphology (i.e., Tier 1), special habitat feature, and water quality data were collected specific to the survey site, and parameters describing Tier 3 aquatic habitat characteristics were collected specific to individual habitat units delineated during the surveys (USFS, 2001). In some cases, this approach resulted in habitat characteristic data being collected for multiple habitat units at one site. Data collection protocols used for the 2008 aquatic habitat assessments in the transportation corridor/Cook Inlet study areas are similar to those used for the modified Tier 1 and Tier 3 aquatic habitat surveys of the mainstem and tributaries discussed in Section 11.3.1.1; details and variations specific to the transportation corridor aquatic habitat surveys are described below.

Several channel morphology parameters were recorded during the aquatic habitat assessments in the transportation corridor (Table 11-4). In 2008, channel type classifications were based on definitions provided in Paustian et al. (1992). As an alternative to the Paustian et al. (1992) classifications, Rosgen alpha-level stream type classifications were used in 2004 and 2007. Rosgen alpha-level stream type classifications are based on stream characteristics that result from relief, landform, and valley morphology (Rosgen, 1996). Channel form was further described in 2004, 2005, and 2007 by classifying each stream as deeply incised, moderately incised, braided, or alternating as a series of deep pools and long riffles. Channel incision was qualitatively determined by recording left and right bank incision depths and by a visual assessment of channel bed width relative to channel depth. Deeply incised channels were typically deep and narrow, and moderately incised channels were typically wider than they were deep. Braided channels were defined as a network of small channels separated by small and often temporary islands. Stream bank composition was described in terms of the substrates that contributed to the bank composition, and bank stability was ranked as high, moderate, or low. Additional parameters describing channel geometry and flow levels at the time of the survey were recorded in most survey years and include bankfull width, bankfull depth, channel bed width, wetted width, and average depth. These measurements were made using either a Kevlar tape, laser range finder, stadia rod, or incrementally marked wading rod. In 2004, 2005, and 2007, discharge estimates were derived through the collection of wetted width, depth, and velocity data along the length of a cross-sectional transect at each site. For all survey years, stream gradient was determined using a clinometer. In 2008, riparian vegetation types adjacent to the survey area were recorded. Photographs were taken at each site to further document and describe the primary survey site at the time of sampling.

Although actual habitat units were delineated only during the 2008 modified Tier 3 habitat surveys, habitat type composition was determined in all sampling years by estimating the percent of the total

aquatic habitat surface area consisting of different habitat types. Recognized habitat types for all survey years were based on Moore et al. (2006) and are generally the same as those shown in Table 11-2. In 2008, habitat type, habitat unit length, habitat unit wetted width, and percent substrate composition data were collected for all indentified habitat units; for pool habitats, maximum pool depth, pool tail crest depth, and the pool forming factor (e.g., stream meander, boulder) were also determined. All width, length, and depth measurements were made using a Kevlar tape, laser range finder, or stadia rod. Percent substrate composition was also recorded in 2004, 2005, and 2007, although data were specific to the entire stream site rather than individual habitat units. For all survey years, substrate size classes were based on a modified Wentworth scale (Wentworth, 1922) and included organics, sand/silt (<2 mm in diameter), gravel (2 to 64 mm diameter), cobble (64 to 256 mm in diameter), boulder (>256 mm in diameter), and bedrock.

In 2004, 2005, and 2007, assessments of fish cover availability and overall habitat quality for spawning, rearing, and overwintering fish were made. Fish habitat cover was described in terms of the presence of undercut bank, overhanging vegetation, and woody debris (Table 11-4). Field survey crews assessed the spawning, rearing, and overwintering habitat quality of each site using a high-quality to low-quality ranking system. These rankings were based on an overall qualitative assessment of stream characteristics, such as the presence of suitable spawning substrates and fish cover.

Special habitat feature surveys were conducted for all survey years at each transportation corridor survey site (Table 11-4). In 2008, recognized feature types included tributaries, seeps, springs, side channels, and potential fish migration barriers. In 2004, 2005, and 2007, special habitat feature surveys focused solely on potential fish migration barriers. Measurements at special habitat features were made using a Kevlar tape, laser range finder, or stadia rod. In all years, when a potential fish migration barrier was encountered, barrier type (e.g., beaver dam, falls, dry channel) and barrier height were recorded. In 2008 additional data were collected on barrier length and depth below the barrier per USFS protocols (USFS, 2001). Barrier measurements were made using an incrementally marked wading rod or stadia rod. The locations of special features observed during the 2008 surveys were recorded using a handheld GPS unit.

Water quality data were collected at all sites in all years. Parameters that were collected include water temperature, pH, conductivity, dissolved oxygen, and turbidity, although turbidity was only measured in 2004, 2007, and 2008 (Table 11-4). In most cases, water quality measurements were made using a handheld YSI meter. Turbidity measurements in 2004 and 2007 were made using a graduated Secchi tube. The graduated Secchi tube is a transparent tube with a Secchi disc located at the bottom. By filling the tube with stream water and then slowly releasing the water until the Secchi disc is visible, a water column height (i.e., the turbidity measurement) can be determined from the graduated markings on the tube.

11.4 Fish Distribution and Relative Abundance

Several studies were conducted from 2004 through 2008 to document and describe patterns of fish distribution and relative abundance in the mine and transportation corridor/Cook Inlet study areas. Although several of these studies had specific study objectives and used study-specific sampling approaches, a variety of standard fish sampling and capture methods also was used. Details regarding these standard fish capture methods are discussed in Section 11.4.1. Sections 11.4.2 and 11.4.3 describe

the specific study objectives and sampling approaches that were used for studies in the mine and transportation corridor/Cook Inlet study areas, respectively.

11.4.1 Fish Observation and Capture Methods

Several fish sampling methods were employed for fish surveys in the mine and transportation corridor/Cook Inlet study areas. These methods include snorkel surveys, electrofishing surveys, minnow traps, beach seines, fyke nets, gill nets, tangle nets, and angling. Descriptions of how these sampling methods were employed are found below. Additional procedures used for fish species and life stage identifications also are described.

11.4.1.1 Snorkel Surveys

Snorkel surveys were the primary method used to collect fish presence, distribution, and abundance data. Team members trained in fish species identification conducted one-pass snorkel surveys. Before beginning a survey, climatological and hydrological conditions, including the air and water temperatures and water clarity (visibility), were documented. Snorkelers used a plastic salmonid silhouette with parr marks to evaluate visibility. The distance from the snorkeler to the salmon model was determined first when the parr marks on the silhouette were visible during approach and then once they were no longer visible during retreat. Water visibility was calculated as the average of these two distances (Thurow, 1994).

Sample sections were snorkeled by starting at the downstream end and working upstream unless water velocity precluded upstream movement. Snorkel surveys consisted of a single snorkeler when wetted stream widths were less than 16.4 ft (5 m). Observations were made by counting fish on both sides of the stream channel while alternating from left to right counts. For streams with wetted widths greater than 16.4 ft (5 m), the entire area of the stream was sampled by two or more snorkelers moving upstream in tandem or by a single snorkeler moving in a concerted pattern (e.g., up the left bank, down the middle of the channel, up the right bank). Snorkelers visually identified and counted all species encountered; fish counts were grouped by species and life stage or length bin (e.g., 0- to 40-mm fork length [FL]). Snorkel observations were called out to a non-snorkeling team member and recorded on a field data sheet.

In 2007 and 2008, snorkel surveys were calibrated using multi-pass electrofishing depletion sampling (see Section 11.4.1.2). At a minimum, a calibration survey was conducted for each habitat type per stream order per drainage. The majority of snorkel calibrations were conducted within the entire sample unit. Subsampling was required for calibration in units where continuous electrofishing was not possible (i.e., deep pools). Prior to snorkeling, block nets were positioned at the upstream and downstream ends of the calibration unit to increase the likelihood of having a closed sample population. The calibration was conducted at least 2 hours after the completion of the snorkel survey to allow fish disturbed by snorkeling activity to redistribute among preferred habitats (Dolloff et al., 1993).

11.4.1.2 Electrofishing Surveys

Electrofishing was conducted according to National Marine Fisheries Service (NMFS) guidelines (NMFS, 2000). Both single- and multi-pass electrofishing techniques were used. Single-pass electrofishing was used to determine fish presence and distribution, and multi-pass sampling was used to

estimate fish abundance. All electrofishing was conducted with a Smith-Root LS-24 backpack electrofisher unit.

Electrofishing was used in sample sections not conducive to snorkeling, (i.e., shallow water; poor visibility). Sample areas were electrofished by a team of two or three moving in an upstream direction. One team member operated the electrofishing unit while other team members used 3-mm nylon mesh dip nets to capture fish as they were encountered. In wide streams, two electrofishing teams were necessary to adequately sample the reach. Captured fish were held in covered 20-L buckets and identified to species. Life stage and FL were recorded.

Protocols for determining population estimates from multi-pass depletion electrofishing are described in Johnson et al. (2007). Block nets were placed at the upstream and downstream end of each sampled habitat unit to limit fish immigration and emigration. Each pass consisted of an electrofishing sweep from the downstream end of the habitat unit toward the upstream end. Up to four passes were made. The upstream and downstream nets were checked for fish after the completion of each pass. Captured fish were placed directly into a closed aerated container. When collection was completed, fish were placed into an anesthesia bath containing ambient stream water and one part clove oil to nine parts ethanol solution at a concentration of 50 milligrams per liter. Each fish was identified to species and life stage, measured for FL to the nearest mm, and placed into a 20-liter (L) bucket with an aerator where they were allowed to recover before being returned as close as possible to the capture point. When high numbers (e.g., greater than 100) of slimy sculpin (*Cottus cognatus*) were captured during three- and four-pass electrofishing, sculpin captured during the first pass were measured to FL, but those in subsequent passes were assigned to a length bin (e.g., 0 to 40 mm) and enumerated. Depletion estimates were germane to species and life stage.

11.4.1.3 Minnow Traps

Minnow traps with 0.64-centimeter (cm) wire mesh were used as an alternative fish capture method to collect fish presence and distribution data where electrofishing and snorkeling were ineffective because of stream conditions (e.g., turbid or deep water, presence of adult salmon). Minnow traps were baited with processed salmon eggs in perforated plastic bottles. Minnow traps were set in habitats (e.g., pools, undercut banks, beaver ponds) likely to maximize catch over a period of 2 to 24 hours (h). Captured fish were removed from minnow traps, placed in 20-L holding buckets, identified to species, measured for FL, and released near the point of capture.

11.4.1.4 Beach Seines

Various sized beach seines with mesh sizes of 0.64 to 1.43 cm were used as an alternative fish collection method in sample areas where electrofishing and snorkeling were ineffective because of stream conditions (e.g., turbid or deep water, presence of adult salmon). The beach seine was deployed across the stream channel beginning at the upstream end of a sample area and slowly worked toward the downstream end of the sample area. At the bottom of the sample unit, the roving end of the beach seine was maneuvered in a sweeping arc to the shore, pivoting about the fixed end. During each seine haul, fish were corralled to the shoreline for collection, removed by dip nets, and placed in 20-L holding buckets. Captured fish were identified to species, measured for FL, and released near the point of capture.

11.4.1.5 Nets

Gill nets and tangle nets were used for fish sampling in lakes. Nets were generally deployed for 2 to 5 h of soak time and were continuously monitored, with fish retrieval occurring immediately after fish capture. Available nets were approximately 15 m wide and 3 m high, with mesh sizes of 5 to 9 cm. The most effective net for capturing fish with minimal stress and injury was used.

11.4.1.6 Angling

Angling was used when collection was targeting adult fish (e.g., radio telemetry studies). Fly rods or spinning gear was used. To minimize fish handling stress, barbless hooks were used, and fish were landed as quickly as possible. Generally, captured fish were identified to species, measured for FL, and released near the point of capture, although variation in handling procedures was dependent upon the specific objectives of the study (e.g., rainbow trout radio-tagging).

11.4.1.7 Species and Life Stage Identification

All observed fish were identified to species and life stage when possible, and FL was measured to the nearest mm for captured and handled fish. All field crew members were trained in species identification. Life stages of fish were based on length frequency distributions. Pacific salmon (i.e., chinook, chum, coho, pink, and sockeye salmon) were segregated as young-of-the year (i.e., age 0+ fish), juveniles (i.e., age 1+ and age 2+ fish), and adults based on apparent differences in size and the appearance of parr marks. Life stages of resident salmonids were classified as young-of-the year (i.e., age 0+ fish), juvenile (i.e., small fish with parr marks and a minimum age of 1+), subadult (i.e., small fish without parr marks), and adult (i.e., larger fish without parr marks or fish with spawning coloration). Non-salmonid fish life stages were based on species-specific length frequency distributions and included young-of-the year (i.e., age 0+), juvenile, and adult fish.

11.4.2 Fish Surveys in the Mine Study Area

From 2004 through 2008, fish distribution and abundance surveys were conducted at 2,962 sample sites in the mine study area (Table 11-5; Figure 11-5). Sites were located in mainstem, tributary, off-channel, and lake habitats of the NFK, SFK, and UT, as well as in the upper reaches of the KR (i.e., from RKm 16.55 to the NFK and SFK confluence), in Kaskanak Creek, and in one lake in the Lower Talarik Creek watershed. Because of the proximity of some sample sites to others, these 2,962 sample sites are collectively represented by 2,850 discrete locations in the mine study area, as well as one and three discrete locations in the Kaskanak and Lower Talarik Creek watersheds, respectively. Table 11-6 shows the specific fish observation and capture methods used throughout the 5-year study period among the defined environmental baseline document (EBD) reaches in the KR, NFK, SFK, and UT; methods used in Kaskanak Creek and Lower Talarik Creek are also shown in Table 11-6.

Although several mainstem and tributary sites sampled were in areas of special interest (e.g., SFK ephemeral reach) or were selected for specific purposes (e.g., winter fish surveys, radio telemetry fish tagging), field data from all fish sampling sites were used to describe fish distribution throughout the mine study area. Sampling protocols varied among the specific locations targeted by certain studies and among specific study objectives. Therefore, methods described herein have been grouped into the following categories: general fish distribution and abundance surveys, fish surveys in off-channel

habitats, winter fish surveys, mainstem index surveys, salmon spawning escapement surveys, and radio telemetry surveys. Specific study objectives and sampling protocols for each of these study categories are described in the sections that follow.

11.4.2.1 Fish Distribution and Abundance Surveys

From 2004 through 2008 fish surveys were conducted in selected mainstem, tributary, and lake habitats in the KR, NFK, SFK, and UT watersheds. Additionally, one lake in the Lower Talarik Creek drainage and one site in Kaskanak Creek were sampled. The primary objectives of these studies were as follows:

- Document patterns of fish distribution and abundance in the mine study area.
- Compare fish abundance and fish density among habitat types within the mine study area.

Across the 5 sampling years, mainstem and tributary sites and lake sites were surveyed (Table 11-5). With the exception of the winter fish surveys and fish tagging efforts related to the radio telemetry studies (see Section 11.4.2.3 and Section 11.4.2.6, respectively), these sites were surveyed in July to September 2004, June to August 2005, June to September 2006, May to September 2007, and June to October 2008. The one site on Kaskanak Creek was sampled in August 2004, and a single lake in the Lower Talarik Creek watershed was sampled in August 2005 and September 2008. Sampling sites were surveyed using a variety of sampling methods (see Section 11.4.1). Method and protocol selection was based on stream characteristics (e.g., water depth and velocity, water clarity) and the goal of each specific task (e.g., fish distribution versus fish density sampling). When specific tasks used particular sampling protocols, details of sampling methodologies are provided. Coordinate data describing fish sampling locations were paired with fish presence data so that the distribution of fish species within the mine study area could be discerned.

In 2008, fish distribution surveys were often conducted in accordance with fish-habitat association surveys (see the Fish-Habitat Associations section below). These surveys occurred in the mainstem and tributary reaches of the NFK, SFK, and UT that had been previously surveyed using modified Tier 3 aquatic habitat survey protocols (USFS, 2001). Surveys typically progressed in an upstream direction, with sampling occurring at habitat units that had been flagged by habitat crews, and were continued until the upstream extent of potential fish habitat was reached. Primary methods of fish capture were snorkeling and electrofishing. Fish observations and coordinates representing fish locations were recorded as field crews moved upstream. In some instances, survey crews began at the headwaters and continuously electrofished in a downstream direction until fish were determined to be present. For surveys performed in a downstream direction, a GPS waypoint representing the point at which fish were first observed was taken, and the location was marked in the field with survey flagging. Fish observations were enumerated by species and life stage. All captured fish were measured for FL and released near the point of capture.

Throughout the 2004 through 2008 study period, areas of special interest were identified because of a unique habitat characteristic (e.g., the SFK ephemeral reach) or because of the identification of a previously existing data gap. These special interest areas included the upper reaches and tributaries of the NFK watershed (from RKm 43.4 to the headwaters), the SFK ephemeral reach (from RKm 34.3 to 51.7), the upper reaches of the mainstem SFK upstream of Frying Pan Lake (from RKm 57.0 to the headwaters), the lower reaches of the UT mainstem (from Iliamna Lake to RKm 14.5), and lake habitats. Fish

distribution and abundance surveys were conducted in these focus areas to ensure their representation within the broader study area. Other areas (e.g., the UT headwaters) were not given special interest with regard to fish distribution sampling, because such areas were already represented by rigorous fish sampling approaches. Details regarding fish survey protocols used in these special interest areas and those used to determine relative fish abundance and fish density among habitat types are provided below.

Fish Distribution and Abundance in the NFK Headwaters

In August and September 2008, mainstem and tributary reaches in the upper NFK watershed were sampled for fish distribution and abundance data. The specific goal of this study was to document the upper extent of fish distribution in this river system. The mainstem NFK sampling began at RKm 43.4 and progressed upstream to all mainstem and tributary headwaters, with NFK tributary 1.260 being the downstream-most tributary surveyed as part of this study. To ensure that a minimum of 25 percent of the fish habitat upstream from this location was sampled, field crews snorkeled or electrofished 250 m of stream per km. Coordinates describing specific sample locations were recorded using a handheld GPS unit. Additionally, GPS waypoints describing locations of visually observed fish outside of the defined 250-m sample reaches were recorded. Seventy discrete sampling and fish observation sites were defined during these field surveys. All observed fish were identified by species and life stage. Captured fish were measured for FL and released near the point of capture.

Fish Distribution and Abundance in the SFK Ephemeral Reach

A portion of the mainstem SFK has been observed to dry up in later winter/early spring (i.e., February to April) and in mid- to late summer (i.e., July to August). Although the geographic extent of this periodic drying has been observed to vary among years and seasons, the maximum extent of drying is thought to occur from just upstream of SFK tributary 1.190 (i.e., RKm 34.3) to RKm 51.7. Loss of flow has multiple potential impacts on fish, including de-watering of redds, fish stranding, and food source limitations. Therefore, fish distribution and abundance patterns in the ephemeral reach were assessed under varying flow conditions.

Five sampling sites, ranging from RKm 34.9 to 50.8, were sampled on five different occasions: late June/early July 2005, August 2005, July 2006, late June/early July 2007, and August 2007. These sampling periods were selected so that abundance estimates during high (i.e., late June to early July), moderate (i.e., July), and low (i.e., August) flow conditions could be compared. The survey length for each site was typically 100 m, although low-flow sampling conditions sometimes precluded the ability to conduct the survey over this distance. In these instances, the entire length of the wetted channel at the site was sampled. Snorkel surveys were the primary method of sampling, but electrofishing was used in conjunction with or as an alternative to snorkeling for four sampling events. All observed fish were enumerated by species and life stage; fish captured during electrofishing surveys were also measured for FL and released at the capture point after the sampling event was completed.

In addition to the five standard ephemeral reach study sites, 41 other sites within the SFK ephemeral reach were sampled for fish distribution and abundance data throughout the study period. Surveys were conducted in May to July 2004, July to August 2005, June to July and September 2006, May and July 2007, and August 2008. The majority were sampled on only a single occasion, primarily for determining fish distribution and relative abundance in the mine study area. As with other fish distribution and

abundance surveys, a variety of fish capture methods were used depending on stream conditions at the time of sampling (see Section 11.4.1).

Fish Distribution and Abundance in the SFK Watershed Upstream of Frying Pan Lake

Initial efforts to determine fish distribution and relative fish abundance in the SFK watershed upstream of Frying Pan Lake involved concentrated sampling at 15 discrete sample sites in the mainstem SFK, and at a single tributary site on SFK tributary 1.330. Nine of the mainstem sites were surveyed in June and September 2006, and again in late June/early July and August 2007. Snorkel surveys and supplemental hook-and-line sampling were conducted at these sites, with survey lengths of 30 to 120 m. The other seven sampling locations were affiliated with the 2004 Tier 1channel morphology transects (see Section 11.3.1.1) and were snorkel surveyed in July 2005. As with other fish distribution and abundance surveys conducted elsewhere in the mine study area, all observed fish were enumerated by species and life stage, and captured fish were measured for FL. Coordinate data were recorded to describe the location of each sample site.

In addition to these 16 concentrated sampling sites, 388 other mainstem and tributary sites in the SFK watershed upstream of Frying Pan Lake were also sampled throughout the 2004 through 2008 study period. Of these sites, 117 were sampled in 2004 through 2007, and 271 were sampled in 2008. The 271 sites that were surveyed in 2008 represent a subsample of the habitat units delineated during the 2008 modified Tier 3 aquatic habitat surveys conducted in the upper SFK watershed (USFS, 2001; see Section 11.3.1.1). During this study year, sampling coverage within the upper SFK watershed extended to the upstream extents of all available fish habitat. Additional details regarding the 2008 fish sampling protocol are provided in the Fish-Habitat Associations section below. Data from all 404 sampling locations in the upper SFK watershed were used to describe fish distribution and relative abundance patterns upstream of Frying Pan Lake.

Fish Distribution and Abundance in the Lower UT

The lower mainstem UT from Iliamna Lake to RM 9 (RKm 14.5) was surveyed for fish in September 2008, following the completion of habitat surveys that were conducted along the same stream reaches (USFS, 2001; see Section 11.3.1.1). Twenty nine transects had been established at 0.31 mile (0.5-km) intervals and flagged by the habitat crew during their earlier surveys. Of these 29 transects, 27 were sampled for fish distribution and abundance data. Two transects located at RKm 0.5 and 1.0 could not be surveyed because of swift currents that were assessed to be a safety risk for snorkelers. At each of the 27 transects sampled, 15-minute (min) snorkel surveys were conducted in the mainstem channel and in all side channels present at that interval. Because of the abundance of side channels in the lower reaches of the mainstem UT, 55 unique main channel and side channel sites were sampled. At each sample site, two snorkelers identified and enumerated fish by species and life stage, as a third crew member recorder the observed counts. Sampling at each site was focused on microhabitats likely to provide sufficient cover and refuge for juvenile and adult fish.

Fish Distribution and Abundance in Lake Habitats

Thirty-three lakes were also sampled for fish distribution and abundance data (Table 11-5). Frying Pan Lake was included among the 25 lakes that were sampled in the SFK watershed. Big Wiggly Lake and Black Lake represent the NFK watershed, and Lake 2 was the single lake that was surveyed in the Lower

Talarik Creek watershed. Survey periods included July to September 2004; August 2005; July and September 2006; May, July, and September 2007; and September to October 2008. Sampling methods included gill/tangle nets, minnow traps, beach seines, angling, and snorkel surveyed. All fish were identified to species and life stage; captured fish were measured for FL and returned to the capture point.

Fish-Habitat Associations

While all available fish sampling data were used to describe fish distribution throughout the study area, several of the fish sampling protocols were designed to allow for the estimation of relative fish abundance and fish density among habitat types. The recognized habitat types are the same as those used for the modified Tier 3 aquatic habitat surveys (USFS, 2001; see Section 11.3.1.1). Generally, two approaches were used for these fish-habitat association surveys.

The first approach links fish sampling sites to the modified Tier 3 aquatic habitat surveys so that fish abundance surveys were conducted at a subset of the habitat units delineated during the habitat surveys (see Section 11.3.1.1). The selection of most fish sampling sites in 2008 used this approach. Habitat survey crews selected habitat units for fish sampling by randomizing the first preferred (e.g., pool, riffle, glide) and non- preferred (e.g., cascade) habitat type within each surveyed stream and then every fourth and tenth unit thereafter, respectively (Dolloff et al., 1993). The goal was to sample a minimum of 25 percent of preferred habitats and 10 percent of non-preferred habitats. Each selected habitat unit was marked with a waypoint and flagging. After a minimum of a 1-day time lapse, fish survey crews returned to these habitat units to estimate the number and density of fish in each habitat unit. A total of 1,721 delineated habitat units was sampled for fish between June and September 2008 (Table 11-7). The NFK, SFK, and UT drainages were represented by 560, 700, and 461 of these sites, respectively. The NFK sites were primarily in NFK tributary 1.190, although 56 of the NFK sites were main channel habitat units that were surveyed in conjunction with the off-channel habitat studies (see Section 11.4.2.2). In the SFK, 59 mainstem habitat units were sampled and the remaining 641 sites were in tributaries. All of the UT sites were in tributaries. The entire habitat unit was sampled for fish when the unit length was less than or equal to 131 ft (40 m). When a unit was greater than 131 ft (40 m) in length, only 131 ft (40 m) of the unit was sampled. The linkage with Tier 3 habitat data allowed for abundance estimates to be tied directly to specific habitat types.

The second approach used to estimate relative fish abundance and fish density among different habitat types relied on the collection of habitat data at the time of fish sampling. This approach was used during the 2004 through 2007 fish surveys; among these survey years, 267 sites distributed among the KR, NFK, SFK, and UT watersheds were sampled for fish and habitat data (Table 11-7). The habitat and sampling parameters recorded by survey crews include habitat type, sample length, wetted width, substrate type, and cover type (see Section 11.3.1.1).

Among all survey years, the primary fish capture methods used to estimate relative fish abundance among habitat types were snorkeling and electrofishing. Minnow traps were also used on occasion for fish abundance estimation, particularly when site conditions were not conducive to snorkeling or electrofishing surveys. These sampling techniques are described in detail in Section 11.4.1. Captured fish were measured for FL, enumerated by species and life stage, and released near the point of capture. Relative fish abundance was estimated for each habitat type, following the method of Hankin and Reeves (1988).

In some instances, removal sampling was employed to attempt a more rigorous approach to estimating total fish abundance within a sample area. Removal sampling was used with minnow traps and electrofishing at various sample locations in the study area and typically involved a minimum of three removal events at one location. For electrofishing depletion surveys in 2008, a four-pass maximum was used to minimize potential impacts on the sample population. Captured fish were identified to species, measured for FL, and held outside of the sample unit until the removal survey was completed. All fish were returned near the point of capture after the completion of the survey.

11.4.2.2 Fish Distribution and Abundance Surveys in Off-Channel Habitats

From 2005 through 2008, off-channel habitat studies, consisting of habitat, fish, and instream flow study components, were conducted in the NFK, SFK, and UT watersheds. The habitat and instream flow components are described in Section 11.3.1.2 and Section 11.5, respectively. For the fish sampling component, the primary objectives were as follows:

- Compare fish distribution and abundance patterns between main channel and off-channel habitats.
- Compare fish distribution and abundance patterns among off-channel habitat types.
- Provide fish presence and relative abundance data for use in instream flow model development (see Section 11.5).

In order to facilitate direct comparisons of relative fish abundance and fish density data between mainstem and off-channel habitats, representative off-channel habitats and adjacent mainstem areas were sampled for fish distribution and abundance data. Sampling site locations were directly tied to the main channel and off-channel transects that were established as part of the instream flow study component; see Section 11.5 for details regarding transect and site establishment. Although 169 off-channel sites located along the off-channel transects were sampled for fish distribution and abundance data (Table 11-5), 142 of those sites were sampled so that fish abundance per 100 m of survey length could be determined and compared with main channel fish abundance estimates (Table 11-8). Seventy-six of the off-channel sites were located in side channels, which were considered to be a unique type of off-channel habitat; therefore, relative fish abundance and fish density comparisons were made among the three different types of aquatic habitat locations (i.e., main channel, side channel, and off-channel). Fish abundance data from 88 mainstem sites were used in the comparison (Table 11-8). In the SFK watershed, 12 of the 14 main channel sites were located at the main channel midpoint of 12 SFK off-channel habitat transects, and the other two sites were associated with mainstem instream flow transects. Among the 18 UT main channel sites, half were located at off-channel transect midpoints, and others were located at mainstem transects. The 56 NFK main channel sites were located between 10 bankfull widths downstream of the downstream-most transect and 10 bankfull widths upstream of the upstream-most transect.

Main channel and off-channel sites were typically sampled between early summer and early fall, although specific sampling months tended to vary among watersheds and years. In the SFK watershed, fish sampling at off-channel and associated main channel sites occurred in September 2005, June and August 2006, and July 2007. For the UT, off-channel sites were sampled in July and October 2007; corresponding main channel UT sites were sampled in July 2005, July to August 2006, and June. July, and October 2007. Off-channel and main channel sites in the NFK were sampled between late July and mid-August 2008.

To derive estimates of relative fish abundance among off-channel habitat types, habitat data (e.g., habitat type, wetted width) were also collected at the main channel and off-channel sampling sites. For the 2005 through 2007 SFK and UT surveys, habitat data collection occurred at the time of fish sampling. For the 2008 NFK surveys, habitat data were collected between late July and mid-August using modified Tier 3 aquatic habitat surveys (USFS, 2001). Off-channel habitat types and habitat sampling protocols are described in Section 11.3.1.2.

The 2005 through 2007 off-channel fish surveys were typically conducted over a length of 197 ft (60 m), so that 98 ft (30 m) upstream and downstream of the point where each site was intersected by the off-channel transect were surveyed. If the off-channel habitat site was less than 197 ft (60 m) in length, then the entire site was sampled. Snorkel surveys were the primary method used. In units that were pond-like and circular in shape, snorkelers made several passes in an attempt to cover the entire width of the unit. Bank-side observations were made in sections that were too shallow to sample otherwise. Two-pass snorkeling was conducted in deeper habitat units or those with substantial cover to increase accuracy (Slaney and Martin 1987). All observed fish were identified and enumerated by species and life stage. Captured fish were also measured for FL and released near the point of capture.

In 2005 through 2007, the corresponding mainstem sites were sampled primarily using multi-pass snorkeling. Electrofishing was used as a secondary sampling method in sites unsuitable for snorkeling (e.g., poor water quality conditions, shallow water). Snorkel surveys were calibrated by either replicating the snorkel survey or multi-pass electrofishing depletion estimates. All observed fish were identified and enumerated by species and life stage. Captured fish were also measured for FL and released near the point of capture.

The 2008 NFK off-channel habitat fish surveys were conducted in 37 of the 38 habitat units that were delineated during the modified Tier 3 aquatic habitat surveys conducted in the NFK off-channel habitat study area (Table 11-8; see Section 11.3.1.2); one site was not sampled due to dry conditions at the time of the survey. As described above under Fish Habitat Associations, the entire habitat unit was surveyed only if the unit length was less than or equal to 131 ft (40 m). For large and uniform sites (e.g., beaver ponds), the survey team subsampled an area representing 15 to 30 percent of the total habitat. Although snorkeling was the primary sampling method used, multi-pass depletion electrofishing or minnow trapping was used when stream conditions (e.g., water depth, visibility) precluded the ability to snorkel. A maximum of three electrofishing passes was used. Any fish visually observed during the survey were identified by species, life stage, and enumerated. Captured fish were measured for FL and released at the point of capture.

For the 2008 mainstem NFK survey, habitat units delineated during the modified Tier 3 aquatic habitat survey (see Section 11.3.1.2) in the mainstem NFK were sampled for fish abundance data; therefore, 56 mainstem sites were sampled for use in comparing fish abundance between main channel and off-channel habitats in the NFK (Table 11-8). Snorkel surveys were the primary sample method; electrofishing and beach seining were used when stream conditions (e.g., visibility, water depth) precluded the ability to snorkel. The snorkel team consisted of five divers and two recorders. Divers were spaced equidistantly and progressed downstream in a uniform fashion. All observed fish were identified and enumerated by species and life stage. Captured fish were also measured for FL and released near the point of capture.

11.4.2.3 Winter Fish Surveys

In April 2004 through 2007 and in late October and early November 2006, winter fish surveys were conducted in the NFK, SFK, and UT watersheds, and in the upper reach of the KR. These sampling periods coincided with iced-over and partially frozen stream conditions in early winter and the ice-out period in late winter. The primary objective of the winter fish surveys was to document fish presence and relative fish abundance in the mine study area during winter months when ice conditions are present.

Sample locations were selected in the KR, NFK, SFK, and UT watersheds based on ice conditions at the time of sampling. One hundred thirty-three locations were sampled specifically for this objective, with four of these sites located in off-channel habitats. In addition, 24 of the study sites affiliated with the mainstem and off-channel instream flow studies (see Section 11.4.2.2 and Section 11.5) were sampled from late October to early November 2006 and in early April 2007. Out of these 24 sites, seven were located in the main channel, and 17 were off-channel habitats.

Site conditions, including open water area, ice thickness, and water depth, dictated the sampling techniques used at each site. Electrofishing and baited minnow traps were the primary survey techniques. Electrofishing was performed in open water streams when possible. In areas with ice cover, minnow traps were set through holes in the ice. Additionally, visual observations of fish were made through openings in the ice using direct observation, aquascopes, and face snorkeling. All observed fish were identified by species and life stage. Captured fish were measured for FL and released at the point of capture. Notes regarding ice conditions, habitat type, substrate, and water temperature were recorded. GPS waypoints were collected to mark sample locations.

11.4.2.4 Mainstem Index Fish Surveys

Standardized, repeatable fish sampling was conducted at 55 mainstem index sites in the NFK, SFK, and UT in 2004, 2005, 2007, and 2008, and at a single index site in Kaskanak Creek in 2004 (Figure 11-4). The primary objectives of these surveys were as follows:

- Determine relative fish abundance and fish density among habitat types.
- Assess temporal changes in fish densities and habitat associations over time.

In 2004, 2005, and 2007, index sampling occurred at 12 pre-established mainstem monitoring sites that were co-located with water quality and hydrology sites in the NFK, SFK, and UT (Table 11-9; Figure 11-4. In addition, three tributary sites (i.e., NK119A, SK119A, and UT119A) and one site in Kaskanak Creek were also surveyed using the mainstem index survey protocols. Standard fish sampling targeted juvenile salmonids, if present, and consisted of sampling with 0.25-inch (0.64-cm) steel mesh minnow traps baited with salmon eggs. Ten traps were set in a variety of habitat types at each station within a stream reach of 328 to 1,312 ft (100 to 400 m). Trap locations were recorded on a GPS unit, marked with stakes, and delineated on sketch maps so that the same trap locations can be used from year to year. Traps were fished for about 24 h. Captured fish were identified, counted, measured, and released. Index species at each site were selected in 2004 based on catchability (Table 11-9). With repeated sampling across the survey years, temporal changes in fish-habitat associations were assessed.

In 2008, the fish index study was expanded to include sampling sites ranging along the entire lengths of the mainstem NFK, SFK, and UT. Specifically, 43 additional index sites were established at 4.33-km

intervals along the mainstem NFK, SFK, and UT (Figure 11-3). Fish collection and abbreviated modified Tier 3 habitat surveys were conducted at each index site in August 2008 (see Section 11.3.1.1). The length of each index site was 131 ft (40 m), or four times the bankfull width, whichever was the lesser of the two values. Among the 43 index sites, 61 individual habitat units were delineated, and fish sampling was conducted specific to each delineated habitat unit and habitat type. To accommodate variation in habitat complexity and substrate composition among sites, the standardized protocol for 2008 index sampling included a full snorkel pass over the entire site length, as well as multi-pass beach seining, so that each site was surveyed in full using both fish sampling methods. Snorkel surveys were conducted in an upstream direction. Anchored lines were used to facilitate an upstream snorkel when the current was too swift to snorkel upstream unaided. Following the snorkel survey, three beach seine passes were made using a seine with a mesh size of 0.25 to 0.52 inches (0.64 to 1.43 cm) and an attached 10 ft (3m) bag. Where young-of-the-year salmonids were abundant, dip nets were used as alternative capture method because beach seining was ineffective. All captured fish were identified to species, measured for FL, and returned to the sample area when sampling was complete. Fish densities specific to fish sample method and habitat type were then calculated for each index site, so that temporal changes in fish densities and habitat associations can be assessed given repeated sampling of these sites in years after 2008.

11.4.2.5 Salmon Escapement Surveys

Salmon escapement surveys were initiated in 2004 and continued through 2008. Aerial surveys were used to quantify spawning salmon throughout the entire lengths of the mainstem NFK, SFK, and UT, and in selected tributaries in the study area, including Big Wiggly Lake on NFK tributary 1.240 (Figure 11-6). The primary objectives of the salmon escapement study were as follows:

- Document spatial and temporal distribution of anadromous salmon spawning in the mine study area.
- Obtain estimates of salmon escapement.

Survey timing and frequency varied among years (Table 11-10). Surveys typically ranged from early July through early to mid-October. In 2008, the survey period was extended until zero fish was observed (i.e., until mid-November). Because of time and weather constraints as well as helicopter availability, 2 to 3 days were typically required to cover the entire survey area in the NFK, SFK, and UT watersheds. As the escapement study progressed over the years, refinements were made to survey methods. including an increased total number of surveys flown and shorter duration between survey flights (Table 11-10).

Despite differences in survey timing among sampling years, methods used to conduct individual surveys were generally consistent among years. Surveys were conducted from a low-flying helicopter at an altitude of 100 to 200 ft (30.5 to 61 m) and at a ground speed of 5 to 20 mi/h (8 to 32 km/h). In 2004 through 2007, two qualified observers conducted each survey so that fish counts made by the first observer could be recorded by a secondary observer present at the time of the survey; field data were recorded in field notebooks and data sheets and entered into an electronic database. In 2008, a single qualified observer used a handheld digital voice recorder to record survey data. Survey data were then transcribed onto data sheets for entry into an electronic database format. Polarized glasses were used by observers to enhance visibility. Observed adult salmon were enumerated by species through direct counts of individual adult fish or estimated cluster counts (e.g., 50, 100, 500, 1,000). Estimated cluster counts were made when large numbers of fish were in concentrated areas and individual counts were not feasible

or possible. Fish counts were also estimated when counts of individual fish were impaired by environmental conditions (e.g., weather, turbidity, glare). Carcasses observed during surveys were enumerated by species. Environmental conditions during surveys were assessed using qualitative indices. Recorded qualitative environmental variables include weather, sun angle, glare, flow volume and depth, turbidity, stream bottom color, aquatic vegetation and debris, overhanging vegetation, ice cover, and surveyor fatigue. Using a handheld GPS unit, waypoints were recorded to document the extent of each survey, areas of concentrated fish spawning, the upstream extent of salmon, and areas where environmental factors affected the counting process. Additional notes were recorded to describe any other conditions affecting the surveyors' abilities to enumerate fish, and to document any deviations from the schedule or changes to the methodology.

Methodologies for estimating observer efficiency were also utilized. Observer efficiency estimates are derived through comparisons between the primary observer's counts and those made by a second observer. For the 2004 through 2007 aerial surveys, the two observers counted fish simultaneously. Thirteen calibration reaches were defined for the 2004 through 2007 surveys, with three to six reaches per drainage. In 2008, video recordings of selected calibration reaches were made immediately following the primary observer's initial survey, and videos were later reviewed by a second observer on a high-definition television. In late June 2008, six calibration reaches were delineated in each watershed and marked with survey flagging. However, these established calibration reaches were replaced by roving calibration reaches in mid-July 2008, because the pre-established reaches typically lacked fish densities sufficient for calibrating observer efficiency. With roving calibration reaches, the primary observer selected different reaches in each stream for video filming. A stratified approach was used to select calibration reaches representative of different stream and survey conditions (e.g., wide stream with little cover; heavily vegetated stream) so that calibration coefficients could be adjusted to survey conditions, if necessary. GPS waypoints describing the upstream and downstream extent of all 2004 through 2008 calibration events were recorded.

Escapement was estimated using the area-under-the-curve (AUC) method. According to this method, salmon counts from periodic surveys are used to generate total escapement by fitting a curve of the counts over time, integrating the area under the curve to derive a total number of fish days, and dividing this total by the mean number of days fish are present in the stream. AUC estimates are a function of the number of fish that move into an area, the time fish remain alive in that area, and the accuracy of the counts as determined by observer efficiency during the counting surveys. Two AUC models were used to estimate escapement from fish counts. The Trapezoidal Model (Neilson and Geen, 1981; Bue et al., 1998) has been used to estimate escapement with aerial fish counts since 1981. This model uses a linear interpolation to estimate fish counts in reaches where survey data are missed because of weather or logistical limitation. The second model, the Maximum Likelihood Estimation (MLE) model (Hilborn et al., 1999), uses temporal autocorrelation of counts to generate a modeled distribution of daily abundance that is compared to period survey counts; this model relies upon independently derived estimates of mean survival time.

Site-specific residence times were estimated based on 4 years of adult salmon migration and carcass observations. In addition, separate AUC estimates were computed using literature-derived values. Stream residence time has been shown to vary within a stream and spawning season as well as between streams and years (Perrin and Irvine, 1990; Fried et al., 1998; Lady and Skalski, 1998; Manske and Schwarz, 1999). Thus, estimates were bracketed using low and high literature values for each species when available.

Interpolations were made for the 2004 through 2007 data sets when the first or last survey counts were not zero. The assumptions of the trapezoidal model are (1) the fish observed during the first survey entered the stream one survey life earlier, (2) the fish observed during the last survey were out of the system within one survey life after the last survey, and (3) no additional fish entered the study area. For the statistical model, it was assumed that (1) no fish had entered the survey area before July 1, and (2) no fish remained in the survey area one survey life after the last survey.

11.4.2.6 Radio Telemetry Surveys

Radio telemetry was used to gather temporal and spatial data for adfluvial rainbow trout in the study area. A rainbow trout radio telemetry study was conducted in 2007 and 2008 to investigate seasonal distribution and migration patterns of rainbow trout in the UT and other streams associated with Iliamna Lake; this rainbow trout radio telemetry study is ongoing through 2009.

Rainbow Trout Radio Telemetry Surveys

The primary objective of the rainbow trout radio telemetry study was to investigate seasonal distribution and migration patterns of rainbow trout populations foraging and spawning in the UT.

The study was initiated in late summer 2007 with a focus on adult rainbow trout believed to be foraging in the UT. It was anticipated that many of these foraging fish would subsequently return to Iliamna Lake. It was unknown whether a proportion of these fish would spawn in the UT or elsewhere within the Kvichak River watershed. Later in 2007, the Alaska Department of Fish and Game regional biologist requested that the study be expanded to specifically target the population of rainbow trout spawning in the UT. Therefore, in spring 2008, the study was expanded to also include rainbow trout that had spawned in the UT. The study was continued through fall 2009 to document the migratory behavior of the UT rainbow trout spawning population, including potential migrations to nearby lakes and/or streams within the Iliamna Lake watershed, and to continue documenting the migratory behavior of the foraging fish group. In addition, information was collected on stream fidelity for both the spring spawning and late summer foraging incursions.

Thirty-eight foraging fish in the mainstem UT were captured for tagging between late August and mid-September 2007, and 59 post-spawned fish were captured for tagging between late-May and early-June 2008. Angling with barbless hooks was used to collect fish, because it was the least intrusive method with minimal fish handling stress. Angling efforts generally consisted of three to five people fishing within a designated area near a mobile tagging station. Fly rods or spinning gear was used. Fish were landed as quickly as possible to minimize stress. Radio transmitters (Lotek Model SR-M11-35) were surgically implanted into the abdominal cavities following methods described by Summerfelt and Smith (1990).

The tracking area focused on rainbow trout habitats within the Iliamna Lake watershed downstream to the upper extent of tidal influence in the Kvichak River, with special emphasis on the Lower Talarik Creek and the UT (Figure 11-7). Other tributaries within the study area included Pete Andrews, Middle Talarik, Zhakar, Dennis, Belinda, and Chekok creeks and the Newhalen, Knutson, Pile, Tazimina, Iliamna, Copper, and Gibraltar rivers, as well as the Iliamna Lake shoreline.

A combination of active (i.e., aerial) and passive (i.e., fixed) tracking was used to monitor fish movements. Fixed telemetry stations were positioned at the mouths of the Lower Talarik Creek and UT to

provide continuous monitoring of transmitter movements as fish enter and exit the creeks. Aerial surveys were conducted by fixed-wing plane and/or helicopter, depending on time of year, weather conditions, and availability. Aerial surveys occurred once a month from February through mid-April when fish were less active. As fish movement increased (i.e., from mid-April through May), aerial surveys were conducted once every 2 weeks, and when rainbow trout were most active and salmon spawning runs were returning to Iliamna Lake tributaries (i.e., from June through October), survey frequency was increased to once a week. From late fall through early spring, aerial surveys occurred approximately once a month.

Tracking data were combined into a single database and analyzed using GIS software. Movement patterns were displayed so that an analysis of fish movement patterns could be conducted. The distance each radio-tagged fish traveled from the UT release site was calculated. The data were also used to examine and document seasonal migration timing and geographical migration patterns.

11.4.3 Fish Surveys in the Transportation Corridor/Cook Inlet Study Areas

In 2004, 2005, 2007, and 2008, fish surveys were conducted at the survey sites described in Section 11.3.2. The objectives of the transportation corridor fish surveys were as follows:

- Document fish presence at representative stream crossing locations (primary survey sites)within the transportation corridor/Cook Inlet study areas.
- Document site-specific channel morphology and habitat data to describe existing aquatic habitat conditions upstream and/or downstream of the primary survey sites, or on nearby tributaries (support survey sites).
- Describe fish distribution and abundance at selected survey sites.
- Describe relationships between aquatic habitat characteristics and fish presence and abundance at the selected survey sites.

Of the 180 stream crossing sites that were surveyed for habitat data in 2004, 2005, 2007, and 2008 (see Section 11.3.2), 134 stream crossings contained a wetted channel and were therefore sampled for fish presence and abundance data. Sixty-seven sites were sampled in August and September 2004, 12 were sampled in July 2005, 31 were sampled in September and October 2007, and 24 were sampled in September 2008. Four of the sites that were sampled in 2004 and 2005 were sampled on a second occasion in fall 2007. Sampling protocols among survey years were largely consistent. As with the habitat surveys, the length of stream sampled at each crossing was 200 m or 40 times the average stream bed width. The lesser of the two distances was chosen as the sample length. Single-pass snorkeling and electrofishing were the primary methods used to assess fish presence. Single-pass snorkel surveys were used in place of electrofishing when adult salmon were present in the sample reach or when conditions were unsuitable to electrofishing. On one occasion in 2005, five minnow traps were used because of unsuitable electrofishing conditions. All observed fish were enumerated by species and life stage. Fish captured by electrofishing and minnow trapping were measured for FL and released near the point of capture. The one primary difference in survey protocols used among the study years was that in 2008 fish presence and abundance data were collected specific to the habitat units delineated during the modified Tier 3 aquatic habitat surveys (USFS, 2001; see Section 11.3.2). In 2004, 2005, and 2007, individual habitat units were not delineated during habitat surveys; therefore, fish presence and abundance data were collected specific to each stream crossing site.

11.5 Instream Flow Assessment

The instream flow studies were initiated in 2004 and continued through 2008 as a component of the environmental baseline studies within the mine study area. Methodologies for the instream flow study focused on gathering site-specific environmental data for use in model development to characterize the existing relationship between flow regimes and fish habitat conditions and to predict potential impacts of altered flow regimes on the availability and use of these habitats. The instream flow study consisted of various components, including mainstem and off-channel flow and habitat assessments, and temperature and fluvial geomorphology studies. Each of these study components is discussed in the sections that follow.

11.5.1 Main Channel Instream Flow Assessment

The major objectives of the mainstem instream flow studies were as follows:

- Describe existing main channel habitats with regard to channel profiles, flow regimes, and habitat conditions (e.g., habitat types, substrate, cover).
- Define species and life stage specific relationships between flow and fish habitat.
- Estimate the amount of available habitat by species and life stage under baseline flow conditions in the mainstem NFK, SFK, and UT, and in the upper portion of the mainstem KR.

Instream Flow Incremental Methodology (IFIM) measurements were made at 92 transects in 2005 through 2007 and at 46 new transects established in 2008, following the methodologies described below (Figure 11-8). Field reconnaissance for instream flow study site selection was conducted in 2004 and resulted in the establishment of flow-habitat study sites based on a combination of professional judgment and a stratified random approach. In 2008, selected transect locations were based on a review of the previously established transects, habitat types, and channel characteristics. Transect locations were identified on GIS-derived maps, and final transect selections were made jointly with members of the Technical Working Group during a field reconnaissance in May 2008. Mainstem instream flow transects were located on the KR (five transects), NFK (35 transects), SFK (40 transects), and UT (43 transects). Transects were also established on three tributaries: NFK1.190 (NFK watershed; three transects), SFK1.190 (SFK watershed; six transects), and UT1.190 (UT watershed; six transects).

11.5.1.1 Flow-Habitat Surveys

Instream flow-habitat surveys were conducted at varying flows to develop the hydraulic modeling of select habitat variables over a range of flow conditions experienced in NFK, SFK, and UT watersheds. Sampling was coordinated with annual hydrograph variation and was based on a review of existing hydrology data from the study area. Three distinct flow levels were targeted for transect sampling: low-flow (approximately 80 percent exceedance), mid-flow (approximately 50 percent exceedance), and high-flow (approximately 20 percent exceedance).

Consistent data collection procedures, as outlined by Trihey and Wegner (1981), were used across sampling years. In 2005, IFIM flow-habitat surveys were conducted three times (i.e., during the June high-flow, July mid-range flow, and August low-flow periods) at each established transect. In 2006, the majority of flow-habitat sites were visited twice during the high to mid-flow period and again during the

low-flow period to collect additional data for use in habitat modeling. In 2007, flow-habitat surveys were conducted at eight new transects that were sampled four times over high and mid-range flows. In addition, flow-habitat surveys were conducted at 20 previously established NFK transects to capture the mid-range flow conditions that were not surveyed in 2006. The 46 new transects added in 2008 were sampled during each of the three targeted flow periods.

A crew of two or three individuals experienced in IFIM field data collection and modeling conducted the fieldwork. Physical and hydrological measurements were measured along established transects at each sampling location. At each established transect, the following activities were initially conducted:

- Locations of transects – Transect locations were recorded and mapped in a field book and on a topographic map or on an ortho-rectified aerial photograph. Additionally, coordinates describing transect locations were recorded in the field using a handheld GPS unit. Muted survey flagging was used to mark the position of each transect.
- Establishment of transect benchmarks – Permanent surveying benchmarks were established at each transect. All survey measurements within a site, including headpin elevations and WSEs, were referenced to an arbitrary benchmark elevation of 100 ft (30.5 m). The benchmark (e.g., bedrock or boulder point, star-bolt anchors, rebar) was placed above the floodplain of the river and marked with survey flagging.
- Establishment of working pins – Working pins (e.g., wood stakes, tree stem or branch, star-bolt anchors) were established on both sides of the river. These working pins were positioned in such a way that the line connecting these points was perpendicular to the main flow of the stream channel. A Kevlar surveying tape was stretched across the stream channel and connected to these points during the collection of instream flow data.
- Survey of headpin elevations and completion of level loop – Following the installation of the head pins, a level loop survey was completed to establish pin elevations. Elevation data were obtained using an automatic level and stadia rod (0.01-ft accuracy). The level loop was considered accurate, if it closed within 0.02 ft (0.6 cm) of the benchmark elevation.

Data were collected for each transect and at set intervals across each transect during targeted flow periods. The intervals were established so that each transect was represented by a minimum of 20 intervals and the flow in any single cell (i.e., the area of measurement between any two intervals) did not exceed 5 percent of total flow in 2004 through 2007 or 10 percent of total flow in 2008. The following data were recorded once for each transect:

- Stream reach and transect number.
- Habitat type – classified as glide, run, riffle, pool, cascade, and island complex following definitions described in Bain and Stevenson (1999).
- Sampling date, time, investigators, and flow – information regarding when data were collected, who collected the data, and under what flow conditions the data were collected.
- WSE (to nearest 0.01 ft [0.3 cm]), instrument manufacturer, and serial number – WSE measured at three locations (i.e., left bank, center of channel, right bank) within the channel.
- Photographs – each transect was photographed under each of the three flow conditions.

The following data were collected at each interval across each transect:

- Bed elevations (to nearest 0.01 ft [0.3 cm]) – measured during low-flow conditions using an automatic level and stadia rod, or calculated as the difference between the average WSE at the time of sampling and water depth.
- Water depth (to nearest 0.05 ft [15.2 cm] – measured using either a 4-ft or 6-ft top setting rod, depending on water depth.
- Mean column water velocity (to nearest 0.01 ft/second [0.3 cm/second]) – measured using a Swoffer Model 2100, Marsh McBirney, or Price AA velocity meter; measured at 60 percent of the depth if depth was less than or equal to 2.5 ft (0.76 m), or at 20 and 80 percent depths if depth was greater than 2.5 ft (0.76 m). Velocity meters were calibrated according to the manufacturer's instructions prior to the first field trip and field-calibrated during each subsequent trip. Velocity meter serial number, propeller assembly, and calibration number were noted for each transect surveyed.
- Dominant and subdominant substrate – visually assessed and classified for each cell based on a modified Wentworth Scale (Wentworth, 1922). Substrate composition data were collected during the mid-range flow sampling period; however, when new interval locations were added during subsequent sampling periods (as was necessary for maintaining the interval location criteria, as discussed above, given changing flow conditions), substrate data were collected at the time in which the interval point was first established.
- Cover – visually assessed each cell for the presence of bank cover, object cover (e.g., overhanging boulders), and woody debris cover.

All data were reviewed prior to departing the sample site to ensure that all necessary data were collected and legible. After each field effort, field notes were photocopied, checked, and entered into computer data files. The latest version of the United States Fish and Wildlife Service (USFWS) microcomputer software of Physical Habitat Simulation Model (PHABSIM for Windows; v.1.20; PHABSIM DOS version) was used for all hydraulic and habitat modeling analysis (Waddle, 2001). Based on channel morphologies, the most appropriate computer model (i.e., IFG4, MANSQ, WSP) was selected to develop stage-discharge relationships for the various transects.

11.5.1.2 Habitat Suitability Criteria Curve Development

To produce a series of habitat-versus-flow relationships by species and lifestage for each instream flow transect, Habitat Suitability Criteria (HSC) curves were linked with the hydraulic and habitat models in PHABSIM. The characteristics of HSC curves have a major influence on calculations of the relationship between flow and potential habitat. For some species and life stages, HSC curves were based on existing literature-derived curves, and for other species and life stages, site-specific data were collected and used to develop HSC curves. Site-specific microhabitat use data were collected at redd locations in 2005, 2006, and 2008, and at observed fish locations in 2007 and 2008.

Redd sampling occurred in 2005, 2006, and 2008 in the NFK, SFK, and UT watersheds. To maximize the number of redd observations for as many of the target species as possible, sample site selection was based on redd abundance and distribution information obtained from aerial observations, including those made as part of the salmon escapement study. For 2005 and 2006, sampling was timed with chinook and

sockeye salmon spawning; therefore, the sampling occurred in late July 2005, and in early August 2005 and 2006. All 2005 redd sampling occurred in the NFK and SFK, and sampling efforts for 2006 included the NFK, SFK, and UT. In early August 2008, redds were measured opportunistically in the NFK, SFK, and UT in conjunction with the low-flow sampling period. August 2008 species associations included chinook, chum, and sockeye salmon. To target coho salmon redds, additional surveys were completed in mid-September 2008 in the NFK, SFK, and UT while coho spawning was occurring.

Several parameters were recorded at each redd location (Table 11-11). Species, depth, and velocity were recorded for all sampled redds in all years. Species was determined by direct observation of fish use of a redd or by direct observation of fish presence in the vicinity of a redd. In 2005 and 2006, water depth and velocity were measured at multiple locations relative to each redd; locations included the upstream end of a redd, the upstream left edge of a redd, the upstream right edge of a redd, and the center of a redd. In 2008, depth and velocity were measured only at the upstream end of each redd. Depth measurements were recorded to the nearest 0.1 ft (3 cm) using a top-setting rod. Mean velocity measurements (i.e., at 60 percent of the water depth) were made to the nearest 0.01 ft/second (0.3 cm/sec) using a Swoffer Model 2100, Marsh McBirney, or Price AA current meter. Substrate classifications were made using a modified Wentworth Scale (Wentworth, 1922). In 2005 and 2006, substrate data were collected only at a subset of the redds sampled. In 2005, primary (i.e., dominant), secondary, and tertiary substrates were recorded. Substrate data for 2006 follow the same ordination and extend to the quaternary and quinary levels; the associated percent composition for each of these levels was also recorded in 2006. Dominant and subdominant substrate types, as well as percent composition for the dominant substrate type, were recorded in 2008.

Data on other parameters were collected at redd locations, although the recorded parameters varied among sampling years (Table 11-11). The habitat type in which each redd was located was recorded in 2005; habitat type classifications were based definitions modified from Moore et al. (2006; Table 11-2). Water temperature was recorded for a subset of the sites in 2005 and 2006, and substrate temperature was recorded for a subset of the 2006 sampled redds. In 2008, redd dimensions were recorded using procedures described in Reiser and White (1981). Specifically, measurements made included pit depth, tail depth, length, upper width, middle width, and lower width. When sampled redds occurred in proximity to one another, redd dimensions and boundaries were obscured; therefore, the complete set of redd dimension measurements could not be made for all redds.

To develop site-specific HSC curves for various species and life stages, microhabitat use data (e.g., depth, velocity, substrate, cover) were collected at observed fish locations in 2007 and 2008. In 2007, 25 sites were sampled for microhabitat use data. These 25 sites were aligned with mainstem instream flow transects and are representative of the mainstem NFK (three sites), SFK (eight sites), and UT (14 sites). Sampling occurred between mid-June and mid-July 2007 in conjunction with fish abundance snorkel surveys that were conducted at these same locations. Additional surveys were conducted in the mainstem NFK, SFK, and UT in mid-August 2008. Sample site selection in 2008 was based on maximizing the number of observations for as many of the target species as possible; the 2008 sample locations were typically associated with the mainstem index study sites (see Section 11.4.2.4).

For both the 2007 and 2008 sampling efforts, snorkel surveys were used to obtain observations of juvenile and adult fish habitat use. Starting at the downstream end of the study site, snorkelers proceeded in an upstream direction. When fish were observed holding in a fixed position, a colored weight was dropped at

the point of initial observation. At each fish observation point, data pertaining to species, life stage, depth, velocity, substrate, and cover were recorded. Specific details regarding the manner and method of microhabitat data collection varied between the sampling years and are described in Table 11-12.

Prior to analyzing the microhabitat data, an evaluation of the different methods available for developing HSC curves was completed. Three methods are commonly used for converting habitat utilization frequency data into HSC curves: function fitting, nonparametric tolerance limits, and histogram analysis (Bovee, 1986; Slauson, 1988). A statistical analysis was completed to select the method best suited to the site-specific data collected.

11.5.2 Off-Channel Habitat Instream Flow Assessment

The primary objectives of the off-channel habitat instream flow assessment were as follows:

- Characterize the quality and quantity of aquatic habitats within representative off-channel areas adjacent to mainstem rivers.
- Describe off-channel habitats with regard to channel profiles, habitat conditions (e.g., water depth, habitat type, substrate, cover, water quality), and connectivity to mainstem streams.
- Understand off-channel habitat function relative to mainstem flow patterns.
- Evaluate mechanisms of off-channel habitat connectivity with mainstem channels.

The off-channel habitat instream flow study was initiated in September 2005 with the establishment of 15 off-channel habitat transects in the SFK. Eleven of the 15 transects were positioned in proximity to main channel instream flow transects to provide linkage between main channel and off-channel sites. In 2007, the study was expanded into the UT. Sixteen transects adjacent to or between existing UT mainstem instream flow transects were established. The study was further expanded in 2008 through the inclusion of six transects in the NFK. The NFK transect locations were focused in an area with abundant off-channel habitat. All off-channel habitat transects were established perpendicular to the dominant flow and were approximately 984 ft (300 m) long on either side of the main channel with the main channel marking each transect's approximate center. Each off-channel habitat transect was surveyed to collect physical and hydrological data along the entire length of each transect. For the SFK and UT transects, each off-channel habitat unit intersected by a transect was established as an off-channel habitat site and subsequently sampled to collect habitat and fish data (see Sections 11.3.1.2 and 11.4.2.2 for habitat and fish sampling protocols, respectively). The number of SFK and UT sites per transect varied from one to 10. In 2008, only a subset of the intercepted NFK off-channel habitats was selected for habitat and fish sampling; therefore, two or three off-channel habitat sites representative of the habitats encountered were sampled for each NFK transect.

11.5.2.1 Valley Bottom Surveys

Physical and hydrological data along each off-channel habitat transect were collected at two or three different flow regimes. Data collection methodologies were designed so that valley bottom profiles could be mapped and variation in off-channel habitat WSEs could be linked to main channel flow conditions. The SFK transects were sampled in September 2005 and August 2006, UT transects were sampled in June and September 2007, and NFK transects were sampled in June, July, and August 2008. Using protocols

similar to those described above for the establishment of main channel instream flow transects and control points (e.g., head pins, tail pins), off-channel habitat transects were established at the time of initial sampling.

Valley bottom surveys were conducted along the length of each transect using a Real Time Kinematic Differential Global Positioning System (RTK DGPS) unit or more traditional methods involving a standard handheld GPS unit, an auto level, stadia rod, and measuring tape. At each off-channel habitat encountered, WSEs at wetted edges were recorded, and wetted depths were measured so that the bottom profile each habitat unit could be determined. Cover and dominant and subdominant substrate were also recorded within each off-channel habitat site. Cover and substrate classifications are consistent with those used during main channel transect surveys, as discussed in Section 11.5.1 above. Ground elevations were measured and recorded along the linear portions of the transect lacking aquatic habitat. Main channel WSEs associated with each off-channel habitat transect were also measured during each survey.

11.5.2.2 Off-Channel Connectivity Surveys

To obtain a greater understanding of relationships between main channel flow conditions and off-channel habitat availability, a series of connectivity surveys were conducted between June and August 2008 for the mainstem NFK, SFK, and UT. Potential inlets and outlets to the mainstem were identified using orthophotos and maps. A two-person field crew then visited each site and identified additional connections that were not observed during the remote mapping exercise. For each identified connection, field data were collected so that the relationship between the mainstem WSE and the bed elevation of the hydraulic control at the connection point could be used in conjunction with instream flow models to assess how flow changes might alter the availability of off-channel fish habitat. Water surface and hydraulic control bed elevations were measured using an RTK DGPS or an auto level and stadia rod.

11.5.3 Water Temperature Monitoring and Modeling

Water temperature can affect a variety of salmonid species and their life history functions, including the timing of adult upstream migrations and juvenile/smolt downstream migrations, the timing of spawning and duration of egg incubation, growth rates, and overall rates of survival (Quinn, 2005; McCollough et al., 2001; Sauter et al., 2001; Bjornn and Reiser, 1991). Temperatures in streams can vary hourly, daily, seasonally, annually, and spatially, with the degree of variation dependent on meteorological, topographical, and hydrological characteristics, including patterns of runoff and groundwater exchange. Because stream temperature can be directly influenced by both surface and groundwater flow, monitoring programs were designed and implemented to collect baseline data on both surface water and groundwater temperatures within the mainstem NFK, SFK, and UT systems. The primary objectives of the water temperature monitoring and modeling study were as follows:

- Collect baseline data on existing surface water and groundwater temperature regimes within the mine study area.
- Develop flow-sensitive surface water temperature models for the NFK, SFK, and UT so that potential effects of altered flow regimes on water temperatures can be assessed.

Monitoring of surface water temperatures was initiated in 2004 and continued through 2008 to collect baseline data on the existing surface water temperature regimes within the NFK, SFK, and UT systems.

Continuous instream water temperatures have been measured at various locations and various time periods since 2004 at intervals ranging from 1 min to 2 h. Water temperatures have been monitored at the following three types of stations:

- Pebble Project hydrology gaging stations – These continuous stations monitor both stage and water temperature. Water temperatures at these stations have been measured primarily during summer ice-free periods since 2004. There are seven sites in the SFK watershed, five sites in the NFK watershed, and seven sites in the UT watershed.
- Pebble Project water temperature monitoring stations – These continuous stations monitor water temperature. Water temperatures at these stations have been monitored year-round using Onset Hobo Pendant monitors. In August 2007, 29 of these stations were initially installed. In October 2008, nine additional stations were added to the network. Among these 38 sites, 11 are located in the SFK watershed, 13 are in the NFK watershed, and 14 are in the UT watershed.
- United States Geological Survey (USGS) hydrology gaging stations – These continuous stations monitor both stage and water temperature. The USGS gaging stations on the mainstem NFK, SFK, and UT are NK100A (USGS Gage No. 15302250), SK100B (USGS Gage No. 15302200), and UT100B (USGS Gage No. 15300250), respectively. Water temperatures from these stations have been compiled for July 2006 through September 2008.

Recorded thermal data were synthesized, and daily average, maximum, and minimum temperatures were computed and plotted for each station. The data were also applied in the development of water temperature models (see below) that can be used to assess whether potential project operations that influence streamflow may also affect water temperatures within the NFK, SFK, and UT.

To assess groundwater temperatures, a series of Onset Hobo Pendant recorders were installed at 27 sites within the mainstem rivers in 2005. These were concentrated in areas of known groundwater upwelling and exchange and included one site in the NFK, 14 sites in the SFK, and 12 in UT. The recorders were positioned within the gravel at depths of 6 and 12 inches (15 and 30 cm) and were left in place throughout the year. Data from the recorders have been downloaded for analysis; recorders from some sites could not be relocated and were assumed to have been dislodged. These data will be useful for characterizing baseline intragravel water temperatures and for evaluating possible groundwater influences on fish utilization and survival within the mainstem systems.

The USFWS Stream Network Temperature Model (SNTEMP; Version 3, revised in May 2005; Theurer et al., 1984) was subsequently used to develop flow-sensitive surface water temperature models for each mainstem system. These models were based on a combination of empirical and synthetic hydrological, meteorological, and stream geometry conditions. The model accounts for the physical processes of heat transfer and includes the following components: (1) a heat transport model that predicts the average mean daily water temperature and diurnal fluctuations in water temperature as functions of stream distance; (2) a heat flux model that predicts the energy balance between the water and its surrounding environment; (3) a solar model that predicts the solar radiation penetrating the water as a function of latitude, time of year, and meteorological conditions; (4) a shade model that predicts the solar radiation-weighted shading resulting from both topography and riparian vegetation; and (5) meteorological corrections that predict changes in air temperature, relative humidity, and atmospheric pressure, as functions of a change in elevation. In addition to assisting in the characterization of baseline thermal conditions, the temperature models can be used to predict potential temporal and spatial changes in temperatures that could occur as a

result of any changes in flow regimes because of project operations, and to assess flow and temperature change effects on fish species within these systems.

11.5.4 Fluvial Geomorphology Studies

Fluvial geomorphology is the study of river form and the physical and biological conditions and processes influencing channel morphology. Channel morphology can be characterized in terms of numerous parameters, including measures of channel geometry (e.g., width, depth, slope), cross-section shape, riverbed grain size distribution, planform shape, channel conveyance, sediment transport capacity, and measures of the ways in which each of these features may change. Fundamental conditions and processes influencing channel morphology and the ways in which it may change include the underlying local and upstream geology, hydrology, hydraulics, sediment supply, sediment transport, and biophysical influences. In turn, these various characteristics of channel form and function influence the quantity and quality of aquatic and terrestrial habitat for plants and animals dependent on the river environment for all or part of their life history. The fluvial geomorphology study was conducted to link predicted changes in hydrology and drainage area with changes in fish and aquatic habitat, and to characterize general fluvial geomorphic conditions in the study area. An additional study element focused on the characterization of the quality of spawning gravels within the mainstem NFK, SFK, and UT. The major objectives of the fluvial geomorphology study were as follows:

- Characterize existing fluvial geomorphic conditions in the mine study area.
- Assess potential effects of changes in hydrology and drainage area on aquatic habitats within the mine study area.
- Characterize the quality of spawning gravels in the mainstem NFK, SFK, and UT.

Geomorphology studies were initiated in 2005 and focused on describing channel geometry relationships and completing some initial hydraulic modeling in the SFK and UT systems. The results from the 2005 pilot study suggested more mobile riverbed conditions than expected based on published research. The analysis of the 2005 data also suggested that simple hydraulic approximations of stage-discharge relationships could not be applied to accurately model hydraulic conditions influencing channel stability and sediment transport, and that additional field data were needed in more sites to better describe the relation between channel geometry and geomorphic processes. Work was reinitiated in 2007 and included the collection of field data from the mainstem NFK and re-sampling of the 2005 fluvial geomorphology study sites. Fifty-two fluvial geomorphology study sites were established: 15 in the mainstem NFK, 16 in the mainstem SFK, 17 in the mainstem UT, one in the mainstem KR; two in SFK tributaries; and one in a NFK tributary. Data collected included survey information required for hydraulic modeling (based on the Hydraulic Engineering Center River Analysis System [HEC-RAS]), pebble count data (Wolman, 1954; Kondolf, 1997), site photographs, visual-based Manning's *n* roughness coefficient estimates, bank material composition, field notes, and qualitative estimates of bank vegetation types and densities. The 2007 effort resulted in the identification of a characteristic discharge approximating bankfull flow conditions (Leopold and Maddock, 1953). The bankfull discharge is a representative metric that has been related to hydrologic and hydraulic conditions influencing channel form, primarily in alluvial channels, and may be used under certain circumstances to relate changes. The 2007 work also included the collection of single bulk gravel samples in selected fluvial geomorphology sites to begin assessing fine sediment levels in the river bed substrates as part of a pilot study. A radio rock study was also conducted

in 2007 to evaluate riverbed mobility in more detail. The particle mobility study focused on a single site in the NFK co-located with a USGS stream gaging station. Nineteen radio-tagged rocks were deployed and monitored from September 15 to 30, 2007. In 2008, single bulk gravel samples were collected in additional fluvial geomorphology sites and in new sites containing spawning habitat. Three replicate gravel samples were also collected from nine sites with spawning habitat to statistically assess pre- and post-spawning fine sediment levels, and to address the question of how the particle size distribution in known salmon spawning locations is affected by spawning fish, fall high-flow events, and the subsequent resorting of bed materials.

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TABLES

TABLE 11-1
Parameters recorded during 2004-2008 mainstem and tributary aquatic habitat surveys in the KR, NFK, SFK, UT, and Kaskanak Creek watersheds. Parameters are grouped by survey types.

Parameter	Methodology	Watersheds Sampled by Year				
		2004	2005	2006	2007	2008
Modified Tier 1 aquatic habitat surveys (USFS 2001)						
channel type	based on Paustian et al., 1992	NFK, SFK, UT	SFK, UT		UT	NFK, SFK, UT
channel profile	incremental depth measurements using Kevlar tape and an incrementally marked wading rod	NFK, SFK, UT			UT	
bankfull width	Kevlar tape; laser range finder	NFK, SFK, UT			UT	NFK, SFK, UT
bankfull depth	stadia rod; incrementally marked wading rod	NFK, SFK, UT			UT	NFK, SFK, UT
channel bed width	Kevlar tape; laser range finder	NFK, SFK, UT			UT	NFK, SFK, UT
average wetted width	Kevlar tape; laser range finder	NFK, SFK, UT			UT	NFK, SFK, UT
bank incision depth	stadia rod; incrementally marked wading rod	NFK, SFK, UT			UT	
bank slope length and angle	stadia rod; incrementally marked wading rod	NFK, SFK, UT				
discharge	flow meter; float method (USGS, 1977)	NFK, SFK, UT			UT	NFK, SFK, UT
stream gradient	water surface elevation measurements using an auto level and stadia rod; clinometer	NFK, SFK, UT			UT	NFK, SFK, UT
substrate distribution	Wolman pebble count (Wolman, 1954)	NFK, SFK, UT			UT	NFK, SFK, UT
Modified Tier 3 aquatic habitat surveys (USFS 2001)						
mesohabitat type	based on Moore et al. (2006)	NFK, SFK, UT	SFK, UT		UT	NFK, SFK, UT
habitat unit length	hip chain; Kevlar tape; laser range finder	NFK, SFK, UT	SFK, UT		UT	NFK, SFK, UT
habitat unit wetted width[a]	Kevlar tape; laser range finder	NFK, SFK, UT	SFK, UT		UT	NFK, SFK, UT
habitat unit average depth	stadia rod					NFK, SFK, UT

Parameter	Methodology	Watersheds Sampled by Year				
		2004	2005	2006	2007	2008
dominant and subdominant substrate classes	based on modified Wentworth scale (Wentworth, 1922)	NFK, SFK, UT	SFK, UT		UT	
percent substrate composition	based on modified Wentworth scale (Wentworth, 1922)					NFK, SFK, UT
percent bank erosion	visual assessment					NFK, SFK, UT
percent undercut bank	Kevlar tape; stadia rod; incrementally marked wading rod	NFK, SFK, UT	SFK, UT		UT	NFK, SFK, UT
riparian vegetation types	visual assessment	NFK, SFK, UT	SFK, UT		UT	NFK, SFK, UT
cover types	visual assessment					NFK, SFK, UT
percent cover	visual assessment					NFK, SFK, UT
number of large woody debris key pieces and clusters	visual assessment	NFK, SFK, UT	SFK, UT		UT	NFK, SFK, UT
maximum pool depth	stadia rod; incrementally marked wading rod	NFK, SFK, UT	SFK, UT		UT	NFK, SFK, UT
pool tail crest depth	stadia rod; incrementally marked wading rod	NFK, SFK, UT	SFK, UT		UT	NFK, SFK, UT
pool forming factor	visual assessment					NFK, SFK, UT
Special habitat feature surveys						
feature type	tributary, seep, spring, or fish migration barrier					NFK, SFK, UT
feature location	hand-held GPS					NFK, SFK, UT
percent flow contribution of tributaries, seeps, and springs	visual assessment					NFK, SFK, UT
water temperature of tributaries, seeps, and springs	thermometer reading					NFK, SFK, UT

Parameter	Methodology	Watersheds Sampled by Year				
		2004	2005	2006	2007	2008
fish migration barrier type	visual assessment					NFK, SFK, UT
barrier height	stadia rod					NFK, SFK, UT
barrier length	stadia rod					NFK, SFK, UT
water depth below barrier	stadia rod					NFK, SFK, UT
Qualitative stream habitat surveys						
stream type	based on Rosgen alpha-level classifications (Rosgen, 1996)	NFK, SFK, UT, Kaskanak Creek				
relative stream gradient	ranked as low, medium, or high	NFK, SFK, UT, Kaskanak Creek				
bank composition	visual assessment	NFK, SFK, UT, Kaskanak Creek				
bank stability	ranked as low, moderate, or high	NFK, SFK, UT, Kaskanak Creek				
percent habitat type composition	based on Moore et al. (2006)	NFK, SFK, UT, Kaskanak Creek				
cover types	visual assessment	NFK, SFK, UT, Kaskanak Creek				
percent substrate composition	based on modified Wentworth scale (Wentworth, 1922)	NFK, SFK, UT, Kaskanak Creek				
beaver dam presence	visual assessment	NFK, SFK, UT, Kaskanak Creek				

Parameter	Methodology	Watersheds Sampled by Year				
		2004	2005	2006	2007	2008
spawning, rearing, and overwintering habitat quality	ranked as low, moderate, or high	NFK, SFK, UT, Kaskanak Creek				
Anecdotal habitat data collection						
mesohabitat type	based on Moore et al. (2006)	NFK, SFK, UT	KR, NFK, SFK, UT	KR, NFK, SFK, UT	KR, NFK, SFK, UT	
sample length	Kevlar tape	NFK, SFK, UT	KR, NFK, SFK, UT	KR, NFK, SFK, UT	KR, NFK, SFK, UT	
wetted width	Kevlar tape	NFK, SFK, UT	KR, NFK, SFK, UT	KR, NFK, SFK, UT	KR, NFK, SFK, UT	
substrate types	based on modified Wentworth scale (Wentworth, 1922)	NFK, SFK, UT	KR, NFK, SFK, UT	KR, NFK, SFK, UT	KR, NFK, SFK, UT	
cover types	visual assessment	NFK, SFK, UT	KR, NFK, SFK, UT	KR, NFK, SFK, UT	KR, NFK, SFK, UT	
Mesohabitat mapping field surveys						
mesohabitat type	based on Moore et al. (2006)		NFK, SFK, UT		NFK, SFK, UT	
habitat unit length	laser range finder		NFK, SFK, UT		NFK, SFK, UT	
channel bed width	laser range finder				NFK, SFK, UT	
habitat unit location	hand-held GPS/PDA		NFK, SFK, UT		NFK, SFK, UT	

a In 2004, 2005, and 2007, habitat unit wetted widths were recorded only for pool habitat types.

TABLE 11-2
Mesohabitat type descriptions, modified from Moore et al. (2006)

Mesohabitat Type	Description
Cascade	Fast, turbulent, flow; many hydraulic jumps, strong chutes, and eddies; 30-80% white water. High gradient; usually 3.5-10.0% slope. Much of the exposed substrate composed of boulders organized into clusters, partial bars, or step-pool sequences.
Riffle	Fast, turbulent, shallow flow over submerged or partially submerged gravel and cobble substrates.
Run/Glide	An area with generally uniform depth that is greater than the maximum substrate size, and fast flow with little surface turbulence.
Pool	Area with a flat surface slope and low water velocity that is deeper than the average channel depth. Substrate is highly variable.
Backwater/Slough	Low velocity area along channel margins (alcoves included). Part of the active channel at most flows.
Beaver Complex	Water impounded by the creation of a beaver dam.

TABLE 11-3
Parameters recorded during 2005-2008 off-channel aquatic habitat surveys in the NFK, SFK, and UT watersheds. Parameters are grouped by survey types.

Parameter	Methodology	Watersheds Sampled by Year			
		2005	2006	2007	2008
Modified Tier 3 aquatic habitat surveys (USFS 2001)					
mesohabitat type	based on Moore et al. (2006)				NFK
habitat unit length	Kevlar tape; laser range finder				NFK
habitat unit wetted width	Kevlar tape; laser range finder				NFK
habitat unit average depth	stadia rod				NFK
percent substrate composition	based on modified Wentworth scale (Wentworth, 1922)				NFK
percent bank erosion	visual assessment				NFK
percent undercut bank	Kevlar tape; stadia rod				NFK
riparian vegetation types	visual assessment				NFK
cover types	visual assessment				NFK
percent cover	visual assessment				NFK
number of large woody debris key pieces and clusters	visual assessment				NFK
maximum pool depth	stadia rod				NFK
pool tail crest depth	stadia rod				NFK
pool forming factor	visual assessment				NFK
Special habitat feature surveys					
feature type	tributary, seep, spring, or fish migration barrier				NFK
feature location	hand-held GPS				NFK
percent flow contribution of tributaries, seeps, and springs	visual assessment				NFK
water temperature of tributaries, seeps, and springs	thermometer reading				NFK
fish migration barrier type	visual assessment				NFK
barrier height	stadia rod				NFK

Parameter	Methodology	Watersheds Sampled by Year			
		2005	2006	2007	2008
barrier length	stadia rod				NFK
water depth below barrier	stadia rod				NFK
Anecdotal habitat data collection					
mesohabitat type	based on Moore et al. (2006)	SFK	SFK	SFK, UT	
sample length	Kevlar tape	SFK	SFK	SFK, UT	
wetted width	Kevlar tape	SFK	SFK	SFK, UT	
substrate types	based on modified Wentworth scale (Wentworth, 1922)	SFK	SFK	SFK, UT	
cover types	visual assessment	SFK	SFK	SFK, UT	

TABLE 11-4
Parameters recorded during 2004, 2005, 2007, and 2008 aquatic habitat surveys at stream crossings associated with the transportation corridor study area. Parameters are grouped by survey types. For each parameter, years of data collection are indicated by "x."

Parameter	Methodology	Year			
		2004	2005	2007	2008
Channel morphology surveys					
channel type	based on Paustian et al,. 1992				x
stream type	based on Rosgen alpha-level classifications (Rosgen, 1996)	x		x	
channel incision	visual assessment	x	x	x	
bank composition	visual assessment	x	x	x	
bank stability	ranked as low, moderate, or high	x	x	x	
bankfull width	Kevlar tape; laser range finder			x	x
bankfull depth	stadia rod; incrementally marked wading rod			x	x
channel bed width	Kevlar tape; laser range finder	x	x	x	x
average wetted width	Kevlar tape; laser range finder	x	x	x	x
average depth[a]	stadia rod; incrementally marked wading rod	x	x	x	x
discharge	flow meter	x	x	x	
stream gradient	clinometer	x	x	x	x
riparian vegetation types	visual assessment				x
Aquatic habitat surveys					
percent mesohabitat type composition	based on Moore et al. (2006)	x	x	x	x
mesohabitat type[a]	based on Moore et al. (2006)				x
habitat unit length[a]	Kevlar tape; laser range finder				x
habitat unit wetted width[a]	Kevlar tape; laser range finder				x
maximum pool depth[a]	stadia rod				x
pool tail crest depth[a]	stadia rod				x
pool forming factor[a]	visual assessment				x

Parameter	Methodology	Year			
		2004	2005	2007	2008
percent substrate composition[a]	based on modified Wentworth scale (Wentworth, 1922)	x	x	x	x
percent undercut bank	visual assessment	x	x	x	
percent overhanging vegetation	visual assessment	x	x	x	
percent woody debris cover	visual assessment	x	x	x	
spawning, rearing, and overwintering habitat quality	ranked as low, moderate, or high	x	x	x	
Special habitat feature surveys					
feature type	tributary, seep, spring, side channel, or fish migration barrier				x
feature location	hand-held GPS				x
wetted width of tributaries, seeps, springs, and side channels	Kevlar tape; laser range finder				x
average depth of tributaries, seeps, springs, and side channels	stadia rod				x
fish migration barrier type	visual assessment	x	x	x	x
barrier height	stadia rod; incrementally marked wading rod	x	x	x	x
barrier length	stadia rod				x
water depth below barrier	stadia rod				x
Water quality sampling					
water temperature	YSI hand-held meter	x	x	x	x
pH	YSI hand-held meter	x	x	x	x
conductivity	YSI hand-held meter	x	x	x	x
dissolved oxygen	YSI hand-held meter	x	x	x	x
turbidity	Secchi tube; YSI hand-held meter	x		x	x

a. In 2008, parameter was recorded specific to individual habitat units; in other survey years, parameter was recorded specific to the entire stream crossing site.

TABLE 11-5
Number of mainstem, tributary, lake, and off-channel habitat fish sampling sites in the KR, NFK, SFK, UT, Kaskanak Creek, and Lower Talarik Creek watersheds in 2004-2008

	Number of Fish Sampling Sites by Drainage						
Site Type	**KR**	**NFK**	**SFK**	**UT**	**Kaskanak Creek**	**Lower Talarik Creek**	**Total**
mainstem and tributary sites	14	790	1071	884	1	0	2760
lake sites	0	2	25	5	0	1	33
off-channel habitat sites	0	37	75	57	0	0	169
Total	**14**	**829**	**1171**	**946**	**1**	**1**	**2962**

TABLE 11-6
Summary of fish sampling methods, excluding aerial surveys, used in the KR, NFK, SFK, and UT EBD reaches and in the Kaskanak Creek and Lower Talarik Creek drainages from 2004 through 2008. Use of each method for each month and year combination is indicated by "x."

EBD Reach/ Drainage	Year	Method	Month							
			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
KR	2004	minnow trap	x							
	2005	snorkel				x				
	2006	snorkel				x	x			
	2007	snorkel				x				
	2008	angling						x		
NFK-A	2004	electrofishing					x			
		minnow trap					x			
	2005	electrofishing	x							
		minnow trap	x				x			
		snorkel				x				
	2006	snorkel				x	x			
	2007	angling						x		
		snorkel				x				
	2008	angling						x		
		seine					x			
		snorkel					x			
NFK-B	2004	minnow trap	x							
	2005	electrofishing	x							
		minnow trap	x							
		snorkel				x				
	2006	electrofishing								x
		snorkel				x	x			
	2007	snorkel				x				
	2008	seine					x			
		snorkel					x			

EBD Reach/ Drainage	Year	Method	Month							
			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
NFK-C	2004	angling			x					
		electrofishing				x	x	x		
		minnow trap	x				x			
	2005	angling					x			
		electrofishing	x							
		minnow trap	x				x			
		snorkel				x				
	2006	angling					x			
		electrofishing	x							x
		minnow trap	x							
		snorkel				x	x			
	2007	angling		x				x		
		gill/tangle net						x		
		snorkel				x				
	2008	angling						x		
		electrofishing					x	x		
		gill/tangle net						x		
		minnow trap						x		
		seine					x			
		snorkel					x	x		
NFK-D	2004	angling		x	x		x			
		electrofishing					x			
		minnow trap	x				x			
	2005	angling		x			x			
		electrofishing				x	x			
		minnow trap				x				
	2006	angling					x			
		electrofishing					x			
	2007	angling					x			
		gill/tangle net					x	x		

EBD Reach/ Drainage	Year	Method	Month							
			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
	2008	angling						x	x	
		dip net					x			
		electrofishing						x		
		gill/tangle net						x	x	
		seine					x			
		snorkel					x			
NFK-E	2005	electrofishing				x				
	2008	electrofishing					x	x		
		seine					x			
		snorkel					x			
NFK-F	2005	electrofishing				x				
	2008	electrofishing					x	x		
		snorkel					x			
SFK-A	2004	electrofishing					x			
		minnow trap	x				x			
	2005	electrofishing	x			x				
		minnow trap	x				x			
		snorkel				x				
	2006	electrofishing	x							x
		minnow trap	x							x
		snorkel				x	x	x		
	2007	electrofishing	x			x				
		minnow trap	x							
		snorkel				x				
	2008	seine					x			
		snorkel					x			
SFK-B	2004	electrofishing				x	x			
		minnow trap	x				x			

EBD Reach/ Drainage	Year	Method	Month							
			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
	2005	angling		x			x			
		electrofishing	x			x				
		gill/tangle net					x			
		minnow trap	x				x			
		snorkel				x		x		
	2006	angling				x				
		aquascope								x
		electrofishing	x		x	x	x		x	
		minnow trap	x						x	x
		snorkel			x	x	x	x	x	x
	2007	angling						x		
		dip net				x				
		electrofishing	x			x				
		minnow trap	x			x				
		snorkel	x			x				
	2008	angling						x		
		electrofishing				x	x	x		
		minnow trap						x		
		seine					x			
		snorkel				x	x	x		
SFK-C	2004	angling			x	x				
		electrofishing				x	x			
	2005	angling		x						
		electrofishing			x	x	x			
		gill/tangle net					x			
		minnow trap				x				
		snorkel			x	x	x			
	2006	angling			x	x		x		
		gill/tangle net						x		
		snorkel			x	x		x		

EBD Reach/ Drainage	Year	Method	Month							
			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
	2007	angling		x						
		dip net				x				
		electrofishing				x				
		gill/tangle net				x		x		
		minnow trap				x		x		
		snorkel			x	x	x			
	2008	electrofishing				x	x	x		
		seine					x			
		snorkel				x	x			
SFK-D	2004	electrofishing				x				
		minnow trap	x							
	2005	angling		x						
	2006	angling			x					
		electrofishing							x	
		minnow trap							x	
		snorkel			x					
	2007	angling		x						
	2008	seine					x			
		snorkel					x			
SFK-E	2004	angling				x	x			
		electrofishing				x	x			
		gill/tangle net				x	x			
		minnow trap				x	x			
		seine					x			
	2005	angling					x			
		electrofishing					x			
		gill/tangle net					x			
		snorkel				x				

EBD Reach/ Drainage	Year	Method	Month							
			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
	2006	angling			x					
		electrofishing	x						x	
		minnow trap							x	
		snorkel			x			x		
	2007	angling		x			x			
		gill/tangle net				x		x		
		minnow trap				x		x		
		snorkel			x	x	x			
	2008	angling						x		
		electrofishing			x		x	x		
		minnow trap			x					
		seine					x			
		snorkel			x		x			
UT-A	2007	angling					x	x		
	2008	angling		x	x					
		seine					x			
		snorkel					x	x		
UT-B	2005	snorkel				x				
	2006	snorkel					x			
	2008	seine					x			
		snorkel					x	x		
UT-C	2004	electrofishing					x			
		minnow trap	x				x			
	2005	electrofishing	x			x	x			
		minnow trap	x				x			
		snorkel				x				
	2006	electrofishing	x				x			
		minnow trap	x							x
		snorkel				x	x			

EBD Reach/ Drainage	Year	Method	Month							
			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
	2007	angling			x		x			
		electrofishing	x		x	x				
		minnow trap	x							
		snorkel			x	x				
	2008	dip net					x			
		seine					x			
		snorkel					x			
UT-D	2004	electrofishing					x			
		minnow trap	x				x			
	2005	electrofishing	x							
		minnow trap	x				x			
		snorkel				x				
	2006	electrofishing	x							x
		minnow trap	x							x
		snorkel				x				
	2007	electrofishing	x		x	x				
		minnow trap	x			x			x	
		snorkel	x		x	x			x	
	2008	angling						x	x	
		dip net					x			
		seine					x			
		snorkel					x			
UT-E	2004	angling			x			x		
		electrofishing					x	x		
		minnow trap	x							
	2005	minnow trap	x							
		snorkel				x				
	2006	minnow trap	x							x
		snorkel				x				

EBD Reach/ Drainage	Year	Method	Month							
			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
	2007	electrofishing	x		x	x			x	
		minnow trap	x			x			x	
		snorkel			x	x			x	
	2008	seine					x			
		snorkel					x			
UT-F	2004	angling			x					
		electrofishing				x	x			
		minnow trap	x				x			
	2005	electrofishing	x		x	x	x			
		minnow trap			x		x			
		snorkel			x	x				
	2006	electrofishing	x				x			
		minnow trap	x							x
		snorkel					x			
	2007	angling		x						
		electrofishing	x			x	x	x		
		gill/tangle net				x				
		minnow trap	x			x		x		
		seine				x		x		
		snorkel				x				
	2008	angling						x	x	
		electrofishing				x	x	x		
		minnow trap				x				
		seine					x			
		snorkel				x	x			
UT-G	2004	electrofishing				x	x			
		minnow trap	x				x			
	2005	electrofishing	x				x			
	2006	minnow trap	x							x

EBD Reach/ Drainage	Year	Method	Month							
			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
	2008	electrofishing					x			
		seine					x			
		snorkel					x			
Kaskanak Creek	2004	electrofishing					x			
		minnow trap					x			
	2005	minnow trap					x			
Lower Talarik Creek	2005	angling					x			
	2006	angling					x			
	2007	angling					x			
		gill/tangle net					x			
	2008	angling						x		
		gill/tangle net						x		

TABLE 11-7
Number of mainstem and tributary fish sampling sites in the KR, NFK, SFK, and UT watersheds in 2004-2008 used to determine fish abundance among habitat types

Survey Year(s)	Number of Fish Sampling Sites by Drainage				
	KR	NFK	SFK	UT	Total
2004-2007	6	41	103	117	267
2008	0	560	700	461	1721
Total	**6**	**601**	**803**	**578**	**1988**

TABLE 11-8
Number of main channel and off-channel fish sampling sites in the NFK, SFK, and UT watersheds in 2005-2008 used to determine fish abundance among channel locations

Site Type	Number of Fish Sampling Sites by Drainage			
	NFK	SFK	UT	Total
main channel	56	14	18	88
off-channel (including side channels)[a]	37	54	51	142
off-channel (excluding side channels)	9	35	22	66
side channel	28	19	29	76
Total	**93**	**68**	**69**	**230**

a. Side channels were considered to be a unique type of off-channel habitat and were treated as such for fish abundance comparisons among channel locations.

TABLE 11-9
2004, 2005, and 2007 fish index sites and species in the NFK, SFK, UT, and Kaskanak Creek watersheds. Sites are grouped by watershed.

Site	Index Species[a]
NFK	
NK100A	Juvenile coho and chinook salmon
NK100B	Juvenile coho and chinook salmon, Dolly Virden
NK100C	Juvenile coho salmon, Dolly Virden , and arctic grayling
NK119A	Mixed-age Dolly Varden
SFK	
SK100A	Juvenile coho and chinook salmon
SK100B	Juvenile chinook salmon and Dolly Varden
SK100C	Not sampled in 2004—dry stream
SK100F	Mixed-age arctic grayling
SK100G	Juvenile arctic grayling
SK119A	Juvenile coho salmon and Dolly Varden
UT	
UT100B	Juvenile coho salmon
UT100C	Juvenile coho salmon and rainbow trout
UT100D	Juvenile coho salmon and Dolly Varden
UT100E	Mixed-age Dolly Varden
UT119A	Mixed-age Dolly Varden
Kaskanak Creek	
KC100A	Juvenile coho salmon

a. All index species are juvenile salmon or subadult resident fish.

TABLE 11-10
Logistics data associated with 2004-2008 aerial surveys

Survey Year	First Survey Date	Last Survey Date	Number of Surveys	Survey Frequency (days)
2004	07/12/04	10/14/04	7	14-22
2005	07/11/05	10/05/05	9	11-12
2006	07/02/06	10/07/06	11	9-12
2007	07/05/07	10/10/07	18	5
2008	07/01/08	11/22/08	26	5

TABLE 11-11
Microhabitat data collected at redd locations in the NFK, SFK, and UT watersheds in 2005, 2006, and 2008

	% of Total Redds Sampled for which Each Parameter Was Recorded		
Parameter	**2005**	**2006**	**2008**
species	100	100	100
depth	100	100	100
velocity	100	100	100
substrate	60	50	100
habitat type	100	0	0
water temperature	30	66	0
substrate temperature	0	66	0
redd measurements	0	0	100
Total Number of Redds Sampled	**60**	**171**	**509**

TABLE 11-12
Microhabitat data collected at fish observation locations in the NFK, SFK, and UT watersheds in 2007 and 2008

Parameter	Year	
	2007	2008
species	representative species include arctic grayling, chinook salmon, coho salmon, Dolly Varden, lamprey, rainbow trout, sockeye salmon, and whitefish	representative species include arctic grayling, chinook salmon, coho salmon, Dolly Varden, rainbow trout, sockeye salmon, and whitefish
life stage	representative life stages include juveniles and adults	representative life stages include juveniles and adults
fork length	not collected	estimated fork length of fish based on visual observation
fish count	not collected	count of fish by species and estimated fork length at each microhabitat location
water depth	not collected	water depth at each microhabitat location
focal water column position	not collected	percent of water depth at which representative fish were observed
focal depth	depth at which representative fish were observed	not collected, but can be calculated as Water Depth x Focal Water Column Position
mean velocity	not collected	mean water column velocity; measured at 60% water depth
focal velocity	water velocity at which representative fish were observed	water velocity at which representative fish were observed
substrate	primary, secondary, tertiary, and quaternary substrate types within a 1-ft radius from observed fish location, and associated percents of composition using a modified Wentworth Scale (Wentworth 1922)	dominant and subdominant substrate types using a modified Wentworth Scale (Wentworth 1922)
cover	cover type(s)	primary, secondary, and tertiary cover types

FIGURES

156°20'0"W
156°0'0"W
155°40'0"W
155°20'0"W
155°0'0"W
60°0'0"N
59°50'0"N
59°40'0"N

Swan River
Koktuli River
North Fork Koktuli River
South Fork Koktuli River
Black Lake
Groundhog Mountain
Nondalton
Big Wiggly Lake
NFK L.190
Kaskanak Mountain
SFK L.190
Frying Pan Lake
Koktuli Mountain
UT L.350
Talarik Creek
UT L.190
UT L.60
Sharp Mountain
Upper Talarik Creek
Chiquita Lake
Kaskanak Creek
First Creek
Lake #2
Newhalen River
Iliamna
Newhalen
Iliamna Lake

Legend

UT 1.60 Tributary Name Example
Watershed Boundary
General Deposit Location

N
W
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THE pebble PARTNERSHIP

Figure 11-1
Consolidated Study Program 2004-2008
Fish and Aquatic Resources
Mine Study Area

Alaska State Plane Zone 5
1983 North American Datum
Units Feet

Kilometers
0 2 4

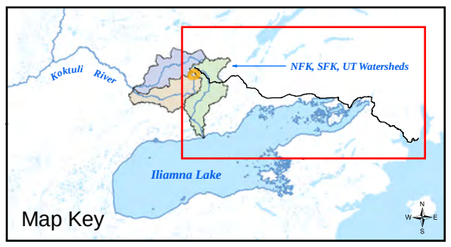
Miles
0 1 2

September 2011

Author: R2 - JJZ

155°20'0"W
155°0'0"W
154°40'0"W
154°20'0"W
154°0'0"W
153°40'0"W
60°0'0"N
59°50'0"N
59°40'0"N

Lake Clark
Tazimina River
Groundhog Mountain
Nondalton
Chekok Creek
Canyon Creek
Knutson Creek
Pile River
Frying Pan Lake
Talarik Creek
Upper Talarik Creek
Roadhouse Mountain
River
Newhalen River
Knutson Mountain
Chekok
Knutson Bay
Pedro Bay
Lonesome Bay
Pile Bay
Iliamna
Northeast Bay
Roadhouse Bay
Eagle Bay
Pedro Bay
Flat Island
Porcupine Island
Triangle Island
Iliamna River
Newhalen
Lake #2
Pile Bay
Williamsport
Bristol Bay Basin
Cook Inlet Basin
Iliamna Lake
Cook Inlet



Legend

- 2004 - 2007 Survey Site
- 2008 Survey Site
- Representative Road Alignment
- Bristol Bay/Cook Inlet Basin Divide
- Watershed Boundary
- General Deposit Location

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Figure 11-2
Consolidated Study Program 2004-2008
Fish and Aquatic Resources
Primary and Support Survey Sites
Transportation Corridor/Cook Inlet Study Areas

Alaska State Plane Zone 5
1983 North American Datum
Units Feet

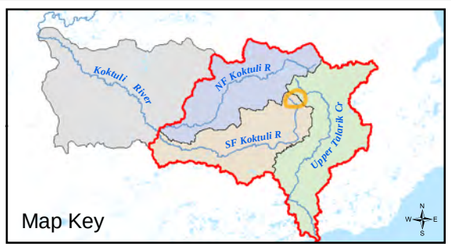
Kilometers 0 2 4
Miles 0 2 4

September 2011

Author: R2 - JJZ

156°0'0"W
155°40'0"W
155°20'0"W
155°0'0"W
60°0'0"N
59°50'0"N
59°40'0"N

Black Lake
Groundhog Mountain
Nondalton
Koktuli River
North Fork Koktuli River
Big Wiggly Lake
NFK 1.190
UT 1.350
Kaskanak Mountain
SFK 1.190
Frying Pan Lake
Koktuli Mountain
South Fork Koktuli River
Talarik Creek
UT 1.190
UT 1.60
Sharp Mountain
Upper Talarik Creek
Newhalen River
Chiquita Lake
First Creek
Lake #2
Iliamna
Newhalen
Iliamna Lake



Legend

- 2004 - 2007 Habitat Survey Site
- 2008 Habitat Survey Site
- *UT 1.60* Tributary Name Example
- Watershed Boundary
- General Deposit Location

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Figure 11-3
Consolidated Study Program 2004-2008
Fish and Aquatic Resources
Modified Tier 3 Aquatic Habitat Survey Sample Areas, Mine Study Area

Alaska State Plane Zone 5
1983 North American Datum
Units Feet

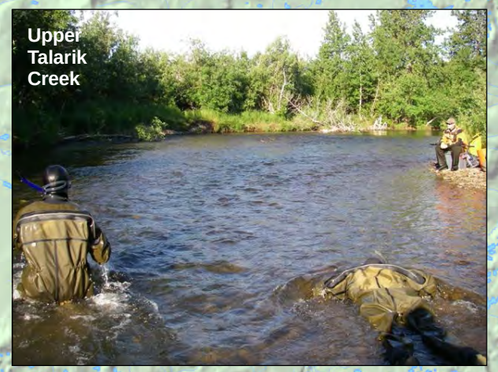
Kilometers 0 2 4
Miles 0 1 2

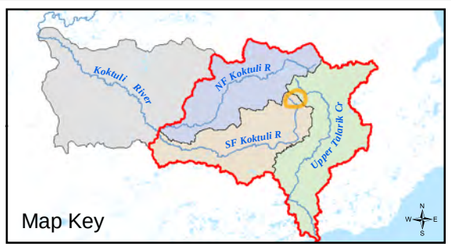
September 2011

Author: R2 - JJZ

156°0'0"W
155°40'0"W
155°20'0"W
155°0'0"W
60°0'0"N
59°50'0"N
59°40'0"N

Black Lake
Groundhog Mountain
Nondalton
Koktuli River
North Fork Koktuli River
NFK 1.190
Big Wiggly Lake
Kaskanak Mountain
SFK 1.190
Frying Pan Lake
Koktuli Mountain
UT 1.350
South Fork Koktuli River
Sharp Mountain
UT 1.190
Upper Talarik Creek
UT 1.60
Talarik Creek
Newhalen River
Chiquita Lake
Kaskanak Cr
Lake #2
First Creek
Newhalen
Iliamna
Iliamna Lake





Legend

- 2004 - 2007 Mainstem Index Site
- 2008 Mainstem Index Site
- *UT 1.60* Tributary Name Example
- Watershed Boundary
- General Deposit Location

N W E S

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Figure 11-4
Consolidated Study Program 2004-2008
Fish and Aquatic Resources
Mainstem Index Sites Sampled
Mine Study Area

Alaska State Plane Zone 5
1983 North American Datum
Units Feet

Kilometers 0 2 4
Miles 0 1 2

September 2011

Author: R2 - JJZ

156°0'0"W
155°40'0"W
155°20'0"W
155°0'0"W
60°0'0"N
59°50'0"N
59°40'0"N

Black Lake
Groundhog Mountain
Nondalton
Koktuli River
Big Wiggly Lake
North Fork Koktuli River
NFK 1.190
Kaskanak Mountain
UT 1.350
SFK 1.190
Frying Pan Lake
Koktuli Mountain
South Fork Koktuli River
Talarik Creek
UT 1.190
UT 1.60
Sharp Mountain
Upper Talarik Creek
Newhalen River
Chiquita Lake
Kaskanak Cr
Lake #2
First Creek
Iliamna
Newhalen
Iliamna Lake

Legend

- Fish Survey Location
- UT 1.60 Tributary Name Example
- Watershed Boundary
- General Deposit Location

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Figure 11-5
Consolidated Study Program 2004-2008
Fish and Aquatic Resources
Fish Distribution and Abundance Survey Locations
Mine Study Area

Alaska State Plane Zone 5
1983 North American Datum
Units Feet

Kilometers 0 2 4
Miles 0 1 2

September 2011
Author: R2 - JJZ

156°0'0"W
155°40'0"W
155°20'0"W
155°0'0"W
60°0'0"N
59°50'0"N
59°40'0"N

Black Lake
Groundhog Mountain
Nondalton
Koktuli River
North Fork Koktuli River
NFK 1.240
UT 1.390
Big Wiggly Lake
NFK 1.190
UT 1.410
UT 1.350
Kaskanak Mountain
SFK 1.190
Frying Pan Lake
Koktuli Mountain
South Fork Koktuli River
Talarik Creek
UT 1.190
UT 1.60
Upper Talarik Creek
Sharp Mountain
Chiquita Lake
Lake #2
First Creek
Newhalen River
Iliamna
Newhalen
Iliamna Lake

Legend

- North Fork Koktuli (NFK) Survey Segment
- South Fork Koktuli (SFK) Survey Segment
- Upper Talarik (UT) Survey Segment
- *UT 1.60* Tributary Name Example
- Watershed Boundary
- General Deposit Location

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Figure 11-6
Consolidated Study Program 2004-2008
Fish and Aquatic Resources
2008 Aerial Spawning Survey Segments
Mine Study Area

Alaska State Plane Zone 5
1983 North American Datum
Units Feet

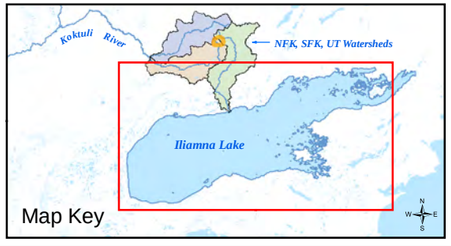
Kilometers 0 2 4
Miles 0 1 2

September 2011

Author: R2 - JJZ

155°40'0"W
155°20'0"W
155°0'0"W
154°40'0"W
154°20'0"W
59°40'0"N
59°30'0"N
59°20'0"N

River
Newhalen
Chekok
Pedro Bay
Iliamna
Newhalen
Flat Island
Porcupine Island
Triangle Island
Pile Bay
Lake #2
UTC Tower
LTC Tower
Pete Andrews Creek
Upper Talarik Creek
Lower Talarik Creek
Cooper River
Iliamna Lake
Kakhonak River
Kakhonak Lake
Gibraltar River
Dennis Creek
Belinda Creek
Gibraltar Lake
Kvichak River



Legend

- Radio Telemetry Tower
- General Deposit Location

N
W E
S

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Figure 11-7
Consolidated Study Program 2004-2008
Fish and Aquatic Resources
Rainbow Trout Radio Telemetry Study Area

Alaska State Plane Zone 5
1983 North American Datum
Units Feet

Kilometers
0 2 4

Miles
0 2 4

September 2011

Author: R2 - JJZ

156°0'0"W
155°40'0"W
155°20'0"W
155°0'0"W
60°0'0"N
59°50'0"N
59°40'0"N

Black Lake
Groundhog Mountain
Nondalton
Koktuli River
Koktuli River
Big Wiggly Lake
Koktuli River
North Fork Koktuli River
NFK 1.190
Kaskanak Mountain
UT 1.350
SFK 1.190
Frying Pan Lake
Koktuli Mountain
Talarik Creek
South Fork Koktuli River
UT 1.190
UT 1.60
Sharp Mountain
Upper Talarik Creek
Newhalen River
Chiquita Lake
First Creek
Iliamna
Newhalen
Lake #2
Iliamna Lake

Legend

- ▲ 2004 - 2007 Instream Flow Study Site
- △ 2008 Instream Flow Study Site
- *UT 1.60* Tributary Name Example
- Watershed Boundary
- General Deposit Location

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Figure 11-8
Consolidated Study Program 2004-2008
Fish and Aquatic Resources
Instream Flow Study Sites
Mine Study Area

Alaska State Plane Zone 5
1983 North American Datum
Units Feet

Kilometers 0 2 4
Miles 0 1 2

September 2011
Author: R2 - JJZ

Pebble Project
Environmental Baseline Studies
2004 through 2008

CONSOLIDATED STUDY PROGRAM

12. MARINE

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ACRONYMS

ABR	ABR, Inc.-Environmental Research & Services
ADF&G	Alaska Department of Fish and Game
agl	above ground level
AIC	Akaike Information Criterion
BEESC	Bristol Environmental & Engineering Services Corporation
CSP	consolidated study program
EBD	*Pebble Project Environmental Baseline Document, 2004 through 2008*
EIS	environmental impact statement
ESA	Endangered Species Act
FSP	field sampling plan
GIS	geographic information system
GPS	global positioning system
IIE	Iliamna/Iniskin estuary
MASS	Modern Applied Statistics with S
QAPP	quality assurance project plan
USACE	United States Army Corp of Engineers
wi	Akaike Weight

12. MARINE

The marine component of the environmental baseline description for the Pebble Project includes detailed studies of marine-wildlife and of near-offshore resources (i.e., marine fauna, flora, and their habitats) in the Iliamna and Iniskin bays of Cook Inlet.

Four consultants have worked on the marine study. ABR, Inc.-Environmental Research and Services (ABR) is the lead consultant for the detailed marine-wildlife survey work conducted in the Cook Inlet Study Area. Bristol Environmental & Engineering Services Corporation (BEESC), with support from RWJ Consulting in 2004 and from Pentec Environmental, Inc. starting in 2005, was responsible for the nearshore shore resources. Pentec Environmental was responsible for all nearshore resources for 2006 through 2008.In this consolidated study program (CSP), the work is discussed separately according to the two study elements: marine wildlife and nearshore resources.

12.1 Marine Wildlife — Cook Inlet Study Area

12.1.1 Objectives

Objectives of the marine-wildlife study are as follows:

- Document baseline conditions of marine fauna, flora and habitats in the study area.
- Collect data for input into studies by other disciplines.

The intended outcome of the study is to characterize the seasonal distribution and abundance of marine-oriented fauna, flora and their related habitats in the Iliamna and Iniskin bay area of Cook Inlet. Although all species will be examined, special emphasis has been placed on species that are listed as endangered, such as Steller sea lion; threatened, such as sea otters and Steller's eiders; and on species that have been nominated for listing, such as Kittlitz's Murrelets, under the Endangered Species Act (ESA; U.S. Congress, 1973). Beluga whales were monitored throughout the program when observing for marine mammals. They were not listed as endangered during this study program, but have since been listed under the ESA.

12.1.2 Study Area/Scope

Since 2004, the area for marine-wildlife studies has included locations at and near Williamsport, Knoll Head, North Head, and the nearby open coastline:

- The shoreline of Iniskin Bay.
- The shoreline of Iliamna Bay (including Cottonwood Bay).
- The shoreline of the nearby outer coastline (east almost to Oil Bay and south to Ursus Head).

- Islands and islets near the mouth of Iniskin Bay (the Mushroom Islets and Scott, Vert, Iniskin, and Pomeroy islands).
- Islands and islets near the mouth of Iliamna Bay (White Gull Island, Turtle Reef, and Black Reef).
- Deeper water in the centers of Iliamna and Iniskin bays and in the open bight to the southeast of their mouths.

The scope of the study has changed over time. In 2004, the study focused on boat-based surveys for birds that have a marine orientation during at least one stage of the annual cycle:

- Waterfowl (geese, swans, and ducks).
- Loons.
- Grebes.
- Tubenoses (fulmars and storm-petrels).
- Cormorants.
- Herons.
- Raptors.
- Cranes.
- Shorebirds.
- Larids (jaegers, gulls, and terns).
- Alcids.
- Kingfishers.
- Corvids.

In 2005, the boat-based surveys continued, but the number of field surveys increased, fixed-wing surveys were introduced in collaboration with the terrestrial wildlife and habitat study team (CSP 9), and the taxonomic scope of the study expanded to encompass all marine-oriented wildlife, including the birds listed above as well as four marine-mammal species-groups:

- Mustelids (otters).
- Pinnipeds (seals and sea lions).
- Ursids (bears).
- Cetaceans (whales and porpoises).

In subsequent years, the scope of work changed considerably. In 2006 and 2007, the emphasis of the study was changed from seabirds to focus on wintering ESA-listed species, such as Steller's eiders and sea otters, and on seasonal and geographic patterns of harbor seal populations that haul out within the study area. In 2007, there were no boat-based surveys; most of the work was conducted by helicopter and fixed-wing aircraft.

Table 12.1-1 summarizes the data from work conducted for the marine-wildlife studies in 2004 through 2007. An overview of the study area is presented on Figure 12.1-1.

12.1.3 Methods and Approach

Survey methods for the marine-wildlife study are based on standardized sampling methods used by the U.S. Fish and Wildlife Service and other research organizations.

12.1.3.1 Boat-based Surveys

Boat-based surveys are reconnaissance-level studies conducted to assess the distribution and abundance of marine-oriented wildlife in the study area from early spring to late winter. To conduct boat-based surveys, ABR investigators follow a systematic protocol:

- Sample from a skiff (e.g., Achilles raft, aluminum skiff).
- Follow the shoreline approximately 100 meters from shore.
- Identify, count, and map locations of all marine-oriented wildlife seen on the shoreline or nearshore areas (within 100 meters from the coastline; primarily for raptors and corvids) or in the nearshore zone (within 200 meters from shore) or flying over these areas; however, flying birds are not mapped.
- Describe locations (habitats) and activities (e.g., resting, feeding) of each wildlife sighting.
- Record environmental characteristics associated with each nearshore survey segment.
- Create a geographic information system (GIS) database file that lists locations of all nearshore survey and offshore survey segments. Include all data recorded during nearshore surveys and offshore surveys, including segment numbers, times of sampling, species seen, numbers, sexes and ages, locations, activities, and associated environmental data.
- Use GIS measurements to determine the area sampled in each nearshore segment.
- Use the GIS information to convert counts to estimates of birds/kilometer^2 or mammals/kilometer^2 of area surveyed in each segment.
- Digitize locations of all marine wildlife except flying birds.

12.1.3.2 Helicopter Surveys

All helicopter surveys are flown in a Robinson R44 helicopter (or similar) that follows the shoreline approximately 50 to 100 meters from shore. When necessary, the helicopter occasionally deviates from the nearshore trackline to verify the identification of a large group of birds or mammals in the center of a bay.

During each survey, investigators on each side of the helicopter identify, count, and map Steller's eiders, sea otters, and harbor seals and, when possible, large concentrations of other birds and mammals seen in the nearshore zone or in the centers of bays. Single or small groups of birds or mammals may not be counted or mapped.

These helicopter surveys are flown at a speed of 80 to 130 kilometers per hour and an altitude of 60 meters above ground level (agl), with both Steller's eiders and harbor seals being surveyed at the same time. If harbor seals or Steller sea lions are seen during these surveys, the helicopter rises to approximately 150 meters agl and/or skirts around the animals to minimize disturbance. Also, no surveys are flown within 2 hours of low tide to minimize disturbance of seals, which commonly haul out around the time of that tidal stage.

Locations of Steller's eiders, sea otters, and concentrations of other species of interest are digitized from field maps. Counts are summed to show total numbers. Maps of locations of taxa of interest then are generated from the digitized files.

12.1.3.3 Harbor Seal Aerial Surveys

The standard fixed-wing survey methods for harbor seals that are used in the marine study are the same as those referred to in CSP 9 (Section 9.2.10). Surveys are flown within 2 hours on either side of low tide. The survey aircraft (Cessna 206 or similar) fly a prescribed route in the area of Iliamna, Iniskin, and Cottonwood bays (from Turtle Reef to Oil Bay) and Chinitna Bay (Figure 12.1-1) at 305 meters agl. Two observers map and count or estimate the numbers of all harbor seals at haulouts and photograph groups larger than approximately 20 seals for later comparison and correction of field counts.

Analyses of the number of seals using the survey area include examining the effects of covariates to estimate total numbers and generating a maximal population estimate with the following statistical procedures. Survey totals are analyzed with a generalized linear model. Statistical analysis is conducted with the MASS library for the software package, R (Venables and Ripley, 2002). A candidate set of models has been developed to examine the effects of five covariates on harbor seal numbers: Julian date of survey (Date and Date2, to account for a non-linear relationship between date and number hauled out), time to solar midday (Time_to_Midday), tide height at time of survey (Tide_Height), height above the nearest low tide at time of survey (Relative_Tide_Height), and length of time to closest low tide (Time_to_Low_Tide). All combinations of variables are used, except for the variables Relative_Tide_Height and Time_to_Low_Tide, which are highly correlated.

Tide height during the surveys is estimated from the predicted tide height at stations in the National Water Level Observation Network with the computer program, WXTIDE32. The two closest tide stations are Iliamna Bay (153°35'W, 59°37'N) and Oil Bay (153°16'W, 59°38'N). Most of the seals recorded on past surveys were located on the Iniskin Islands, roughly halfway between these two tide stations. Therefore, the mean tide height between these two tide stations is calculated for the survey times to derive variables for tide height, relative tide height, time to low tide, and height of low tide. The time until solar midday also is calculated. Because the surveys begin in Iliamna Bay and end in Chinitna Bay, and because tidal changes proceed in the same geographic direction (low tides are approximately 1 hour later in Oil Bay than in Iliamna Bay), the tide height is assumed to remain roughly the same at all points of the survey.

Competing models are compared with an information-theoretic approach. For each model, the Akaike Information Criterion (AIC), corrected for small sample sizes (AICc), is calculated. The probability that each model is the "best model" in the candidate set is estimated with the Akaike Weight (wi). Parameter estimates from all models are weighted by the Akaike Weight for each model to get unconditional parameter estimates.

The observed haulout counts are adjusted with the coefficients of the covariates to estimate the number that would have been hauled out at low tide on that date. After calculating the adjusted counts of hauled-out seals, each estimate is corrected for the proportion of seals that were not hauled out at the time of the surveys by using a correction factor.

Because the focus of the analyses is on calculating the maximal number of harbor seals in the survey area, the results of two surveys on which the maximal observed number are expected to be hauled out (late July and early August) are analyzed separately. The covariate-adjusted count is calculated, and the variance in the adjustment is estimated with a parametric bootstrap method; the variance in the bootstrap samples is used to estimate the variance in the adjusted count. Then, the correction factor and its associated standard error are used to calculate the variance of the population level with the formula for the addition of two independent variance estimates.

12.1.4 Major Tasks and Activities

12.1.4.1 Tasks and Activities for 2004

The main tasks and activities for 2004 were to count and determine the distribution of marine birds in the study area at various times of the year. Specific tasks were as follows:

- Survey the distribution and abundance of marine-oriented birds in the study area with standardized boat-based surveys during three seasons (summer, fall, late winter/early spring [the late winter/early spring seasons are described as part of the tasks and activities for 2005, Section 12.1.4.2, below]).
- Describe the seasonal species-composition of the marine-oriented bird community.
- Determine and describe the use of the study area by Steller's eiders and Kittlitz's Murrelets.
- Map locations of marine-oriented birds on the water or shoreline.

Two boat-based surveys for marine-oriented birds were conducted in Iniskin and Iliamna bays and nearby areas: early summer 2004 (June) and late fall 2004 (November/December). During each survey, the distribution and abundance of marine-oriented birds seen on nearshore surveys were plotted, as were the general locations of marine-oriented birds seen during offshore surveys. Each segment was surveyed at least one time per cruise, weather permitting; if time permitted, replicate samples were taken.

12.1.4.2 Tasks and Activities for 2005

The specific tasks and activities for 2005 were the same as in 2004, except for three key changes:

- The taxa of interest were expanded from marine-oriented birds to include marine mammals.
- Standardized boat-based surveys were increased to four events.
- Reconnaissance surveys were conduced by fixed-wing aircraft and helicopter.

Four boat-based surveys for marine-oriented wildlife were conducted in Iniskin and Iliamna bays and nearby areas: late winter/early spring 2005 (March), spring 2005 (May), early summer 2005 (June), and late fall 2005 (November). During each survey, the distribution and abundance of marine-oriented

wildlife seen on nearshore survey segments were plotted, as were the general locations of marine-oriented wildlife seen on offshore survey segments. Each segment was surveyed at least one time per cruise, weather permitting; if time permitted, replicate samples were taken.

Reconnaissance overflights of the terrain and adjacent marine habitats at Seal Spit in Chinitna Bay were conducted as part of the marine mammal surveys described in CSP 9. Surveys of marine habitats were also in part covered by the marine wildlife surveys at Knoll Head and nearby areas (described above).

12.1.4.3 Tasks and Activities 2006

Tasks and activities changed considerably (but not completely) in 2006, as discussed below.

Boat-Based Surveys

In 2004 and 2005, a series of year-round boat-based surveys that provided high-resolution information on the distribution and abundance of marine-oriented birds and mammals, their age and sex ratios, and their activities and habitat locations was conducted. These surveys were conducted in early summer (June 2004, 2005), fall/early winter (November/December 2004, November 2005), late winter (March 2005), and spring (May 2005). In 2006, the second year of this cycle was completed with a late-winter cruise in March 2006 and a spring cruise in May 2006 (the actual days were determined by weather conditions). Data were collected with the same methods used in 2004 and 2005, as outlined in Section 12.1.3.1, above.

Helicopter Surveys

Helicopter-based surveys were not conducted in 2004 or 2005. In 2006, helicopter surveys of the nearshore zone in the region of Knoll Head (Figure 12.1-1) were conducted. They were scheduled for January through April, weather permitting. (Because of severe weather, the January survey was cancelled; surveys were conducted in February, March, and April.) The focal taxa were Steller's eiders and northern sea otters, although data on other species were collected whenever possible. These surveys provide some information on the timing of movements of these taxa out of the bays during the spring.

Harbor Seal Aerial Surveys

In 2005, several aerial-survey flights were completed to photograph and count harbor seals in the study area and in Chinitna Bay from approximately May to December. Methods for these surveys are described in Chapter 9. No surveys for harbor seals were conducted in 2006. In 2006, researchers were finishing the task of counting seals in the 2005 photographs.

12.1.4.4 Tasks and Activities for 2007

The main tasks and activities for 2007 were to conduct several helicopter surveys for marine mammals of interest and to collaborate with the terrestrial wildlife and habitat study team on harbor seal aerial surveys.

Helicopter Surveys

By 2007, one year of winter helicopter surveys had been conducted in the Iliamna/Iniskin Bay area. Data, focused on wintering Seller's eiders and sea otters, were collected in February through April and October through December 2006.

These winter helicopter surveys were continued in 2007 to determine the following:

- When Steller's eiders and sea otters move into and out of the study area.
- Where these species occur when present.
- The distribution and abundance of other wildlife species in the nearshore zone.
- When possible, the location and numbers of concentrations of birds in the offshore zones of these bays.

The surveys were conducted using the same methods used in 2006 (described in Sections 12.1.3.2 and 12.1.4.3), with two primary changes:

- First, a third day of sampling was added to obtain data from the Chinitna Bay area where no information on the distribution and abundance of wildlife in the winter had been collected previously.
- Second, it was proposed to increase the survey effort to 14 surveys (weather permitting): January (1), February (1), March (2), April (2), May (1), August (1), September (2), October (2), November (1), and December (1). The protraction of the survey period and the increased sampling intensity would enable researchers to better quantify when some of the threatened and endangered species (i.e., Steller's eider, sea otter) move into or out of the survey area in numbers and to determine the timing of short-term movements of endangered species through the area (Steller sea lion).

Aside from these changes, surveys were conducted as they were in 2006, as described in Section 12.1.3.2. Helicopter surveys for Steller's eiders, sea otters, and, when possible, concentrations (25 or more individuals) of other marine birds and mammals were conducted in Iniskin, Iliamna, and Chinitna bays (Figure 12.1-2) to cover the winter, spring, and fall seasons. During each trip, two surveys of Iliamna and Iniskin bays were conducted on consecutive dates and one survey was conducted in Chinitna Bay (a second one was also proposed if it could be done on the same day as one of the Iliamna and Iniskin bay survey days). During these surveys, researchers flew over nearshore waters and searched for Steller's eiders and sea otters there and in the centers of bays.

Harbor Seal Aerial Surveys

By 2007, only 1 year of baseline data had been collected on harbor seals (in 2005). That work indicated harbor seals are abundant in the Cook Inlet marine study area; the maximal estimate of seals in the study area in 2005 was approximately 1,450 animals, or up to 27 percent of all seals estimated to inhabit western Cook Inlet.

The standard fixed-wing survey methods for seals used in 2005 (Section 12.1.3.3) were used again in 2007. It was proposed to conduct surveys between spring and fall during 10 sampling events (with two replicate surveys on successive days per survey event, plus a third replicate in late July and early August for population-estimation surveys): April (1), May (1), June (2), July (2), August (2), September (1), and October (1). The specific timing of surveys depended on the timing of low tides each month in relation to the amount of available daylight.

12.1.4.5 Tasks and Activities for 2008

The emphasis of the 2008 marine wildlife program was on studying wintering ESA-listed species, such as Steller's eiders and sea otters, and on seasonal and geographic patterns of populations of harbor seals that haul out within the study area. The objectives, methods, and scope of work for the marine wildlife study are the same as for 2004 through 2007, except as noted below. Table 12.1-1 summarizes work for the marine wildlife program from 2004 through 2008.

The 2008 study included the following tasks:

- Winter helicopter surveys for Steller's eider, sea otter, Steller sea lion, and beluga whale in the Iliamna–Iniskin–Chinitna Bay area were conducted by the same methods used in 2006 and 2007, with an increase in survey effort from 14 surveys in 2007 to 19 surveys in 2008.
- The number of helicopter surveys for harbor seals were reduced from 10 surveys in 2007 to three surveys in 2008. These surveys occurred at critical times of the year when numbers peak at haulouts (June, late July/early August) in 2008.

12.2 Marine Nearshore Resources

The objectives, area, and scope for marine nearshore resource studies are the similar to those for the marine wildlife component, except the taxonomic focus includes a consideration of intertidal infaunal and epifaunal communities, and marine and anadromous fish.

A summary of the tasks completed for marine nearshore-resources studies is provided in Table 12.2-1. Figures 12.2-1 through 12.2-3 give overviews of the study area and sampling locations for specific aspects of the study.

12.2.1 Methods/Approach

The methods for studying marine nearshore resources include boat-based surveys in the offshore zone, as well as a variety of techniques to quantify sediments, water, and faunal/floral communities. All work is conducted from marine vessels chartered from Homer.

12.2.1.1 Boat-based Surveys

Investigators conduct their boat-based surveys in the offshore zone in collaboration with the marine-wildlife study team. The protocols for the latter surveys are described in Section 12.1.3.1, above. The offshore surveys follow a similar standardized protocol:

- Sample a series of strip-transect segments in the offshore zone (central portion) of each bay and in the open bight.
- Follow a fixed trackline (Figure 12.1-1).
- Record ship speed, time, and beginning and ending coordinates for each segment.
- Count all marine-oriented wildlife seen within 150 meters on either side of the boat.

- Describe locations (habitats) and activities (e.g., resting, feeding) of each wildlife sighting.
- Record environmental characteristics associated with each offshore segment.
- Use GIS measurements to determine the area sampled in each offshore segment.
- Use the GIS information to convert counts to estimates of birds/kilometer^2 or mammals/kilometer^2 of area surveyed in each segment.
- Use waypoints in each sampling transect to map approximate locations of each sighting.

12.2.1.2 Mapping of Intertidal Habitat Types

Mapping of intertidal habitats is done to assess the types and characteristics of habitats in portions of the Iliamna/Iniskin estuary (IIE). The area of study includes Iliamna Bay, the lower reaches of Iniskin Bay, and the headlands between the two bays. Intertidal habitat mapping builds on base information from the Cook Inlet Regional Citizen's Advisory Council (Pentec, 1996) and other observations. Where field observations differ significantly from existing information, dominant substrate types observed in the upper, middle, and lower intertidal zones are recorded separately. Habitat mapping includes recording locations using global positioning systems (GPS) for later incorporation into the project GIS base map.

12.2.1.3 Beach Seine Sampling

Beach seine sampling is conducted to study the use of the littoral zone by juvenile salmonids, resident forage fish (e.g., herring, spotted greenlings), and invertebrates. Seining is performed at regular intervals throughout the field season, with more intensive surveys in late May and early June, to study salmonid out-migration through the estuary. Less frequent sampling extends into the fall.

For herring data, investigators initially relied on herring spawn surveys conducted in the IIE and adjacent bays by the Alaska Department of Fish and Game (ADF&G). ADF&G was surveying the area by air on a weekly basis, weather permitting, with at least one on-water survey annually. Coordinating with ADF&G personnel ensured that the BEESC survey methods were consistent with ongoing surveys in the area. ADF&G also had already provided BEESC investigators with data on surveys conducted between 1978 and 2002. In 2006 investigators included their own herring spawn surveys as part of their study program that year (as described in tasks and activities for 2006 in Section 12.2.2, below).

Spotted greenlings are collected to provide tissue samples of a resident forage fish species. The spotted greenling was selected because of its limited migratory range and its potential for human consumption. Tissue samples from collected specimens are analyzed for trace metals, hydrocarbons, or other inorganic chemistry by the project laboratories in accordance with the 2005 field sampling plan and the quality assurance project plan (QAPP) (Appendix F and Appendix G of the *Pebble Project Environmental Baseline Document, 2004 through 2008* [EBD], respectively).

In addition, water temperature and salinity are measured in the field and water samples are taken for contaminant analysis during most beach seining events.

12.2.1.4 Offshore Trawl Sampling

Offshore trawl sampling with a "try-net" occurs between May and September to assess fish populations. Extending the trawling program over the entire summer allows evaluation of both resident and migratory species and event-related species interaction such as herring spawning. A food web study is proposed to analyze stomach contents of key fish species collected from seine and trawl programs to document prey and feeding patterns.

In addition, water temperature and salinity are measured in the field and water samples are taken for contaminant analysis during most trawl sampling events.

12.2.1.5 Intertidal Epibenthic Surveys

Intertidal epibenthic surveys are conducted to characterize the nature and distribution of epibenthic assemblages in the intertidal zone. They are quantified on fixed quadrants on fixed transects. The sampling program has been designed to revisit some sites established in 1978, 1996, and 2004, as well as to establish several new sites along Iliamna Bay. Key historical sampling locations are revisited to ensure that monuments are well established for future reference, as well as to evaluate long-term trends observed in algae and barnacle cover on these beaches.

12.2.1.6 Intertidal Infaunal and Sediment Sampling

Intertidal infaunal and sediment sampling in soft-bottom habitats are conducted to establish the type and distribution of infaunal species in the soft intertidal areas. The study methods include excavating large intertidal infaunal samples (0.25 square meter) and sieving them to collect larger organisms, including bivalves, for contaminant analyses.

Field personnel also use Van Veen water samplers to collect water samples and Van Veen grab samplers to collect sediments. BEESC investigators have also considered the use of side scan sonar mapping to stratify sediment infaunal and epifaunal sampling by habitat type (e.g., sand, silt, or cobble) and the use of bathymetry data to allow stratifying by water depth.

Water temperature and salinity (i.e., specific electrical conductivity) are measured in the field. Collected water samples are sent to the project laboratory for trace metal and other contaminant analysis. Sediment samples are analyzed for grain size, and both sediment and infaunal tissue samples are analyzed for trace metals, hydrocarbons, or other chemistry by the project laboratories in accordance with the FSP and QAPP ((Appendix F and Appendix G of the EBD, respectively).). Infaunal samples collected from the intertidal and subtidal IIE are analyzed by the University of Alaska Fairbanks, Institute of Marine Science, laboratory. Analyses include calculating coefficients of variation for subsequent incorporation into a power analysis.

12.2.2 Major Tasks and Activities

Tasks and Activities for 2004

The main tasks and activities for 2004 were to review existing data; collect preliminary baseline data of sediments, water, and species populations; and interact with agencies and the Pebble Partnership study teams on project planning and implementation.

A thorough literature review of existing marine environment information was completed, including reviewing the following:

- *Navigation Channel Feasibility Report and Environmental Assessment – Williamsport* (USACE, 1995).
- *A Survey of Selected Cook Inlet Intertidal Habitats* (Pentec, 1996).
- *Outer Continental Shelf Environmental Assessment Program* (U.S. Department of Commerce and U.S. Department of Interior, 1986)

In addition, preliminary field studies were conducted at select locations using the following standard marine biological survey techniques:

- Conducting general marine mammal and bird observations, consisting of locating and making qualitative counts. Endangered or threatened species were a priority for observations.
- Conducting sediment, water (surface and bottom), and marine invertebrate sampling at several beaches from July through September 2004.
- Conducting opportunistic sampling of fishes for trace metals concentrations and species identification.
- Documenting field reconnaissance findings and summarizing physical and biological data, then comparing and contrasting the information to existing literature and other available information.

Agency and team interaction included the following:

- Interfacing with project team to further define work scope – ensure minimum environmental impact statement (EIS) requirements.
- Providing support to the project team for interaction with agencies and public, particularly the EIS scoping process.
- Participating in team meetings with the Pebble Partnership and its other consultants.
- Providing environmental input into project design options.
- Making, or assisting with, permit applications.

Tasks and Activities for 2005

The main tasks and activities for 2005 were to study in detail the nature and usage of the nearshore and intertidal habitat in the study area. The 2004 work was designed to include a one-time sampling event

intended to collect a snapshot of marine conditions. Because of the timing of that event, efforts were focused on maximizing the amount of data collected in a very limited time period. To obtain the highest quality data in 2005, the number of field events was substantially increased and the events were scheduled during the most beneficial seasonal and tidal cycles for each study task. The work included the following:

- Mapping of intertidal habitat types.
- Beach seine sampling: Seining was performed biweekly from early May through early July with more intensive surveys in late May and early June. Less frequent sampling extended into late August. Proposed beach seining locations included several beaches (Figure 12.2-1). In 2005, BEESC investigators relied on ADF&G herring spawn survey data.
- Offshore trawl sampling: Trawl samples were taken with a "try-net." The work was conducted concurrent with beach seining activities between May (or ice out) and September.
- Intertidal epibenthic surveys: Quantitative surveys of intertidal epibenthic assemblages were conducted at existing and new sites. Proposed sampling locations are shown on Figure 12.2-2.
- Intertidal infaunal and sediment sampling: Infaunal and sediment sampling was conducted in soft-bottom beach habitats at locations shown on Figure 12.2-2.

Tasks and Activities for 2006

The main tasks and activities for 2006 were to expand on the data collected to date. Surveys were conducted from April 25 through 28 and May 16 through 18, 2006. The 2006 studies include three tasks that were continuations of tasks begun in 2004 and continued in 2005 and one new herring spawn survey task, as described below. Methods for the surveys conducted in 2006, except the herring spawn surveys, are described above.

- Beach seine sampling – To document nearshore fish use, beach seining was proposed—ice and sea state conditions permitting—at 13 stations sampled in previous work (Figure 12.2-3). Sampling was proposed for late April to document early spring use of nearshore habitats, especially by juvenile salmonids. Sampling also was proposed in mid-May in conjunction with the herring spawn surveys (see below). Selected fish were retained for future stomach content analysis.
- Offshore trawl sampling – Trawl sampling was proposed at seven stations sampled in previous work (Figure 12.2-3). Sampling was proposed to occur in late April to document early spring use of shallow and deeper subtidal habitats. Sampling also was proposed for mid-May in conjunction with the herring spawn surveys (see below).
- Intertidal epibenthic surveys – To take advantage of low tides during April and to provide data on spring algal conditions that may provide a spawning substrate for herring, intertidal assemblage data were collected at three rocky habitat stations (Figure 12.2-3). All sampling was proposed to occur during the April survey, except the lower elevation at Scott Island, which would be sampled in May. In addition to the previously sampled lower elevation transect at PS 1, transects were set up, permanently marked, and sampled (in April) on middle and upper elevation rocky substrates in this area. Transects were sampled as described in the 2005 FSP (Appendix F of the EBD).

- Herring spawn surveys (a new task in 2006) – Skiff-based surveys were proposed for spring low tides (late April and mid May) to search for herring spawn deposition. Investigators cruised the shoreline around Scott Island and the Mushroom Islets (areas of historical herring spawning), around Knoll Head, and along Black Reef. (Locations are shown on Figure 12.2-1.) The team was particularly sensitive to areas where high bird or marine mammal activity was observed. They documented the condition of intertidal and shallow subtidal algal assemblages (especially kelp) and the presence or absence of herring spawn. GPS coordinates were taken at all areas visited. Where herring spawn was detected, the following data were recorded:
  - Spawn density (scattered, near continuous, multilayered; including thickness).
  - Substrata used (algae, eelgrass, rock).
  - Elevation relative to mean lower low water.
  - GPS coordinates of boundaries of spawn area.
  - Photographs of spawn deposition.

Tasks and Activities for 2007

The main tasks and activities for 2007 field studies for marine near-foreshore resources included continuation of beach seining, spring otter trawling, and water quality sampling activities.

Tasks and Activities for 2008

The 2008 objectives for the marine nearshore resources study are the same as described in 2006, except as noted below. Figure 12.2-1 shows the study area for the marine nearshore resources study for 2008. Table 12.2-1 summarizes work conducted for the marine nearshore resource studies in 2004 through 2008. The 2008 marine nearshore resources study included the following tasks:

- Continued beach seining at 13 stations sampled in 2004, 2005, 2006, and 2007. These stations were sampled beginning in March until November. The sampling season is longer than that in previous years in order to better understand winter conditions, including a better understanding of the Steller's eider and the western race of sea otter. In addition, additional new stations were sampled (in May and September only) in northern Iniskin Bay in areas shown to have high spring concentrations of shore birds and seals to identify possible prey in the area.
- Continued trawl sampling at seven stations sampled in previous years, from February or March through November, where the sampling season was longer than in previous years. In addition, trawl sampling was performed at new stations (in May and September only).
- Continued skiff based and walking herring spawn surveys during low tides in mid-May, early June, and mid-June along shorelines in the IIE. Surveys focused on areas where ADF&G has reported recent spawning.
- Continued sampling biological tissues for laboratory analysis. Previous sampling efforts were conducted opportunistically. Samples were collected in a systematic manner in 2008 to establish adequate baseline for post-project comparisons.
- Continued intertidal rocky epibiota sampling nearest to Knoll Head in July 2008. Sampling took place previously in July 2005.

- Continued marine water quality sampling for analysis of naturally occurring constituents. Although sampling took place in July 2004, most analyses for these samples were compromised in the laboratory.
- Continued intertidal sediment and infauna sampling at five locations completed 2 years of data collection. The 2008 program aimed to improve data around AC Point and inner Iliamna Bay.
- Continued subtidal benthos and sediment surveys. In previous years, information had only been collected in July for subtidal benthos. The following surveys were conducted in 2008:
  - Subtidal infauna collected at two stations sampled in 2004 near Knoll Head.
  - Diver transects set up and marked at Knoll Head, North Head, and White Gull Island (reference) to document epibiota.
- Sediment levels and trace element analysis in the vicinity of the loading facility were conducted in mid-summer 2008. Surface sediment was sampled in 2004, but 2008 sampling for analysis took both surface and subsurface sediments at Knoll Head and North Head.

12.3 References

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TABLES

TABLE 12.1-1
Pebble Project Environmental Baseline Studies
Study Summary for Marine Wildlife, 2004-2008, Cook Inlet
Consultant: ABR, Inc.

2004 Data Collected or Tasks Completed	2005 Data Collected or Tasks Completed	2006 Data Collected or Tasks Completed	2007 Data Collected or Tasks Completed	2008 Data Collected or Tasks Completed
Information Gathering / Literature Search	Information Gathering / Literature Search & Review	Information Gathering / Literature Search & Review	Information Gathering / Literature Search & Review	Information Gathering / Literature Search & Review
Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan
2004 Study Plan	2005 Study Plan	2006 Study Plan Summary	2007 Study Plan Summary	
Marine Wildlife Surveys by Ship (June, November)	Marine Wildlife Surveys by Ship (March, May, June, November)	Marine Wildlife Surveys by Ship (March, May)		
	Aerial Photography Surveys for Harbor Seals (May to December)		Continue Aerial Surveys for Harbor Seals (June, late July/early August). Search for appropriate Control Study Sites for BACI study design	Continue Aerial Surveys for Harbor Seals (June, late July/early August).
		Marine Surveys by Helicopter for Steller's Eiders, Sea Otters, and Steller's Sea Lions (February, March, April)	Marine Surveys by Helicopter for Steller's Eiders, Sea Otters, and Steller's Sea Lions (February, March, April, May, August, September, October, November, December)	Marine Surveys by Helicopter for Steller's Eiders, Sea Otters, Steller's Sea Lions, and Beluga Whales (January-May and August-December)
Data Entry and Analysis	Data Entry and Analysis	Data Entry and Analysis	Data Entry and Analysis	Data Entry and Analysis
Communication and Data Management	Communication and Data Management	Communication and Data Management	Communication and Data Management	Communication and Data Management
Coordination with NDM, Agency Meetings	Coordination with NDM, Agency Meetings, and Monthly Reporting	Coordination with NDM, Agency Meetings, and Monthly Reporting	Coordination with PLP, Agency Meetings, and Monthly Reporting	Coordination with PLP, Agency Meetings and Monthly Reporting
	2004 Progress Report	Draft Environmental Baseline Document	Finalize Draft Environmental Baseline Document	Finalize Draft Comprehensive Environmental Baseline Document

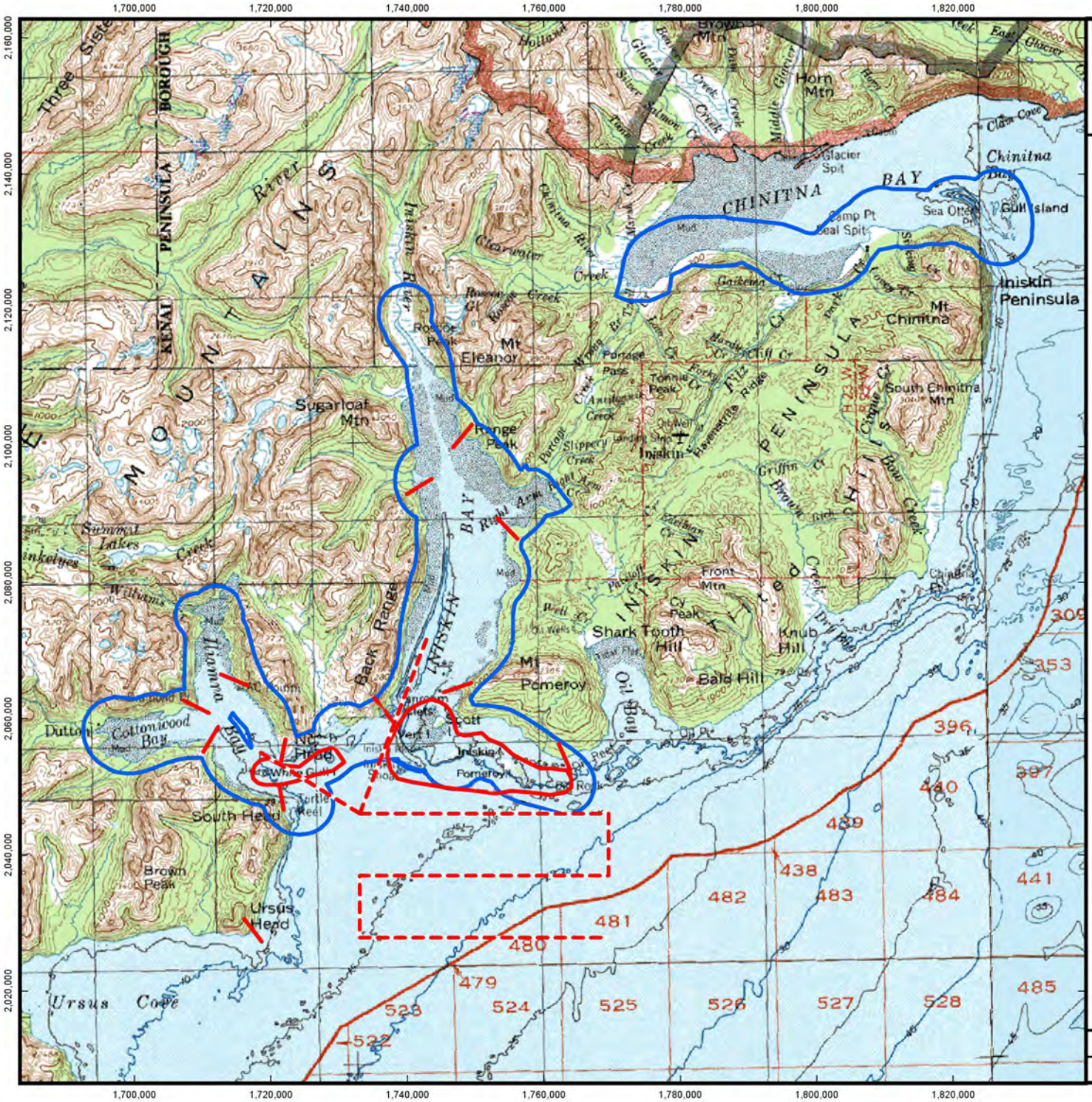
TABLE 12.2-1
Pebble Project Environmental Baseline Studies
Study Summary for Marine Nearshore Resources, 2004-2008, Cook Inlet
Consultants: BEESC / RWJ Consulting / Pentec Environmental

Discipline	2004 Data Collected or Tasks Completed	2005 Data Collected or Tasks Completed	2006 Data Collected or Tasks Completed	2007 Data Collected or Tasks Completed	2008 Data Collected or Tasks Completed
Nearshore Fish and Demersal Invertebrates	Information Gathering/Literature Sythesis	Information Gathering/Literature Sythesis			
	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan
	2004 Study Plan	2005 Study Plan	2006 Study Plan	2007 Study Plan	
	On-site Reconaissance and Station/Transect Selection	On-site Expansion of Station/Transects			
	Year 1 initial Nearshore Beach Seining	Year 2 Spring/Summer Nearshore Beach Seining (May through August)	Year 3 Early Spring Nearshore Beach Seining	Year 4 Early Spring Nearshore Beach Seining	Year 5 Early Spring Nearshore Beach Seining
	Year 1 Initial Otter Trawling Offshore Demersal Areas in Iniskin and Iliamna Bays	Year 2 Spring/Summer Otter Trawling Offshore Demersal Areas in Iniskin and Iliamna Bays (May through August)	Year 3 Early Spring Otter Trawling Offshore Demersal Areas in Iniskin and Iliamna Bays	Year 4 Early Spring Otter Trawling Offshore Demersal Areas in Iniskin and Iliamna Bays	Year 5 Early Spring Otter Trawling Offshore Demersal Areas in Iniskin and Iliamna Bays
	Fish Tissue Collection for Baseline Chemical Analysis	Fish Tissue Collection for Baseline Chemical Analysis			Fish Tissue Collection for Baseline Chemical Analysis
			Iniskin/Iliamna Bay Herring Spawn Survey		
			ADFG Herring Data Analysis		
		Fish Collection for Stomach Content Analysis	Fish Collection for Stomach Content Analysis		
	Year 1 Data Management and QA/QC	Year 2 Data Management and QA/QC	Year 3 Data Management and QA/QC	Year 4 Data Management and QA/QC	Year 5 Data Management and QA/QC
	Year 1 Data Analysis	Year 2 Data Analysis	Year 3 Data Analysis	Year 4 Data Analysis	Year 5 Data Analysis
		2004 Progress Report on Marine Studies	Preparation of Draft Environmental Baseline Document	Preparation of Draft Environmental Baseline Document	Preparation of Draft Environmental Baseline Document
	Coordination with NDM & Agencies	Coordination with NDM & Agencies	Coordination with NDM & Agencies	Coordination with PLP & Agencies	Coordination with PLP & Agencies

TABLE 12.2-1
Pebble Project Environmental Baseline Studies
Study Summary for Marine Nearshore Resources, 2004-2008, Cook Inlet
Consultants: BEESC / RWJ Consulting / Pentec Environmental

Discipline	2004 Data Collected or Tasks Completed	2005 Data Collected or Tasks Completed	2006 Data Collected or Tasks Completed	2007 Data Collected or Tasks Completed	2008 Data Collected or Tasks Completed
Marine/ Benthos Habitat	Information Gathering/Literature Sythesis	Information Gathering/Literature Sythesis			
	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan
	2004 Study Plan	2005 Study Plan	2006 Study Plan		
	On-site Reconaissance and Station/Transect Selection	On-site Expansion of Station/Transects Reflecting Current Design Alternatives			
	Year 1 Intertidal sampling of epibenthos on rocky habitats (late summer)	Year 2 Intertidal sampling of epibenthos on rocky habitats (mid summer)	Year 3 Intertidal sampling of epibenthos on rocky habitats (early spring)		Year 4 Intertidal ssampling of epibenthos on rocky habitats (early spring)
	Year 1 Intertidal sampling for sediment chemistry on sand/mud habitats (late summer)	Year 2 Intertidal sampling for sediment chemistry on sand/mud habitats (mid summer)			
	Year 1 Subtidal sampling for sediment chemistry on sand/mud habitats (late summer)				
	Year 1 Intertidal sampling of infauna on sand/mud habitatas (late summer)	Year 2 Intertidal sampling of infauna on sand/mud habitatas (mid summer)			Year 3 Intertidal sampling of infauna on sand/mud habitatas (mid summer)
	Year 1 Subtital sampling of infauna on sand/mud habitats (late summer)	Analysis of Subtidal sampling of infauna on sand/mud habitats (late summer)			Year 2 Subtital sampling of infauna on sand/mud habitats (late summer)
	Year 1 Diver subtidal ebibenthos surveys				
	Year 1 Marine water quality sampling for trace metals	Analysis of Marine water quality samples for trace elements		Year 2 Marine water quality sampling for trace elements	Year 3 Marine water quality sampling for trace elements
	Invertebrate Tissue Collection for Baseline Chemical Analysis (late summer)	Invertebrate Tissue Collection for Baseline Chemical Analysis (mid summer)			
	Shoreline habitat verification	Shoreline habitat detailed survey	Shoreline habitat detailed survey		
	Year 1 Data Management and QA/QC	Year 2 Data Management and QA/QC	Year 3 Data Management and QA/QC	Year 4 Data Management and QA/QC	Year 5 Data Management and QA/QC
	Year 1 Data Analysis	Year 2 Data Analysis	Year 3 Data Analysis	Year 4 Data Analysis	Year 5 Data Analysis
	Coordination with NDM & Agencies	Coordination with NDM & Agencies	Coordination with NDM & Agencies	Coordination with PLP & Agencies	Coordination with PLP & Agencies
		2004 Progress Report on Marine Studies	Preparation of Draft Environmental Baseline Document	Preparation of Draft Environmental Baseline Document	Preparation of Draft Environmental Baseline Document

FIGURES



THE pebble PARTNERSHIP

Figure 12.1-1
Consolidated Study Program, 2004-2008
General Study and Survey Areas for Marine Wildlife (2004 to 2006) Cook Inlet

Marine Wildlife Survey Areas

- 2004, 2005 and 2006 Nearshore Segment Boundaries for Boat Surveys and 2006 Helicopter Surveys for Sea Otters and Steller's Eiders
- 2004, 2005 and 2006 Offshore Boat Survey Transects
- 2005 Coastal Seal Survey

Miles 0 1 2 3 4 5 6
Kilometers 0 2 4 6 8 10
N

Scale 1:250,000

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

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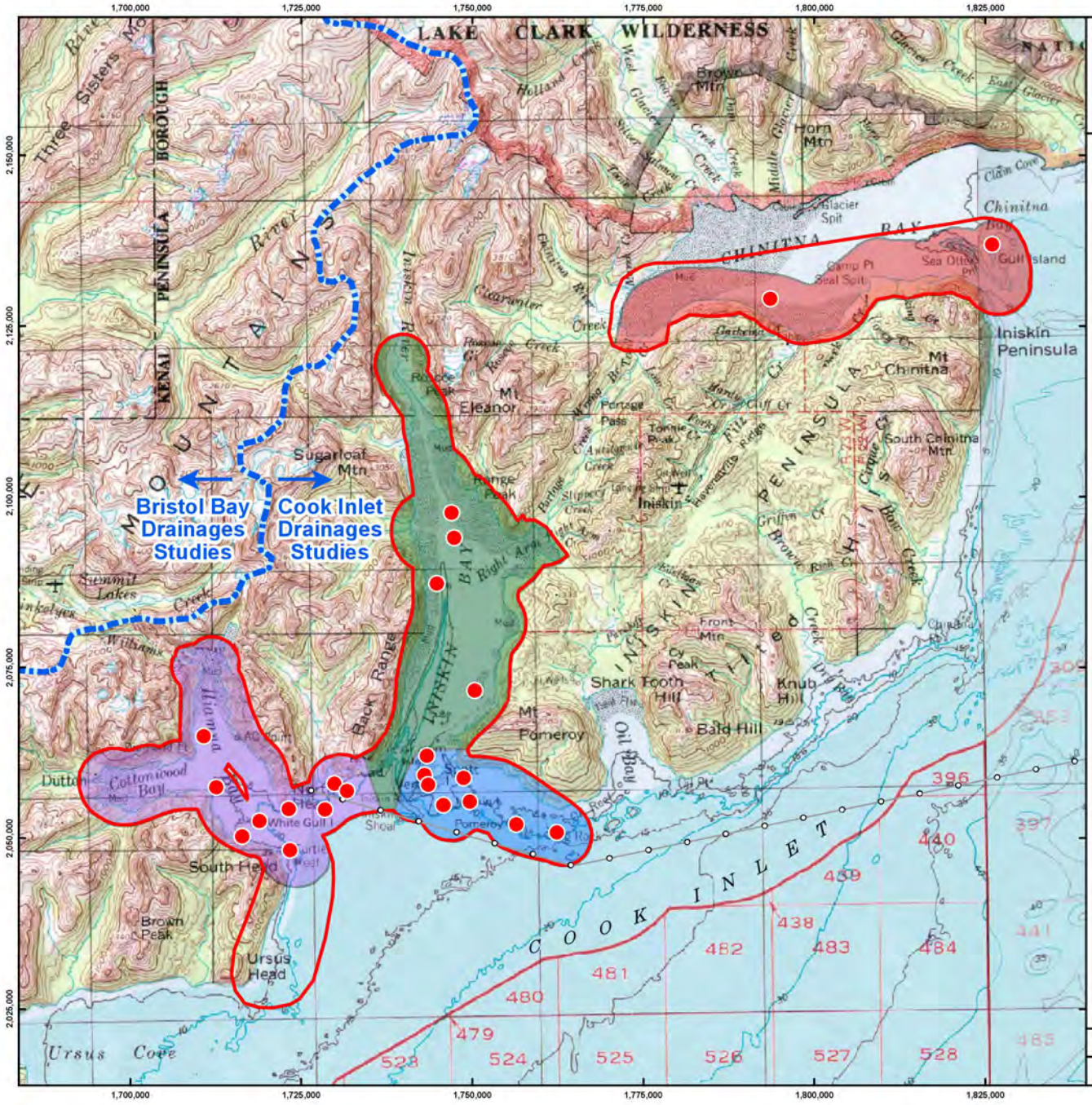
Version: 1, Rev.	Author: ABR-AZC



THE pebble PARTNERSHIP

Figure 12.1-1
Consolidated Study Program, 2004-2008
2007-2008 Survey Areas for Marine Wildlife Studies
Cook Inlet Marine Study Area

Legend

- Marine Wildlife Survey Area

Harbor Seal Survey Areas

- Chinitna Bay Count Area
- Iliamna Bay Count Area
- Iniskin Bay Count Area
- Iniskin Islands Count Area
- Harbor Seal Haul-out Location

Miles 0 1 2 3 4 5 6
Kilometers 0 2 4 6 8 10
N

Scale 1:275,000

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: Marine_Wildlife_StudyPlan2008_v01.mxd	Date: May 6, 2008
Version: 1	Author: ABR-AZC

1,700,000

1,750,000

2,050,000

Summit Lakes

Williams Creek

Williamsport

Diamond Pt

COTTONWOOD BAY
(use inset)

ILIAMNA BAY
(use inset)

A.C. Point

North Head

Knoll Head

Back Range

Sand & Mud

Right Arm

Foul

Bldg

Foul

Reef
(Cov 1 ft at MLLW)

INISKIN BAY

The Toadstools

Mt Pomeroy

Mushroom Islets

Scott I

Iniskin Rk

Iniskin I

Pomeroy I

Iniskin Shoal

Big Rk
(9)

Kelp

Black Reef

White Gull I
(70)

Turtle Reef
rky (15)

South Head

LOCAL MAGNETIC DISTURBANCE
(see note)

THE pebble PARTNERSHIP

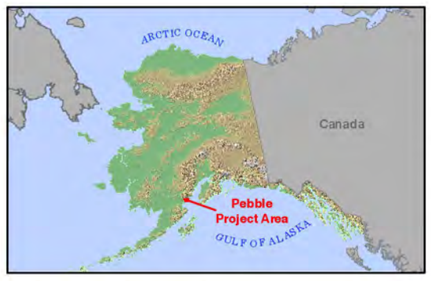
Figure 12.2-1
Consolidated Study Program, 2004-2008
Nearshore Resources
2004 and 2005 Sampling Sites
Cook Inlet

Legend

Beach Seine Site

Samples in 2004

New Site in 2005



N

0 0.6 1.2 1.8 2.4 Miles

0 0.8 1.6 2.4 3.2 Kilometers

Scale 1:70,000

Alaska State Plane Zone 5 (units US feet)
1983 North American Datum

File: Marine_01_V02.mxd	Date: April 12, 2009
Version: 2, Rev.	Author: BEESC-ME / EVW

1,700,000

1,750,000

2,050,000

Sand & Mud

Right Arm

Foul

Rk

Rks

Blds

M

Cl

Reef
(Cov 1 ft at MLLW)

INISKIN BAY

Summit Lakes

Williams Creek

Williamsport

Back Range

2715

2935

2405

2805

2735

2745

A.C. Point

Diamond Pt

ILIAMNA BAY
(use inset)

COTTONWOOD BAY
(use inset)

North Head

Knoll Head

Kelp

Vert

Iniskin Rk

Black Reef
rky

White Gull I
(70)

Turtle Reef
rky (15)

South Head

LOCAL MAGNETIC DISTURBANCE
(see note)

Iniskin Shoal

Iniskin I

Pomeroy I

Big Rk
(9)

The Toadstools

Mt Pomeroy
2385

Mushroom
Islets

Scott I

1740

1745

1335

S Oz

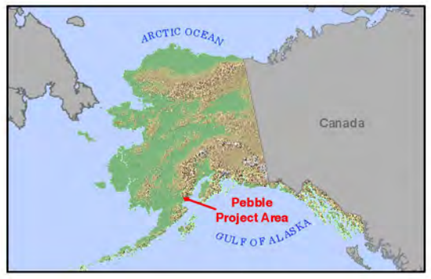
S M

THE pebble PARTNERSHIP

Figure 12.2-2
Consolidated Study Program,
2004-2008
Marine Nearshore Resources
Intertidal Survey Sites
Cook Inlet

Legend

- Rocky Beach
- Soft Beach



N

0 0.6 1.2 1.8 2.4 Miles

0 0.8 1.6 2.4 3.2 Kilometers

Scale 1:70,000

Alaska State Plane Zone 5 (units US feet)
1983 North American Datum

File: Marine_02_V01.mxd	Date: April 9, 2009
Version: 1, Rev.	Author: BEESC-ME / EVW

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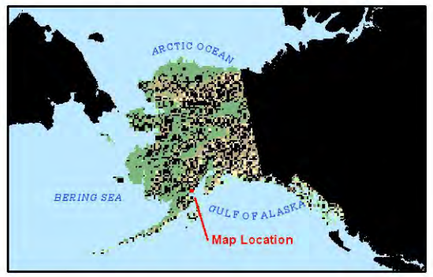
Figure 12.2-3
Consolidated Study Program, 2004-2008
Marine Nearshore Resources
Locations for Marine Benthos and Fish Sampling
Cook Inlet

Legend

Marine Benthos and Nearshore Fish Sampling Locations

- 120-ft Beach Seine
- Intertidal Quadrat
- Trawl

Note: Shoreline may be inaccurate based on tidal variation.



Miles
0 0.5 1 1.5 2 2.5

Kilometers
0 0.9 1.8 2.7

Scale 1:60,000

N

Contour Interval 100 ft
Alaska State Plane Zone 5 (units feet)
1983 North American Datum

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Version: 5	Author: RDI-LS

Pebble Project
Environmental Baseline Studies
2004 through 2008

CONSOLIDATED STUDY PROGRAM

13. SUBSISTENCE AND TRADITIONAL KNOWLEDGE

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Table 13-2, Study Communities Initially Identified in 2004

LIST OF FIGURES (following tables)

Figure 13-1, Consolidated Study Program, 2004-2008, Subsistence and Traditional Knowledge Study Areas, Communities and Schedule

ACRONYMS

ADF&G	Alaska Department of Fish and Game
NEPA	National Environmental Policy Act
SRB&A	Stephen R. Braund & Associates

13. SUBSISTENCE AND TRADITIONAL KNOWLEDGE

Stephen R. Braund & Associates (SRB&A) is the lead consultant for the subsistence and traditional knowledge portion of the Pebble Project environmental baseline studies. The Alaska Department of Fish and Game (ADF&G), Division of Subsistence, is collaborating with SRB&A, by conducting and providing results from systematic household surveys in communities within the Pebble Project area, and by updating information about subsistence hunting, fishing, and gathering that has been collected during previous rounds of ADF&G household surveys.

13.1 Objectives of Study

The objectives of the subsistence and traditional knowledge study are as follows:

- Gather data to document baseline conditions and current use of the study area and adjacent land areas for subsistence living.
- Provide information on subsistence use and traditional knowledge relevant to other discipline studies.

13.2 Proposed Study

13.2.1 Study Area

The study area for the subsistence and traditional knowledge study encompasses all communities whose residents use the area around the Pebble Project for the harvest of subsistence resources or who harvest resources that migrate through or use this area. The communities potentially included are in the Lake Clark and Iliamna Lake region; down river from the Pebble Deposit in the drainages for the Koktuli, Mulchatna, and Nushagak rivers; down river from the deposit in the Kvichak River drainage; and on the Kenai Peninsula that may use the Iniskin and/or Iliamna bay areas (Cook Inlet study area) (Figure 13-1).

13.2.2 Study Scope

The scope of the study is to document historical and existing subsistence use by communities located in the study area. Use is documented through a process of household surveys, individual interviews, and mapping. All communities in the study area are the subject of both ADF&G Division of Subsistence household surveys and SRB&A subsistence interviews and mapping. The only difference between communities is in the scheduling of the work (i.e., field work in some communities in 2005 and in other communities in 2006 or later), as described in detail in the major tasks and activities for each year (Section 13.2.4).

13.2.3 Methods/Approach

The methods for the subsistence and traditional knowledge baseline study include conducting literature searches and field studies, followed by data compilation and analysis, mapping, and document preparation. The approach described herein has been proposed to ensure that the data for characterizing subsistence and traditional knowledge is comprehensive and that the methods are consistent with the expectations of state and federal agencies.

Spatial data on subsistence use exists for the Pebble Project study area. It is based on research conducted in the early 1980s (e.g., research conducted by ADF&G for habitat management purposes). SRB&A investigators are building on that research by conducting subsistence/traditional knowledge interviews to identify and map contemporary (last 10 years) subsistence-use areas in the vicinity of the Pebble Project. In addition, a method to distinguish subsistence areas used more intensely than other areas has been developed and implemented.

SRB&A investigators are focusing on two groups for interviews and mapping on subsistence and traditional knowledge: 1) retired hunters/elders who historically used the study area and 2) hunters who currently (last 10 years) go to the study area. SRB&A investigators do not necessarily interview every hunter who has historically used or who currently goes to the study area. Moreover, their interviews are not a formal questionnaire-style survey based on a probability sample; rather, a liaison person, working with the community, city, and/or tribal governments, selects key knowledgeable individuals to be interviewed.

At the same time, ADF&G Division of Subsistence investigators are conducting systematic household surveys in communities to provide baseline information about subsistence hunting, fishing, and gathering. The format is compatible with information collected in previous rounds of ADF&G household surveys. During the household surveys, ADF&G investigators also gather information on the location of hunting and resource-harvest areas.

Information related to where harvests occur is especially important, and the subsistence/traditional knowledge study program incorporates harvest-location information. It is assembled from the ADF&G harvest-amount data collected during household surveys. ADF&G investigators work closely with the SRB&A team to coordinate the collection of this information when SRB&A investigators are conducting their interviews in the five communities closest to the deposit. For the communities in the Bristol Bay area, ADF&G investigators have not historically collected harvest-location data.

The research parameters include subsistence harvest amounts, harvest locations, harvest-use areas, distribution and sharing of resources, and traditional knowledge. The traditional-knowledge portions of the interviews address subsistence cabins and campsites, changes in key habitat areas, changes in resource abundance, distribution and abnormalities, and the location of winter trails/transportation routes.

For communities closest to the Pebble Deposit, most of the information is dated; the ADF&G Division of Subsistence has subsistence-harvest information for Nondalton (1973, 1980, 1981, 1983), Newhalen (1983 and 1991), Iliamna (1983 and 1991), Kokhanok (1983 and 1992), Port Alsworth (1983), and Pedro Bay (1982 and 1996 [unpublished]). Because of the age of the information, it likely does not reflect current subsistence uses. It is accepted, however, that the residents of these communities currently rely on subsistence hunting, fishing and gathering, for nutrition and to support their way of life. They use a

variety of resources, including salmon and other fish, large land mammals (e.g., caribou, moose, bear, and sheep), small game and furbearers, birds, and wild plants. Four processes are being used to update and provide the best available subsistence information for the study area:

- First, SRB&A investigators are conducting extensive subsistence mapping interviews in all potentially affected communities, as described above.
- Second, ADF&G Division of Subsistence investigators are undertaking ongoing household surveys of subsistence and traditional knowledge in the Lake Clark/Iliamna Lake region. This research is being added as baseline data for the subsistence/traditional knowledge study.
- Third, the ADF&G Division of Subsistence has a cooperative agreement with the National Park Service to systematically survey households about subsistence hunting, fishing, and gathering in Nondalton and Port Alsworth. That work is also ongoing.
- And fourth, the ADF&G investigators, in collaboration with the Pebble Partnership team and members of the study communities, are conducting similar household surveys for the Pebble Project in the Bristol Bay communities.

The ADF&G data-collection methods are identical in all communities. ADF&G investigators train local research assistants in each community to administer their systematic household surveys. The goal is to interview a representative of each year-round household in each community. Participation is voluntary and all individual and household responses are confidential. ADF&G provides the study findings for all communities to the Pebble Partnership project team to be incorporated into the Pebble Partnership subsistence baseline report.

Research occurs according to an integrated schedule, as described in Section 13.2.4 and illustrated in the figures for this consolidated study program. The success, timing, and length of time in the field for the subsistence and traditional-knowledge work depend on the availability and willingness of local residents to participate in the interviews. To facilitate high participation, field trips are planned during periods when subsistence and commercial harvest activities are not intense. In the study program and schedules proposed and described in this document, SRB&A investigators have assumed there are no participation difficulties.

Similarly, ADF&G Division of Subsistence investigators schedule their household surveys for late winter (i.e., January through March). Investigators explored conducting their research earlier (i.e., October and November), but doing so presented the difficulty of inconsistent study years. For example, the historical ADF&G data and the data collected for the Pebble Partnership are based on a January to December calendar year. Conducting the ADF&G household surveys in October or November creates a problem for defining the 12-month harvest-recall period, making it difficult to compare the data sets. Conducting the surveys in January through March allows for an annual harvest recall of the previous calendar year from January through December, which is consistent with both historical ADF&G subsistence data collected in Bristol Bay and the data collected for the Pebble Partnership.

13.2.4 Major Tasks/Activities

Major tasks and activities completed to document subsistence uses/traditional knowledge in the study area are described in the following sections, according to year of work. The work is summarized in Table 13-1.

13.2.4.1 Tasks and Activities for 2004

The primary task for 2004 was to identify the communities whose subsistence activities or resources occur within the Pebble Project area. Communities were "tiered" in 2004 (see Figure 13-1 and Table 13-2) based on their proximity and use of the Pebble Project area. This "tiered" approach also considered current and proposed research to be conducted by the ADF&G Division of Subsistence, and thus the following typology is not simply a potential-effects classification.

- **Tier One** communities (Nondalton, Port Alsworth, Iliamna, Newhalen, and Pedro Bay) have subsistence use areas most likely to overlap with the study area.
- **Tier Two** communities (Kokhanok, Igiugig, Levelock, Ekwok, New Stuyahok, and Koliganek) are further removed from the study area. However, some of these communities (e.g., Kokhanok and Igiugig) are known to use the area north of Iliamna Lake in the study area for subsistence purposes. Pile Bay, although also in the Tier Two area, is primarily a camp with caretaker; therefore, it was not included as a subsistence/traditional knowledge interview community.
- **Tier Three** communities (Ninilchik, Seldovia, Homer, and residents of the west side of Cook Inlet in the vicinity of Chinitna Bay) may or may not use the Cook Inlet study area (near Williamsport). However, there is evidence of historical linkages of these communities to this area.
- **Tier Four** communities (Dillingham, Portage Creek, Naknek, South Naknek, and King Salmon) are down river from the Pebble Deposit. However, several factors are considered as reasons for not undertaking field research in these communities early in the project. Foremost, all of these communities are a considerable distance from the Pebble Deposit, and residents likely do not travel as far as the deposit area during their customary subsistence activities. King Salmon, Naknek, and South Naknek subsistence use areas are generally south of Lake Iliamna. Moreover, Dillingham is more a small town than a village (i.e., Dillingham's population in 2000 was 2,466 persons in 888 households) and as such would require a separate sampling plan and a significant research effort not contemplated in 2004.

Participation of the Tier One and Tier Two communities was identified in 2004 as high priority for the subsistence and traditional knowledge study.

ADF&G Division of Subsistence, in association with the National Park Service, was planning to conduct household surveys in the Tier One communities of Nondalton and Port Alsworth in 2004. Therefore, as part of the 2004 study for the Pebble Project, it was proposed that the ADF&G Division of Subsistence add similar surveys in Iliamna, Newhalen, and Pedro Bay (collectively, the five villages represent the Tier One group of communities). A goal of the work was to collect baseline information about subsistence hunting, fishing, and gathering that was compatible with information collected in previous rounds of ADF&G household interviews. A second goal was to collect information on the location of hunting and harvests of moose and caribou.

The study team proposed that ADF&G Division of Subsistence not conduct household surveys in the six Tier Two communities (Kokhanok, Igiugig, Levelock, Ekwok, New Stuyahok, and Koliganek). The subsistence range of these communities was not definitively known in 2004; therefore, the Pebble Partnership team proposed to first conduct subsistence interviews in these communities to determine the

current extent and any possible overlap of subsistence uses with the study area, before ADF&G investigators did their household surveys. In addition, the Pebble Partnership research team also proposed subsistence mapping interviews in the five Tier One communities. The work would identify current (last 10 years) subsistence use areas near or within the Pebble Project area, including distinguishing those areas used more intensely than other areas.

Additional tasks and activities to support the subsistence and traditional use study in 2004 included the following:

- Preparing planning meetings and work plans. This task included preliminary project meetings, communicating with the Pebble Partnership for project information and clarification, formulating preliminary research designs, proposing work plans, reviewing proposed work plans with the Pebble Partnership, and revising work plans.
- Reviewing published and unpublished literature. A literature review of existing sources of subsistence and traditional knowledge relevant to the study area was conducted to identify and review the scope of any ongoing subsistence or traditional knowledge programs in the study area.
- Reviewing and compiling existing harvest data and subsistence use areas by community.
- Identifying data gaps.
- Preparing preliminary field protocols.
- Initiating contact and coordinating with appropriate community organizations (e.g., traditional councils) for selecting interviewees, finding suitable space to conduct the subsistence mapping interviews, determining honoraria amounts, and obtaining translation (if necessary). Because community participation and identification with the project is critical for success, a protocol respectful to each community that incorporated sensitivity to community schedules, expectations, and desires was developed.

No field work was conducted in 2004.

13.2.4.2 Tasks and Activities for 2005

The main tasks and activities for 2005 were to conduct the field work planned in 2004, including household surveys and traditional knowledge interviews at the Tier One and Tier Two communities identified in 2004 for participation in the subsistence and traditional use study.

The communities associated with each tier of study were slightly adjusted and the number of tier areas was increased from four to five. The tasks and activities were as follows:

- Portage Creek was included in the Tier Two area.
- The number of Tier Four communities was reduced to three: Naknek, South Naknek, and King Salmon.
- The community of Dillingham on Nushagak Bay (formerly a Tier Four community), was included in a revised Tier Three area with the neighboring communities of Clark's Point, Ekuk, Aleknagik, and Manokotak. Both Aleknagik and Manokotak residents use Nushagak Bay and had expressed an interest in being included in the environmental baseline study.

- The former Tier Three area was reassigned as Tier Five.

The Tier One group of communities remained the same.

Therefore in 2005, ADF&G household surveys and SRB&A subsistence mapping interviews were planned in five communities (Nondalton, Newhalen, Iliamna, Pedro Bay, Port Alsworth—all Tier One communities as shown on Figure 13-1). SRB&A investigators also planned to begin their subsistence mapping interviews in the seven Tier 2 communities (Kokhanok, Igiugig, Levelock, Ekwok, New Stuyahok, and Koliganek) and in Portage Creek (originally a Tier Four community in 2004, but now identified as a Tier Two community [see Figure 13-1]).

Additional tasks and activities for 2005 included the following:

- Preparing planning meetings and work plans. This task included project meetings, communicating with the Pebble Partnership for project information and clarification, formulating research designs, and preparing and revising work plans.
- Reviewing published and unpublished literature. A 2004 literature review of existing sources of subsistence and traditional knowledge relevant to the study area was continued to identify and review the scope of any ongoing subsistence or traditional-knowledge programs in the study area.
- Reviewing and compiling existing harvest data and subsistence-use areas by community.
- Identifying data gaps.
- Preparing field protocols.
- Continuing contact and coordination with appropriate community organizations (e.g., traditional councils) for selecting interviewees, finding suitable space to conduct the interviews, determining honoraria amounts, and obtaining translation (if necessary). The protocol respectful to each community developed in 2004 was updated and followed to ensure sensitivity to community schedules, expectations, and desires.
- Conducting at least one visit to each community by two persons to conduct the household surveys and subsistence/traditional-knowledge interviews.
- Ensuring that field work was conducted during a period that did not interfere with harvests/commercial fishing. Community interviews were conditional on council approval and community schedules.
- Compiling, editing, and performing quality-control review of field data and processing/analyzing field data.
- Drafting a preliminary environmental baseline report to accommodate field data.

During this process, the study team coordinated with ADF&G investigators to avoid duplication and ensure that the highest quality report could be prepared.

13.2.4.3 Tasks and Activities for 2006

The work for 2006 continued the research in 2004 and 2005 with some minor adjustments:

- Portage Creek was confirmed and Lime Village was included in the Tier Two area, reflecting the 2005 interviews conducted for Portage Creek and a desire by Lime Village to be included in the study.
- The Tier Five area was expanded to include the community of Tyonek at the north end of Cook Inlet.

The Tier One, Three, and Four groups of communities remained the same.

By 2006, ADF&G investigators had conducted household surveys in all five communities in the Tier One area. ADF&G investigators planned to conduct new surveys in seven of the nine communities in the Tier Two area: Kokhanok, Igiugig, Levelock, Ekwok, New Stuyahok, Koliganek, and Portage Creek. The data from these seven communities would be analyzed to produce an interim report.

SRB&A investigators continued with their subsistence mapping and traditional-knowledge interviews in the Tier One and Two communities: Nondalton, Newhalen, Iliamna, Pedro Bay, Port Alsworth, Kokhanok, Igiugig, Levelock, Ekwok, New Stuyahok, Koliganek, and Portage Creek. SRB&A also worked with the communities to determine whether additional interviews would be necessary.

SRB&A subsistence mapping interviews and additional ADF&G household surveys that were also planned to occur in 2006 or possibly later included the following:

- The revised Tier Three area communities of Dillingham, Clark's Point, Ekuk, Aleknagik, and Manokotak. The reasons for including these communities and the scope of work undertaken for each varied. Although Clark's Point is a relatively small village, Dillingham is more a small town than a village and as such required a more significant effort. Ekuk had very few permanent residents and would be addressed to the extent people reside there. Although not immediately located on Nushagak Bay, the residents of both Aleknagik and Manokotak use Nushagak Bay and therefore expressed an interest in being included in the environmental baseline study.
- The Bristol Bay Borough communities of Naknek, South Naknek, and King Salmon (in the Tier Four area). There were approximately 489 households in these three communities.

Telephone interviews were also proposed for the Kenai Peninsula communities of Ninilchik, Seldovia, and Homer and residents of the west side of Cook Inlet in the vicinity of Chinitna. Telephone interviews were proposed with selected residents in these areas as an exploratory method to gain information on the extent of contemporary subsistence uses, if any, in the vicinity of the Cook Inlet study area. A preliminary list of names for telephone interviews was developed.

13.2.4.4 Tasks and Activities for 2007

The work for 2007 continued the research described for previous years with some minor revisions, including the inclusion of Lime Village in the ADF&G household surveys and the SRB&A subsistence

mapping and traditional knowledge research. The communities and schedule for research are shown on Figure 13-1.

By the spring of 2007, ADF&G Division of Subsistence investigators had completed household surveys in the five Tier One communities (i.e., Nondalton, Newhalen, Iliamna, Pedro Bay, and Port Alsworth), produced a draft report for review, and was completing the final report for these five communities. ADF&G investigators had also completed household surveys in five (Kokhanok, Igiugig, Levelock, New Stuyahok, and Koliganek) of the nine Tier Two area communities, and was preparing a draft report. The SRB&A team was preparing the ADF&G maps for these communities.

Although planned in 2006, household surveys had not been conducted in two of the Tier Two area communities: Ekwok and Portage Creek. The Ekwok community leadership declined to participate, and it was understood that Portage Creek had no permanent households residing there.

Other work planned for 2007 included the following:

- Preparing a draft report for the five Tier Two communities surveyed in early 2007 by ADF&G Division of Subsistence and of the associated ADF&G maps by SRB&A.
- Attempting for the second time to conduct a household survey in Ekwok by ADF&G Division of Subsistence.
- Assessing the possibility of conducting its survey in Portage Creek by ADF&G Division of Subsistence, because agency comments indicated that more than one household resided in the community.
- Initiating household surveys in Manokotak (Tier Three), Lime Village (included into Tier Two), and the three Tier Four communities of Naknek, South Naknek, and King Salmon by ADF&G Division of Subsistence investigators, with assistance from SRB&A investigators.
- Conducting subsistence mapping and traditional-knowledge interviews in the five Tier One communities (i.e., Nondalton, Newhalen, Iliamna, Pedro Bay, and Port Alsworth) and seven of the nine Tier Two communities (Kokhanok, Igiugig, Levelock, Ekwok, New Stuyahok, Koliganek, and Portage Creek) by SRB&A investigators.
- Editing and conducting quality control measures for the field data, processing the field data, and digitizing the mapped information.
- Analyzing and compiling these data, developing data summaries and tables, and preparing maps and a draft environmental baseline report.
- Initiating subsistence and traditional knowledge interviews by SRB&A in three of the five Tier Three area villages (Manokotak, Clark's Point, and Aleknagik) and in Lime Village (Tier Two). This task included compiling, editing, and performing quality control for the field data, digitizing mapped information, processing and analyzing the data, and developing data summaries.

13.2.4.5 Tasks and Activities for 2008

The proposed work for 2008 is the continuation of work in 2005, 2006, and 2007, with some minor revisions. The communities and schedule for research are shown in Figure 13-1.

Any remaining subsistence mapping and traditional knowledge interviews will be completed in the following 12 communities: Nondalton, Newhalen, Iliamna, Pedro Bay, Port Alsworth, Kokhanok, Igiugig, Levelock, Ekwok, New Stuyahok, Koliganek, and Portage Creek.

The following work planned for 2007 will be completed in 2008.

- ADF&G Division of Subsistence, with assistance from SRB&A, will initiate household surveys in six communities (Manokotak, Lime Village, Naknek, Portage Creek, South Naknek, and King Salmon).
- SRB&A will initiate subsistence and traditional knowledge interviews in Naknek, South Naknek, King Salmon, and Lime Village.

SRB&A will continue to edit and perform quality control for the field data, process field data, digitize mapped information, analyze data, compile data, and develop data summaries.

TABLES

TABLE 13-1
Pebble Project Environmental Baseline Studies
Study Summary for Subsistence and Traditional Knowledge, 2004-2008
Consultant: Stephen R. Braund & Associates

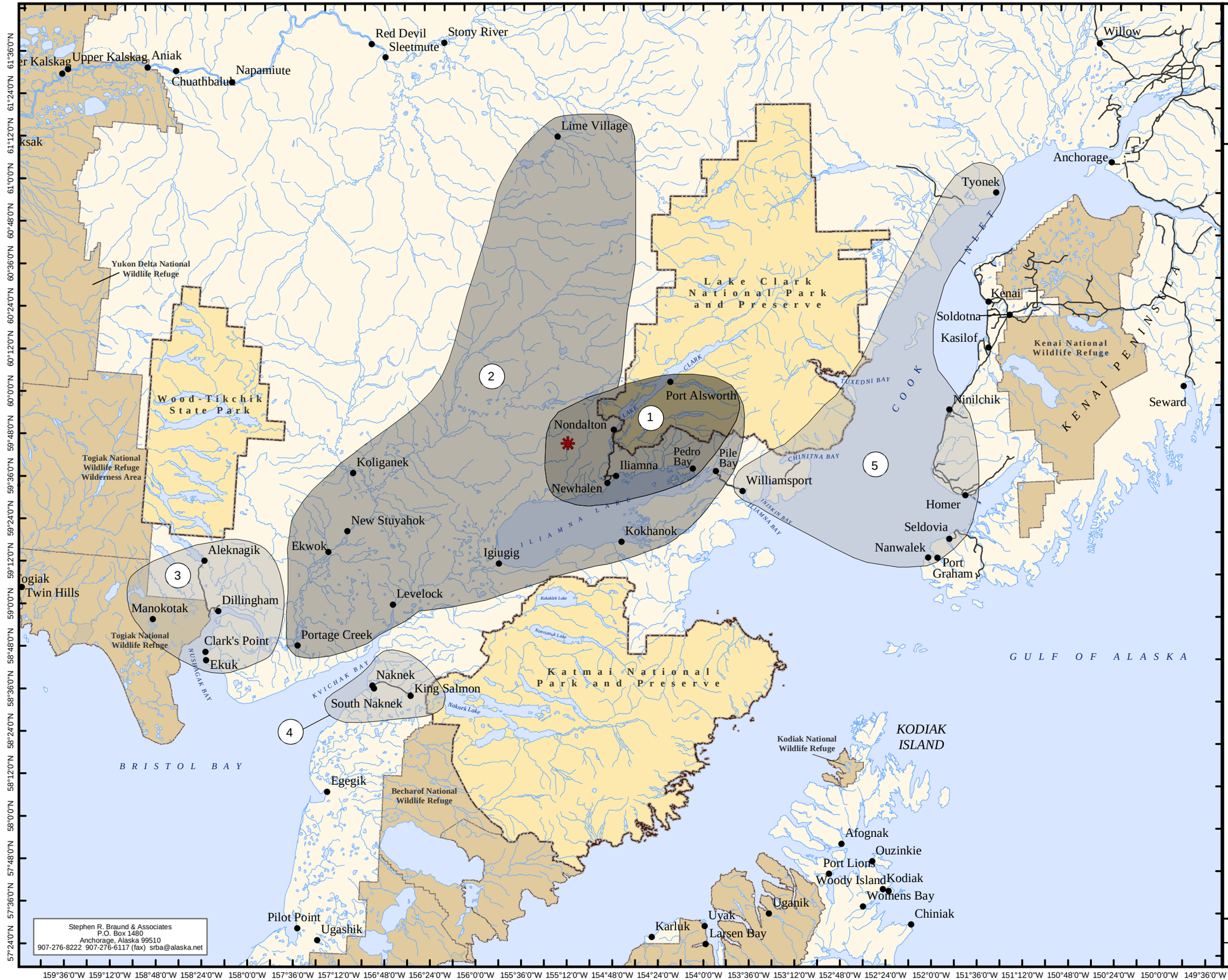
2004 Data Collected or Tasks	2005 Data Collected or Tasks	2006 Data Collected or Tasks	2007 Data Collected or Tasks	2008 Activities
Lit review & background information gathering	Lit review & background information gathering	Continue Literature review	Continue Literature review	Continue Literature review
Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan
2004 Study Plan	2005 Study Plan	2006 Study Plan Summary	2007 Study Plan Summary	2008 Study Plan Summary
Ekwok NMWC Presentation Oct 2004				
Initiate community contacts	Continue community contacts	Continue community contacts	Continue community contacts	Continue community contacts
	ADF&G conduct household survey - 5 communities - Round 1 (Nondalton, Newhalen, Iliamna, Pedro Bay, Port Alsworth)			
		ADF&G household survey - 7 communities (Kokhanok, Igiugig, Levelock, Ekwok, New Stuyahok, Koliganek, and Portage Creek). ADF&G only completed 5 (less Ekwok & Portage Creek)	ADF&G household survey - retry Ekwok; reconsider Portage Creek	ADF&G household survey - retry Ekwok; reconsider Portage Creek
	SRB&A subsistence mapping/TK interviews begun in 12 communities (Nondalton, Newhalen, Iliamna, Pedro Bay, Port Alsworth, Kokhanok, Igiugig, Levelock, Ekwok, New Stuyahok, Koliganek, and Portage Creek). Round 2	SRB&A subsistence mapping/TK interviews; return trips to where not done & return to those communities (of 12) that request additional interviews (Nondalton, Newhalen, Iliamna, Pedro Bay, Port Alsworth, Kokhanok, Igiugig, Levelock, Ekwok, New Stuyahok, Koliganek, and Portage Creek). Round 2	SRB&A subsistence mapping/TK interviews; return trips to where not done & return to those communities (of 12) that request additional interviews (Nondalton, Newhalen, Iliamna, Pedro Bay, Port Alsworth, Kokhanok, Igiugig, Levelock, Ekwok, New Stuyahok, Koliganek, and Portage Creek). Round 2	
		SRB&A add Lime Village mapping/TK Interviews	SRB&A add Lime Village mapping/TK Interviews	SRB&A add Lime Village mapping/TK Interviews
	ADF&G data entry & analysis - 5 communities. Round 1	ADF&G data analysis - 5 communities (Round 1)		
	SRB&A map preparation of ADF&G data - 5 communities. Round 1	SRB&A map edits of ADF&G data - 5 comm. (Round 1)		
	ADF&G report preparation - 5 communities. Round 1	ADF&G submited draft report to SRB&A - 5 communities (Round 1). ADF&G completed community review. Completing final report. Anticipate final Dec 06.		
		ADF&G Data Analysis - 7 Round 2 communities (less Ekwok & Portage Creek)	ADF&G Data Analysis - 7 Round II communities (less Ekwok & Portage Creek)	
		SRB&A map preparation of ADF&G data - 7 comm. (less Ekwok & Portage Creek). Round 2	SRB&A map preparation of ADF&G data - 7 comm. (less Ekwok & Portage Creek)	
		ADF&G report preparation - 7 communities (less Ekwok & Portage Creek) Round 2	ADF&G report preparation - 7 communities (less Ekwok & Portage Creek)	
	SRB&A post field editing & processing field data & notes, compile and analyze data - 12 communities	SRB&A post field editing & processing field data/notes, compile and analyze data - 12 communities	SRB&A post field editing & processing field data/notes, compile and analyze data - 12 communities	
	SRB&A digitize mapping data-12 communities	SRB&A digitize mapping data-12 communities	SRB&A digitize mapping data-12 communities	
	SRB&A QC	SRB&A QC	SRB&A QC	
				Complete any remaining analysis & EBD report writing related to subsistence and TK for 12 communities (Nondalton, Newhalen, Iliamna, Pedro Bay, Port Alsworth, Kokhanok, Igiugig, Levelock, Ekwok, New Stuyahok, Koliganek, and Portage Creek)
				Community Reviews in 12 communities
				Revise community reports after community reviews
		Data entry/analysis Lime Village-did not do in 2006	Data entry/analysis Lime Village	Data entry/analysis Lime Village. Did not do in 2007
			ADF&G household survey - 5 communities (Manokotak, Lime Village, Naknek, South Naknek, King Salmon). Round 3	ADF&G household survey - 5 communities (Manokotak, Lime Village, Naknek, South Naknek, King Salmon). Round 3

2004 Data Collected or Tasks	2005 Data Collected or Tasks	2006 Data Collected or Tasks	2007 Data Collected or Tasks	2008 Activities
			ADF&G Data Analysis - Round 3	ADF&G Data Analysis - Round 3
			SRB&A map preparation of ADF&G data - Round 3	SRB&A map preparation of ADF&G data - Round 3
			ADF&G Report Preparation - Round 3	ADF&G Report Preparation - Round 3
			SRB&A subsistence/TK interviews in four communities (Manokotak, Lime Village, Clark's Point, & Aleknagik)	SRB&A subsistence/TK interviews in four communities (Naknek, South Naknek, King Salmon and Lime Village)
			SRB&A post field editing & processing field data/notes, compile and analyze data, QC - 4 communities	SRB&A post field editing & processing field data/notes, compile and analyze data, QC - 4 communities
			SRB&A digitize mapping data -4 communities	SRB&A digitize mapping data -4 communities
			Interviews in Cook Inlet communities	Interviews in Cook Inlet communities
			Place Name Inventory	Continue Place Name Inventory & seek place names from NPS
	Communication and Data Management	Communication and Data Management	Communication and Data Management	Communication and Data Management
	Data Analysis	Data Analysis	Data Analysis	Data Analysis
	Feasibility Report-Subsistence (9/13/05)			
				SRB&A prepare draft reports- 4 communities
				SRB&A review 4 community reports with community
				Revise community reports after community reviews
Agency Presentation Oct 2004	Agency Presentation Nov 2005	Agency Presentation Nov/Dec 2006	Agency Presentation 2007	Agency Presentation 2008
		Research & Develop Place Names database/map	Research & Develop Place Names database/map	
Coordination with NDM & Agencies	Coordination with NDM & Agencies	Coordination with NDM, agency meetings, and monthly reporting	Coordination with NDM, agency meetings, and monthly reporting	Coordination with PLP, agency meetings, and monthly reporting
	Draft Environmental Baseline Document	Preliminary Environmental Baseline Document	Preliminary Environmental Baseline Document	Preliminary Environmental Baseline Document
			SRB&A incorporate ADF&G findings into SRB&A EBD	SRB&A incorporate ADF&G findings into SRB&A EBD

TABLE 13-2
Study Communities Initially Identified in 2004

Tier 1:		**Tier 3:**	
1	Iliamna	12	Ninilchik
2	Newhalen	13	Homer
3	Nondalton	14	Seldovia
4	Pedro Bay	15	Chinitna Bay (Williamsport)
5	Port Alsworth		
Tier 2:		**Tier 4:**	
6	Kokhanok	16	Portage Creek
7	Igiugig	17	Naknek
8	Koliganek	18	South Naknek
9	New Stuyahok	19	King Salmon
10	Ekwok	20	Dillingham
11	Levelock		
-	Pile Bay - camp with caretaker		

FIGURES



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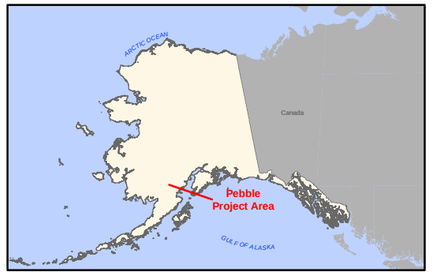
THE pebble PARTNERSHIP

Figure 13-1
Consolidated Study Program, 2004-2008
Subsistence and Traditional Knowledge
Study Areas, Communities and Schedule

- Communities
- General Deposit Location
- Roads
- Rivers

1. SRB&A Subsistence Mapping Interviews and ADF&G HH Survey 2005-2006 - 5 Communities
2. SRB&A Subsistence Mapping Interviews 2005-2006 (except Pile Bay and Lime Village) - 7 Communities and ADF&G HH Survey 2006-2007 (except Ekwok, Lime Village, Pile Bay and Portage Creek) - 5 Communities
3. SRB&A Subsistence Mapping Interviews and ADF&G HH Surveys 2009 or later - 5 Communities
4. SRB&A Subsistence Mapping Interviews and ADF&G HH Survey (plus Lime Village) - 4 Communities 2008
5. Telephone Interviews 2009 or later, except Tyonek



0 100,000 200,000 300,000 400,000 Feet
0 29,000 58,000 87,000 116,000 Meters
Scale 1:2,000,000

N

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: Fig13-1-Sub_Schedule_May08	**Date: June 6, 2008**
Version: 1	**Author: SRB&A**

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Pebble Project
Environmental Baseline Studies
2004 through 2008

CONSOLIDATED STUDY PROGRAM

14. CULTURAL RESOURCES

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Figure 14-4, Consolidated Study Program, 2004-2008, Cultural Resources Survey in the Mine Study Area (2004-2008)

ACRONYMS

AHRS	Alaska Heritage Resource Survey
APE	area of potential effect
NHPA	National Historic Preservation Act
NRHP	National Register of Historic Places
OHA	Office of History and Archaeology, Department of Natural Resources
SHPO	State Historic Preservation Officer
SRB&A	Stephen R. Braund & Associates

14. CULTURAL RESOURCES

Stephen R. Braund & Associates (SRB&A) is leading the cultural resources component of the Pebble Project environmental baseline studies. The objectives and methods/approach for the study, as described throughout this consolidated study program, apply equally to all study areas, except as noted.

Table 14-1 summarizes the study program for the cultural resources studies from 2004 through 2008.

14.1 Objectives of Study

The objectives of the cultural resources study are as follows:

- Identify and document the potential presence of cultural resources in the study area.
- Provide information to other environmental consultants to facilitate their studies.

14.2 Proposed Study Program

14.2.1 Study Area/Scope

The study area for cultural resources is based on the definition of area of potential effect (APE) set forth in the Code of Federal Regulations, Title 36 (36 CFR, Sec. 800.16[d]). An APE is defined as the "geographic area or areas within which an undertaking may directly or indirectly cause alterations in the character or use of historic properties, if any such properties exist."

The study area is divided into two segments, consisting of two sets of potential "undertakings." The first segment is located at and near to the deposit area. The second study area is the transportation corridor/Cook Inlet study areas. The specific boundaries in these locations have not been completely delineated, but currently include a general transportation corridor from the Newhalen River crossing to Iliamna and Iniskin Bays.

The scope of work is to locate, identify, delineate, and inventory the archaeological, historical, ethnographic, and traditional cultural properties in these two study area segments. Any properties located are being assessed for their eligibility for inclusion on the National Register of Historic Places (NRHP) and the Alaska Heritage Resource Survey (AHRS).

Cultural resources may include historic structures and landscapes, prehistoric and historic archaeological sites, and traditional- and religious-use areas.

14.2.2 Methods/Approach

The approach to identifying and assessing the potential effects of the Pebble Project on these resources relies on methods outlined in the following:

- Section 106 of the National Historic Preservation Act (NHPA; U.S. Congress, 1966).
- The NHPA's implementing regulations by the Advisory Council on Historic Preservation (36 CFR, 2005).
- The Alaska Historic Preservation Act (State of Alaska, n.d.).
- *Archeology and Historic Preservation: Secretary of Interior's Standards and Guidelines* (as amended and annotated; U.S. Department of Interior, 1983).

Other relevant legislation applicable to cultural resources includes, but is not limited to, the following:

- The Antiquities Act of 1906 (U.S. Congress, 1906).
- The Archaeological Resources Protection Act of 1979 (U.S. Congress, 1979).
- The Native American Graves Protection and Repatriation Act (U.S. Congress, 1990).

The work includes background preparation and review, followed by ground surveys conducted in stages in each segment of the study area. If located in the field and identified, the extent of each cultural resource is determined and delineated where practical. As investigations at each stage of the study are completed, discovered sites are inventoried and recorded. The sites are then documented and their eligibility for the AHRS and the NRHP is assessed.

The work is implemented according to a tasked approach, described in detail as follows.

14.2.2.1 Task 1: Background Preparation – Planning Meetings and Work Plan

This task includes general project management, such as project meetings and other communication with the Pebble Partnership team for additional project information and clarification, formulation of research designs, and preparation, review, and revision of work plans.

14.2.2.2 Task 2: Literature Review

Historic, ethnographic, and archaeological accounts of the region are reviewed to document prehistoric, historic, and recent cultural uses of the study areas. It is understood that historic and ethnographic accounts may give indications of land use through time in the study areas and could include locations and descriptions of potentially important historic and prehistoric cultural sites and landscapes. It is also understood that consulting the AHRS database and reviewing the archaeological literature on file at the Department of Natural Resources, Office of History and Archaeology (OHA), may provide specific information on previous archaeological research in the area. In addition, aerial and satellite photographs are examined to determine the location of any visible surface features such as structures, caribou drive lines, corrals, and house and cache pits.

These data are critically reviewed and compiled into an historic and ethnographic narrative describing the human presence in the area and into an inventory of archaeological, ethnographic, and historical sites located within and near to the Pebble Project area. This preliminary compilation is used to define subsequent field research strategies. This preliminary document also forms the basis for the final environmental baseline and Section 106 report, which will include the results of the field survey and site

nomination forms for cultural resources in the study area that are determined to be eligible for listing on the National Register.

14.2.2.3 Task 3: Consult with Agencies

Before and during field research, the research team consults on behalf of the Pebble Partnership with relevant state, federal, and tribal entities. These discussions are initiated with the State Historic Preservation Officer (SHPO). The SHPO issues field archaeology permits and manages the database of known cultural resource sites for the State of Alaska, and therefore is the first contact for many federal cultural resource issues depending on a variety of potential factors, including land ownership, funding, surface and subsurface estate, and trust relationships with Tribal entities.

14.2.2.4 Task 4: Field Work—Mine Study Area

The Pebble Deposit area and proximate drainages were surveyed. Survey coverage for this area was intensive, including a systematic pedestrian survey using multiple surveyors walking transects—thus covering most of the area—and frequent subsurface testing in high-probability areas. During their surveys, the study team examines the terrain for surface irregularities and vegetation changes that would indicate the presence of buried cultural remains. Surface features, such as depressions that may represent a former house pit or berms that may indicate the presence of a former habitation wall, all provide surface indications of potential archaeological resources. Erosional and other subsurface exposures are examined for the presence of archaeological materials. Additional test pits may be excavated where there are indications of soil accumulation or possible cultural deposits. Field crews identify areas of high archaeological potential for careful examination. For example, elevated terrain, ridge lines, rock formations and grottoes, benches, relict shorelines of lakes and streams, stream crossings, and areas close to fresh water sources are carefully surveyed, whereas boggy, low-lying areas receive somewhat less attention.

14.2.2.5 Task 5: Field Work—Transportation Corridor/Cook Inlet Study Areas

Subsurface testing is performed at key locations along the transportation corridor/Cook Inlet study areas. Locations along Cook Inlet are the highest probability areas of all project segments for cultural deposits and historic resources.

14.2.2.6 Task 6: Assessment of Information

Following field work and processing of field and published data, the study team completes an annual report of their field observations, which is presented to SHPO and staff with the Advisory Council on Historic Preservation. This task is somewhat iterative with Tasks 2 and Task 4, because a preliminary assessment of cultural resources was required for cultural clearances in areas of exploration activities.

14.3 Major Tasks/Activities

14.3.1 Tasks and Activities for 2004

The tasks and activities for the cultural resources study in 2004 consisted primarily of planning and preliminary field work, as follows:

- Project meetings, communication with the Pebble Partnership for project information and clarification, formulating research designs, and preparing and revising work plans.
- Reviewing published and unpublished literature and the AHRS files maintained by the OHA.
- Consulting with interested state and federal agencies, Native organizations, and other parties.
- Field surveys and testing.

The field work commenced in June 2004. It was planned to intensively survey the mountain valley that contains the Pebble Deposit and surrounding areas. Intensive survey coverage was completed in these areas during the summer, including systematic pedestrian surveys and subsurface testing in high-probability areas. A pedestrian survey was also planned from the deposit area through the transportation corridor study area to the Newhalen River. This work was not completed in 2004.

14.3.2 Tasks and Activities for 2005

The tasks and activities for 2005 were similar to those conducted in 2004, except for minor modifications to the field survey task. The 2005 field season in the west segment of the study area included the unsurveyed (in 2004) portions of the mine study area.

The 2005 field season in the east segment of the study area included the Cook Inlet portion of the transportation corridor/Cook Inlet study areas. Surveys conducted in the Cook Inlet portion of the study area during the summer of 2005 focused on the nearshore area near Knoll Head in Iniskin Bay. The work that was completed involved intensive pedestrian surveys and numerous test pits, because locations near Knoll Head are the highest-probability areas within the study areas for cultural deposits and historic resources.

14.3.3 Tasks and Activities for 2006

The tasks and activities for 2006 were a continuation of those started in 2004 and continued in 2005. The 2006 cultural resources field season in the west segment of the study area included surveys of exploration drilling areas that were not surveyed in 2004 or 2005. Figure 14-1 shows locations SRB&A researchers surveyed in 2004 and 2005 and the area proposed to be surveyed in 2006.

SRB&A researchers surveyed the Knoll Head area in 2005 (Figures 14-2 and 14-3) and located two archaeological sites. In 2006, SRB&A researchers also surveyed the Newhalen River portion of the transportation corridor study area. The 2006 cultural resources field season did not include the transportation corridor east of the Newhalen River.

14.3.4 Tasks and Activities for 2007

The tasks and activities for 2007 were a continuation of work completed from 2004 through 2006, as well as a new task to inventory regional place-names.

By early 2007, SRB&A researchers had completed ground surveys of the west segment of the study area. To the extent that this study area would be expanded or revised in 2007, it was proposed for the 2007 field season to include a survey of additional areas as well as surveys of potential exploration-drilling areas that were not surveyed in 2004, 2005, or 2006. No field surveys were planned in the east segment of the study area in 2007.

For interviews, SRB&A researchers planned to conduct interviews at seven communities in the vicinity of the Pebble Deposit, transportation corridor/Cook Inlet study areas (Igiugig, Iliamna, Kokhanok, Newhalen, Nondalton, Pedro Bay, and Port Alsworth).

The new inventory task proposed in 2007 was to review a regional place-names inventory compiled under contract with the National Park Service.

Cultural resources information obtained during the interviews and review of the place-name inventory were to be included in forthcoming reports.

14.3.5 Tasks and Activities for 2008

The tasks and activities for 2008 include a continuation of the review of the regional place-names inventory compiled under contract with the National Park Service and consultation with state and federal agencies, Native organizations, and other interested parties.

In addition the following tasks will be addressed in 2008:

- Surveys were conducted of exploration-drilling areas that were not surveyed during 2004 through 2007. Figure 14-4 shows areas SRB&A surveyed in 2004, 2005, 2006, and 2007 and the area proposed to be surveyed in 2008 based on the most recent exploration information.
- A field survey was proposed at possible crossing landings on Newhalen River. (One side of the crossing was surveyed in 2006 but it requires additional investigation to verify whether the surface depressions found are cultural or geologic.)
- For interviews, SRB&A researchers planned to conduct interviews at two of the remaining communities in the vicinity of the mine study area, transportation corridor, and port area: in Pedro Bay and Igiugig. (Kokhanok, Newhalen, Nondalton, and Port Alsworth were completed in 2007, and Iliamna declined to participate.)

14.4 References

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TABLE

TABLE 14-1
Pebble Project Environmental Baseline Studies
Study Summary for Cultural Resources, 2004-2008
Consultant: Stephen R. Braund & Associates

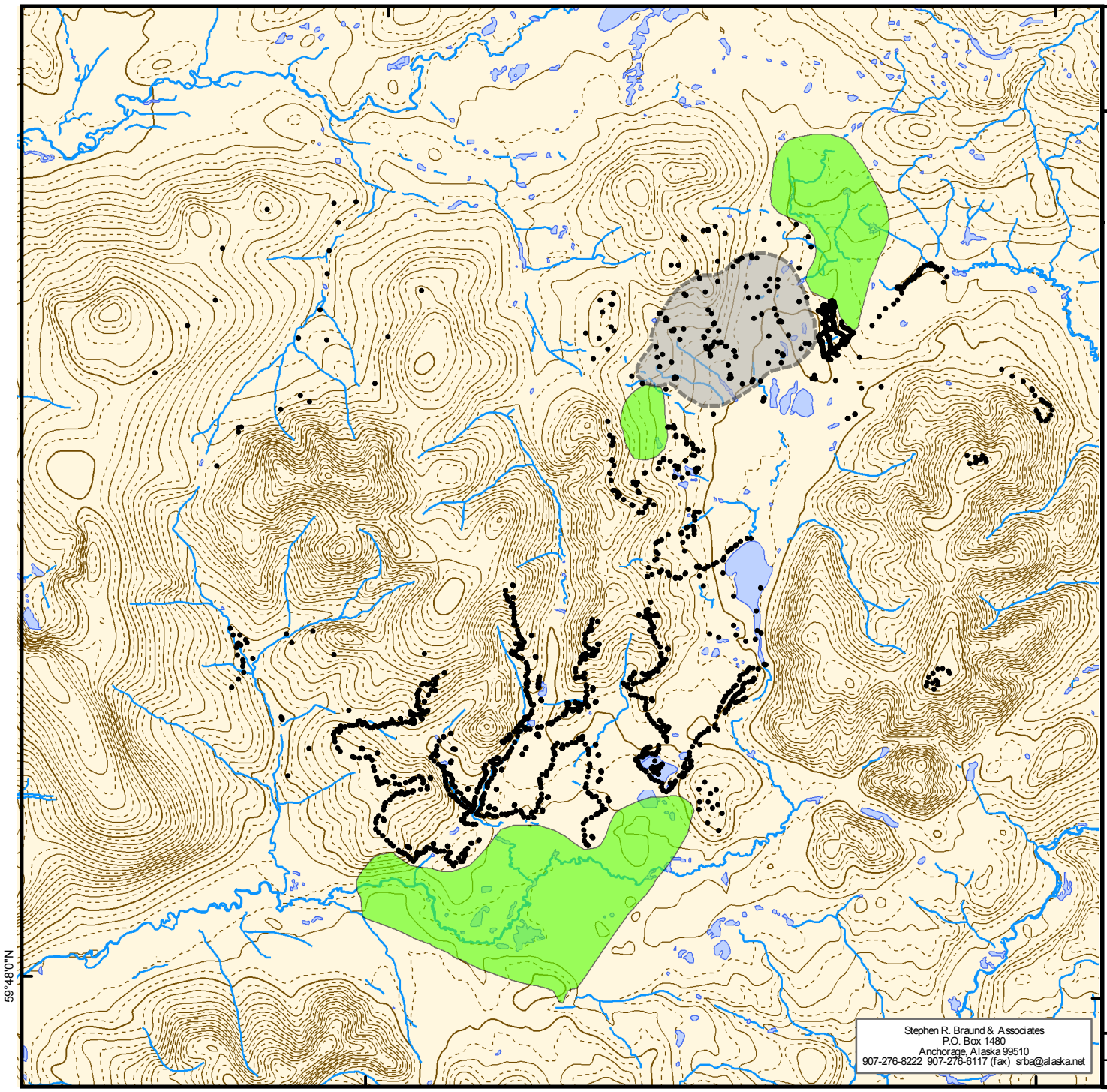
2004 Data Collected or Tasks	2005 Data Collected or Tasks	2006 Data Collected or Tasks	2007 Data Collected or Tasks	2008 Data Collected or Tasks
Mine Study Area				
Lit review & background information gathering	Lit review & background information gathering	Update literature review, AHRS & OHA information	Update literature review, AHRS & OHA information	Update literature review, AHRS & OHA information
Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan
2004 Study Plan	2005 Study Plan	2006 Study Plan Summary	2007 Study Plan Summary	2008 Study Plan Summary
Initiate consultation	Continue consultation	Continue consultation (agencies, Native orgs, others)	Continue consultation (agencies, Native orgs, others). Expand to include field interviews (see study plan).	Continue consultation (agencies, Native orgs, others). Complete field interviews - Pedro Bay & Igiugig
Four trips (June-Sept): field & pedestrian surveys, subsurface testing, and monitoring of ground-disturbing activities. Surveyed the deposit and surrounding areas.	April: surveyed exploration drilling area. August: surveyed areas south and southwest of the deposit.	June: surveyed Upper Talarik Creek, west slope Koktuli Mtn, and deposit area. August: surveyed South Fork Koktuli River & Groundhog Mtn.	Field Survey of additional areas within the Mine Study Area; surveyed exploration-drilling areas.	Survey exploration drilling areas, geotechnical testing sites, seismic shot lines, sump pits & any other ground disturbing activities
Process field data, notes, photographs; compile and analyze data	Process field data, notes, photographs; compile and analyze data	Process field data, notes, photographs; compile and analyze data	Process field data, notes, photographs; compile and analyze data	Process field data, notes, photographs, compile and analyze data
	Compile baseline inventory and description of cultural resources in the vicinity of the project	Compile baseline inventory and description of cultural resources in the vicinity of the project	Compile baseline inventory and description of cultural resources in the vicinity of the project	Continue baseline inventory and description of cultural resources in the vicinity of the project areas based on new field surveys
Presentation and report preparation	Presentation and report preparation	Presentation and report preparation	Presentation and report preparation	Presentation and Report Preparation
Communication and data management	Communication and data management	Communication and data management	Communication and data management	Communication and Data Management
Coordination with NDM & Agencies	Coordination with NDM & Agencies	Coordination with NDM, agency meetings, and monthly reporting	Coordination with NDM, agency meetings, and monthly reporting	Coordination with PLP, agency meetings, and monthly reporting
	2004 CR Progress Report to NDM (1/31/05)			
	2004 CR Progress Report to SHPO (1/31/05)	2005 CR Progress Report to SHPO	2006 CR Annual Progress Report to SHPO (Pending)	2007 CR Annual Progress Report to SHPO
	Feasibility Report--Cultural Resources (9/13/05)			
Agency Presentation-CR Oct 2004	Agency Presentation--Cultural Resources Nov 2005			
	Initial environmental analysis	Draft preliminary environmental baseline document	Draft preliminary environmental baseline document	Preliminary environmental baseline document & CEBD

2004 Data Collected or Tasks	2005 Data Collected or Tasks	2006 Data Collected or Tasks	2007 Data Collected or Tasks	2008 Data Collected or Tasks
Transportation Corridor/Cook Inlet Study Areas				
Lit review & background information gathering	Lit review & background information gathering	Update literature review, AHRS & OHA information	Update literature review, AHRS & OHA information	Update literature review, AHRS & OHA information
Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan	Scope, Schedule, Field Sampling Plan
2004 Study Plan	2005 Study Plan	2006 Study Plan Summary	2007 Study Plan Summary	2008 Study Plan Summary
	Consultation	Continue Consultation	Continue Consultation	Continue consultation (agencies, Native orgs, others). Complete field interviews - Pedro Bay & Igiugig
	June: two field trips to Iniskin Bay port site			
			Facilitate mitigation of any ground-disturbing activities at port site	Facilitate mitigation of any ground-disturbing activities at port site, as requested
		October 2006: Field survey of crossing landing on Newhalen River		Complete field survey of crossing landings on Newhalen River
			Field survey of specific transportation alignments (road, pipeline, powerline) after identified on ground	Field survey of specific transportation alignments (road, pipeline, powerline) after identified on ground
	Process field data, compile and analyze data	Process field data, compile and analyze data	Process field data, compile and analyze data	Process field data, compile and analyze data
	Compile baseline inventory and description of cultural resources in the vicinity of the project	Continue baseline inventory and description of cultural resources in the vicinity of the project	Continue baseline inventory and description of cultural resources in the vicinity of the project	Continue baseline inventory and description of cultural resources in the vicinity of the project areas based on new surveys
		Assess eligibility of known sites for listing on NRHP	Assess eligibility of known sites for listing on NRHP	Assess eligibility for listing on NRHP of known sites as necessary
	Report preparation	Report preparation	Report preparation	Presentation and Report Preparation
	Communication and data management	Communication and data management	Communication and data management	Communication and data management
Coordination with NDM & Agencies	Coordination with NDM & Agencies	Coordination with NDM, agency meetings, and monthly reporting	Coordination with NDM, agency meetings, and monthly reporting	Coordination with PLP, agency meetings, and monthly reporting
		2005 CR Progress Report to SHPO (Pending)	2006 CR Annual Progress Report to SHPO (Pending)	2007 CR Annual Progress Report to SHPO
	Initial environmental analysis	Draft preliminary environmental baseline document	Draft preliminary environmental baseline document	Preliminary environmental baseline document & CEBD
				Arrange artifact curation at repository

Notes:

AHRS = Alaska Heritage Resource Survey
CR = cultural resources
NDM = Northern Dynasty Mines Inc.
NRHP = National Register of Historic Places
OHA = Department of Natural Resources, Office of History and Archaeology
SHPO = State Historic Preservation Officer

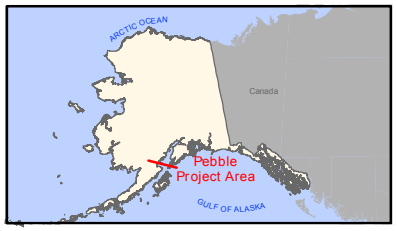
FIGURES



THE pebble PARTNERSHIP

Figure 14-1
Consolidated Study Program, 2004-2008
Cultural Resources
Survey Locations (2004-2006)
Pebble Deposit Area

- 2004-2005 Waypoint
- 2006 Proposed Survey Area
- General Deposit Location



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Meters
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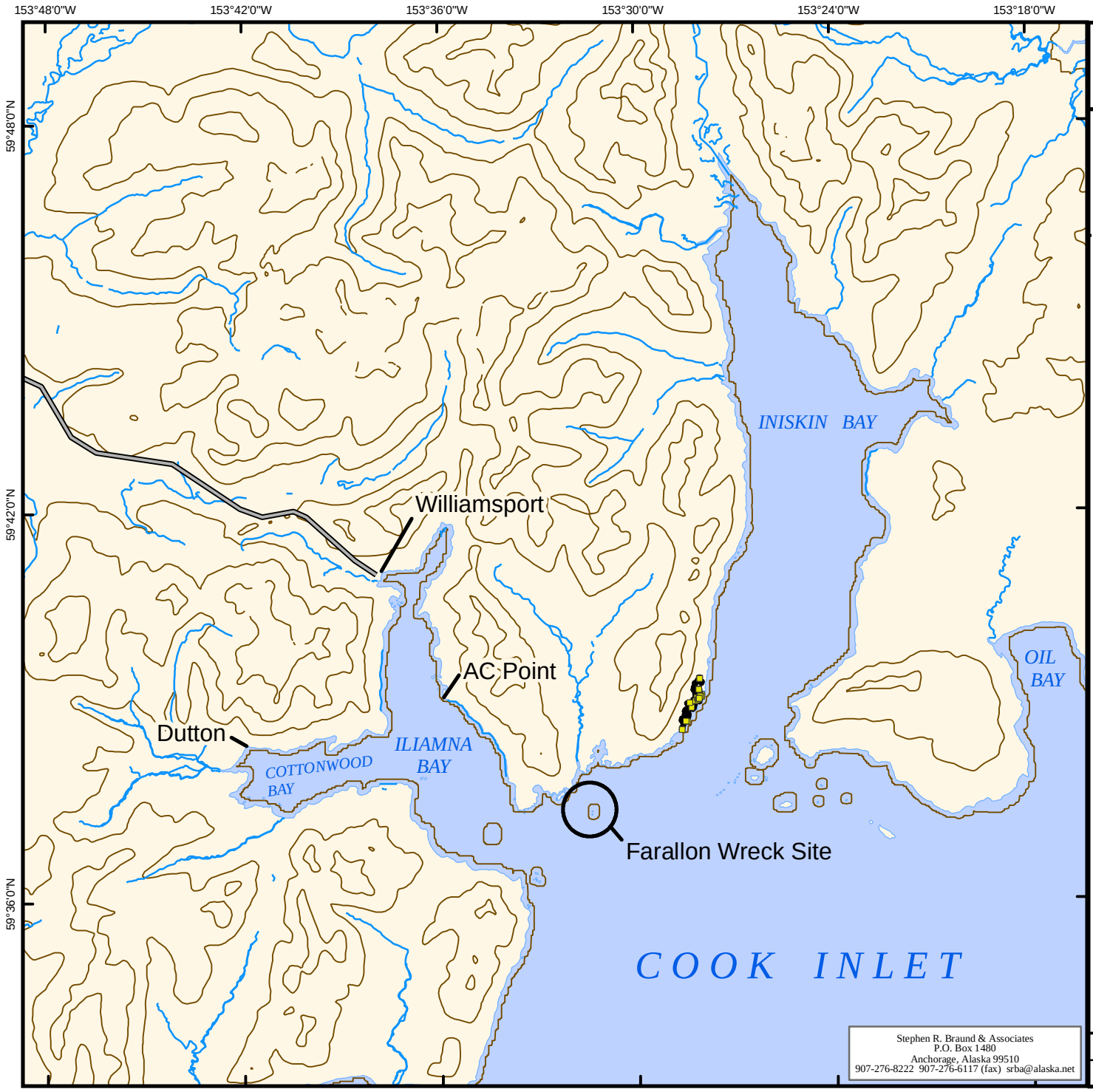
Alaska State Plane Zone 5 (units feet)
1983 North American Datum

CR Survey	Date: April 17, 2009
Version: 1, Rev	Author: SRB&A, PLP



THE pebble PARTNERSHIP

Figure 14-2
Consolidated Study Program, 2004-2008
Cultural Resources
Overview of Study Area (2005-2006)
Iliamna and Iniskin Bays

LEGEND

- Test Pit
- Waypoint
- Williamsport - Pile Bay Road

Feet 0 5,100 10,200 15,300 20,400

Meters 0 1,500 3,000 4,500 6,000

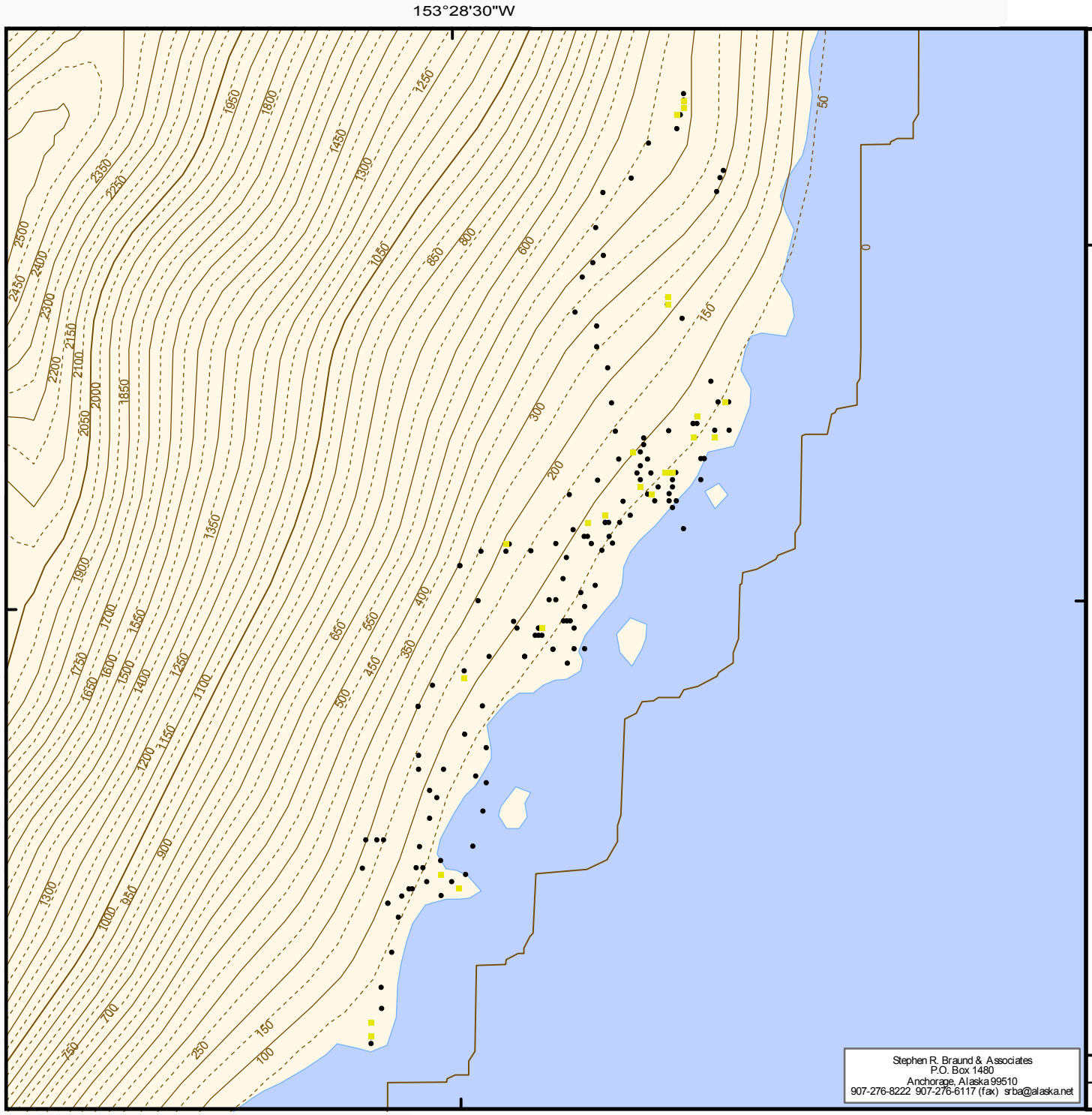
N

Scale 1:160,000

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

CR_port_overview	**Date: April 17, 2009**
Version: 1rev	**Author: SRB&A, PLP**

C

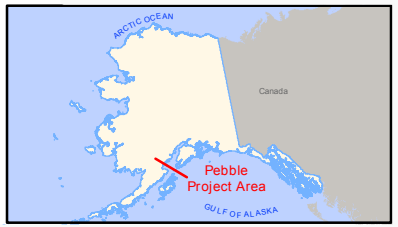


THE pebble PARTNERSHIP

Figure 14-3
Consolidated Study Program, 2004-2008
Cultural Resources Survey Locations (2005)
Knoll Head Area

LEGEND

- Waypoint
- Test Pit



Feet
0 250 500 750 1,000

Meters
0 75 150 225 300

Scale 1:9,000

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

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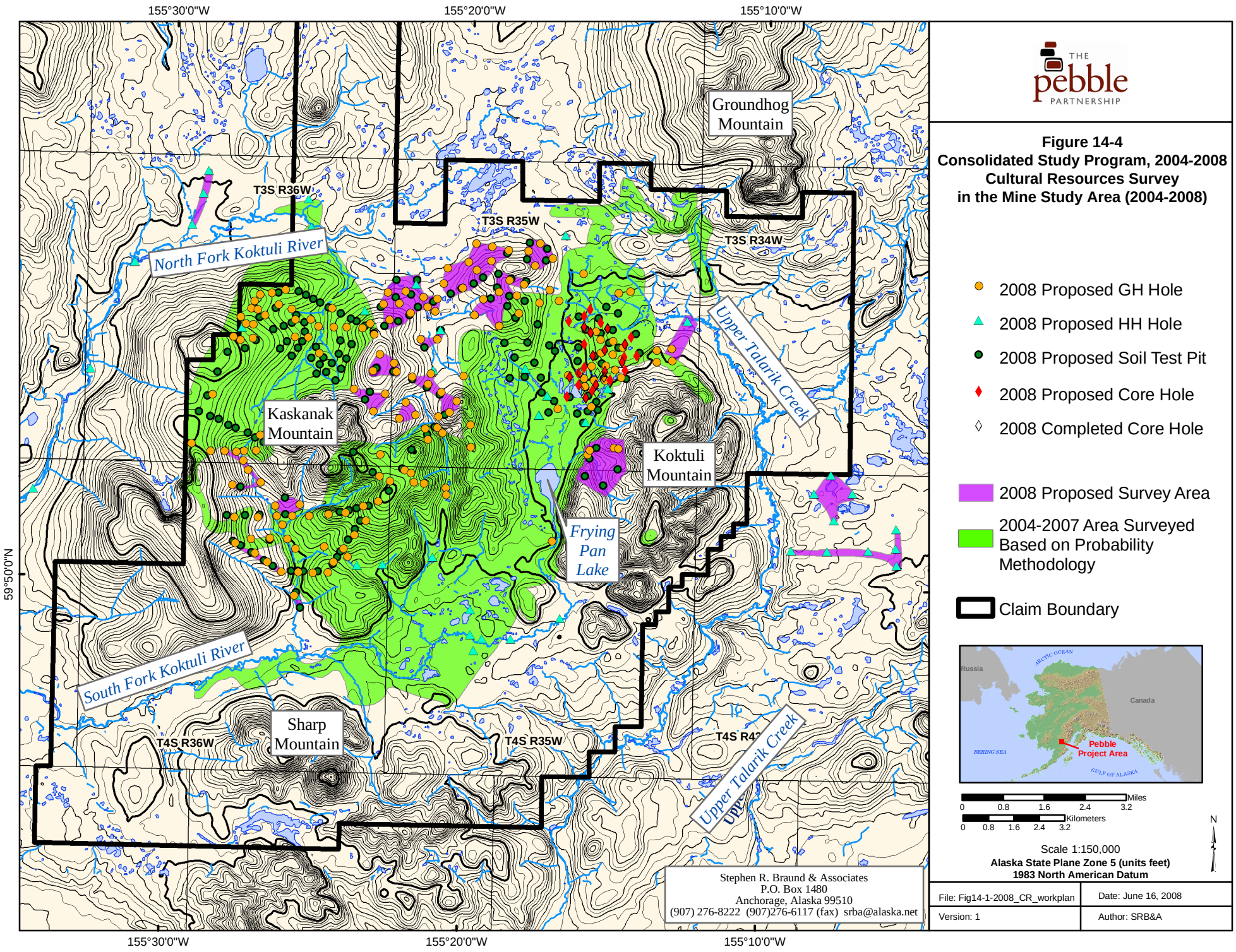
P.O. Box 1480
Anchorage, Alaska 99510
907-276-8222 907-276-6117 (fax) srba@alaska.net

CR_2005_port_survey	Date: April 17, 2009
Version:1, Rev	Author: SRB&A, PLP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155°20'0"W
155°10'0"W
59°50'0"N
Groundhog Mountain
T3S R36W
T3S R35W
T3S R34W
North Fork Koktuli River
Upper Talarik Creek
Kaskanak Mountain
Koktuli Mountain
Frying Pan Lake
South Fork Koktuli River
Sharp Mountain
T4S R36W
T4S R35W
T4S R34W
Upper Talarik Creek
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THE pebble PARTNERSHIP
Figure 14-4
Consolidated Study Program, 2004-2008
Cultural Resources Survey
in the Mine Study Area (2004-2008)
2008 Proposed GH Hole
2008 Proposed HH Hole
2008 Proposed Soil Test Pit
2008 Proposed Core Hole
2008 Completed Core Hole
2008 Proposed Survey Area
2004-2007 Area Surveyed Based on Probability Methodology
Claim Boundary
Russia
Canada
ARCTIC OCEAN
BERING SEA
GULF OF ALASKA
Pebble Project Area
Miles
0 0.8 1.6 2.4 3.2
Kilometers
0 0.8 1.6 2.4 3.2
N
Scale 1:150,000
Alaska State Plane Zone 5 (units feet)
1983 North American Datum
File: Fig14-1-2008_CR_workplan
Date: June 16, 2008
Version: 1
Author: SRB&A

Pebble Project
Environmental Baseline Studies
2004 through 2008

CONSOLIDATED STUDY PROGRAM

15. RECREATION

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Figure 15-2, Consolidated Study Program, 2004-2008, Expanded Study Area for Recreation (2007)

ACRONYMS

ADF&G	Alaska Department of Fish and Game
UCU	Uniform Coding Units

15. RECREATION

Kevin Waring Associates is the lead consultant for the baseline description of recreational uses and activities for the Pebble Partnership in portions of the Bristol Bay and Cook Inlet regions (Figure 15-1). This document describes the 2004 through 2008 consolidated study program for preparing the recreational baseline description.

15.1 Objective of Study

The overall objective of the recreation baseline study is to describe the types, locations, levels, and economic importance of current and expected recreational uses and activities in portions of the Bristol Bay and Cook Inlet regions. Specific objectives are as follows:

- Characterize the existing recreational environment and document baseline recreational uses.
- Collect data for input into work and studies by other disciplines.

15.2 Study Program

15.2.1 Study Area/Scope

The study area for the recreation baseline study generally encompasses the lands and waters throughout portions of the Bristol Bay and Cook Inlet drainages currently used for commercial and non-commercial recreation purposes. These include on-site and off-site lands and waters in the general vicinity of the mine study area and the transportation corridor/Cook Inlet study areas.

Of particular interest are Lake Clark National Park and Preserve, Katmai National Park and Preserve, the Alagnak Wild River, the McNeil River State Game Sanctuary/Refuge, and the drainage basins associated with the Upper and Lower Talarik creeks, Lake Iliamna, and the Kvichak, Koktuli, Mulchatna, and Upper Nushagak rivers. Figure 15-1 depicts the study area for the recreation studies from 2004 through 2006.

After the 2006 field season, agencies and the public expressed concern about the omission of recreation studies in parts of the Nushagak River drainage. In response to their concerns, the western study area boundary was extended along the Nushagak River corridor, west of the original study area (Figure 15-2). These areas possess outstanding public recreational resources and sustain locally and regionally important recreation-related business activities (e.g., transportation services, guiding, lodging, etc.).

15.2.2 Methods/Approach

The study will employ a variety of research, analytic, and interpretive methods/approaches. There are some published information sources for researching recreational visitation and activities in the study area. Much of the most relevant data, however, will need to be culled from the files of state and federal resource agencies responsible for managing public lands and/or regulating recreational activities

(including sportfishing and hunting). Knowledgeable informants, including public agency staff, recreation users, and representatives of user and trade groups, may also contribute valuable insights. Information collected from these sources will be distilled into a profile of consumptive and non-consumptive recreational patterns and trends in the study area. Interpretive maps of recreational uses and activities will be developed as part of the baseline study.

Economic analysis will also be employed. The study area's recreation-related economic sector depends on its appeal for sportfishing and hunting and other recreational activities. This economic sector is exposed to external forces that influence visitation and recreation patterns. The baseline study will apply the tools of economic analysis to estimate the current and prospective economic role of commercial and non-commercial recreation in the study area.

Finally, although recreation is identified as a discrete topic for baseline and assessment studies, it overlaps thematically and geographically with certain other study topics such as land use, subsistence, visual aesthetics, and fish and wildlife habitats. As appropriate, the recreation baseline study effort coordinates with these other study disciplines.

15.2.3 Major Tasks/Activities

The main tasks and activities for the recreation study involve collecting and analyzing information on recreation in the study area, preparing interpretive mapping of major recreational uses and related activities, analyzing the current and future economic role of recreation, and preparing the recreation baseline description. Table 15-1 provides a summary of tasks for the recreation baseline studies in 2004 through 2008.

15.2.3.1 Tasks and Activities for 2004

A specific study program for recreation was not developed in 2004. The discipline depended less on the 2004 summer season field work than did other disciplines (e.g., hydrology, socioeconomics, etc.).

In fall 2004, the Pebble Partnership project managers worked on identifying experienced contractors to conduct a recreation study, and providing them with an introduction to the Pebble Project and the objectives and a conceptual plan for the recreation study. A general outline of the recreation study was prepared, including some preliminary advances in reviewing the availability of existing recreational data sourced from the published literature, agencies, user and trade groups, and commercial recreational operations in the study area (e.g., hunting and fishing guides, lodge operators, and knowledgeable local individuals).

15.2.3.2 Tasks and Activities for 2005

Specific tasks for 2005 expanded on the conception work initiated in 2004, including the following:

- Collecting available published and agency file data on commercial and non-commercial recreational uses and activities in the study area.
- Interviewing federal and state agency staff, representatives of user and trade groups, hunting and fishing guides, lodge and other commercial operators, and other informants knowledgeable about recreation and recreation-related businesses in the study area.

- Compiling statistics on recent and current visitation and recreational activity levels and trends.
- On the basis of data collected, identifying and mapping important recreational areas.
- Identifying and mapping key support bases and busiest travel routes to/from recreational sites.
- Reviewing literature on techniques for economic valuation of recreational resources.
- Estimating the economic contribution of recreation to local and regional economies in the study area.
- Coordinating with subsistence baseline studies in common geographic areas of study to achieve consistent baselines for subsistence and recreational uses of fish and wildlife resources.
- Coordinating with visual asthetics, terrestrial wildlife studies, fish and aquatic habitat studies, and other relevant biophysical studies.
- Integrating the findings of previous tasks from previous years into the baseline description of recreation in the study area.

15.2.3.3 Tasks and Activities for 2006

The major tasks and activities remained generally as described for 2005: collecting and analyzing information on recreation in the study area from a variety of sources, preparing interpretive mapping of major recreational uses and related activities, analyzing the current and future economic role of recreation, and preparing the recreation baseline description.

In 2006, the study was revised to include an additional year of sportfishing, hunting, and visitation data in the database. Additionally, research to date had discovered more comprehensive and detailed data sources on sportfishing and hunting activities in the study area than anticipated in previous years. The 2006 study was revised to add these data to the baseline description and to expand the mapped presentation of sportfishing and hunting in the study area.

The tasks and activities for 2006 also included acquiring newly available annual data series as well as incorporating recent changes in the relevant conditions in the study area into the analysis.

15.2.3.4 Tasks and Activities for 2007

The tasks and activities for 2007 remained generally as described for 2005 and 2006: collecting and analyzing recreation information in the study area from a variety of sources, preparing interpretive mapping of major recreational uses and related activities, analyzing the current and future economic role of recreation, and preparing the recreation baseline description.

As described above, in response to agency and public concern, the western study area boundary was extended to include additional sportfishing and hunting resources and activity west of the original study area along the Nushagak River corridor (Figure 15-1). The interpretive maps for sportfishing and hunting activity are being revised to reflect the expanded study area. Coincidentally, this revision brings the study area for recreation more closely, though not perfectly, into alignment with the study area for the subsistence and traditional knowledge baseline studies.

Two Alaska Department of Fish and Game (ADF&G) Uniform Coding Units (UCUs; geographic areas within Game Management Units) are wholly within the transportation corridor study area. Six other UCUs are partly within but mostly outside the transportation corridor study area. Because the hunt data are aggregated by UCU, the data tabulations and maps commingle the data for the transportation corridor study area with data for territory to the northwest, west, and southwest. As feasible, the original ADF&G hunt reports were retrieved and reviewed to determine the location and level of hunting effort and harvest that actually occurred in the transportation corridor study area. This information may be put into a supplemental report for later integration into an updated recreation baseline study.

The 2007 study activities also incorporated newly available annual ADF&G series data on sportfishing and hunting activity for 2005. Consequently, the sportfishing database covered 7 years (1999 through 2005), and the hunting database covered 6 years (2000 through 2005). Visitation statistics for National Park Service venues in the study area also were updated to incorporate 2006 data. Finally, as appropriate, other baseline information was updated to reflect circumstances as of the time of report preparation.

15.2.3.5 Tasks and Activities for 2008

No new information was collected in 2008. Analysis and reporting of the recreation data collected from 2005 to 2007 continued during 2008.

TABLE

TABLE 15-1
Pebble Project Environmental Baseline Studies
Study Summary for Recreation, All Study Areas, 2004-2008
Consultant: Kevin Waring Associates

2004 Data Collected or Tasks Completed	2005 Data Collected or Tasks Completed	2006 Data Collected or Tasks Completed	2007 Data Collected or Tasks Completed	2008 Data Collected or Tasks Completed
	2005 Study Plan	2006 Study Plan Summary	2007 Study Plan Summary	2008 Study Plan Summary
	Inventory federal, state and other recreational lands and assets	Update all annual data series	Update all annual data series	
	Compile data and trends on visitation and commercial users for national parks & preserves	Verify accuracy of other recreational information	Verify accuracy of other recreational information	Verify accuracy of other recreational information
	Document and quantify as feasible recreational uses and activities	Develop descriptive and interpretive maps to show locale and intensity of recreational activities, especially sportfishing and hunting	Expand study area west of Nushagak River; update interpretive maps	
	Compile and analyze ADF&G sportfishing and hunting data	Coordinate with preliminary results of related baseline studies, e.g., visual aesthetics, terrestrial wildlife, fish and aquatic habitat, etc.	Coordinate with continuing results of related baseline studies	Coordinate with continuing results of related baseline studies
	Identify and locate recreation lodges			
	Identify points of access and travel routes to recreational destinations			
	Collect data on economic importance of commercial and non-commercial recreation			
Coordination with Pebble Partnership and agencies	Coordination with Pebble Partnership and agencies	Coordination with Pebble Partnership and agencies	Coordination with Pebble Partnership and agencies	Coordination with Pebble Partnership and agencies
		Draft recreational baseline description	Update recreational baseline description	Update recreational baseline description

FIGURES

160°0'0"W 158°0'0"W 156°0'0"W 154°0'0"W 152°0'0"W

61°0'0"N 60°0'0"N 59°0'0"N 58°0'0"N

Lime Village
Holokuna River
Nushagak Hills
Red Hills
Koliganek
Mulchatna River
New Stuyahok
Aleknagik
Ekwok
Dillingham
Manokotak
Clarks Point
Ekuk
Nushagak River
Kvichak River
Levelock
Igiugig
Iliamna Lake
Kokhanok
Becharof Lake
Egegik
Bristol Bay
Naknek
South Naknek
King Salmon
Naknek Lake
Bristol Bay Borough
Lake and Peninsula Borough
Matanuska-Susitna Borough
Chilikna R
Lake Clark
Port Alsworth
Nondalton
Iliamna
Newhalen
Pedro Bay
Pile Bay
Williamsport
Mt. Iliamna
Kukaklek L
Nonvianuk L
Kamishak Bay
Augustine Island
Alaska Range
Alaska Peninsula
Cook Inlet
Beluga
Tyonek
Kenai
Soldotna
Clam Gulch
Tustumena Lake
Ninilchik
Kenai Peninsula Borough
Homer
Seldovia
Kodiak Island
Gulf of Alaska
Shelikof Strait
Afognak Island
Port Lions

158°0'0"W 156°0'0"W 154°0'0"W 152°0'0"W

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Figure 15-1
Consolidated Study Program,
2004-2008
Study Area for Recreation (2004-2006)

Legend

- Study Area
- Primary Study Area
- General Deposit Location
- Borough Boundary
- Existing Roads

0 15 30 45 60 Miles

0 30 60 90 Kilometers

N

Scale 1:1,620,000

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

File: RDI_KW_SP_Fig15_1_11X17L_1of1_D05.mxd	Date: April 17, 2009
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160°0'0"W 158°0'0"W 156°0'0"W 154°0'0"W 152°0'0"W

61°0'0"N 60°0'0"N 59°0'0"N 58°0'0"N

Matanuska-Susitna Borough

Lime Village

Beluga

Tyonek

Holitna River

Nushagak Hills

Lake and Peninsula Borough

Alaska Range

Kenai

Soldotna

Cook Inlet

Clam Gulch

Tustumena Lake

Ninilchik

Port Alsworth

Lake Clark

Chilikadrotna R

Kokhuh R

Mt. Iliamna

Red Hills

Nondalton

Kenai Peninsula Borough

Pile Bay

Iliamna

Pedro Bay

Williamsport

Newhalen

Homer

Koliganek

Mulchatna River

Nushagak River

New Stuyahok

Iliamna Lake

Kokhanok

Seldovia

Aleknagik

Ekwok

Igiugig

Augustine Island

Kamishak Bay

Levelock

Kukaklek L.

Kvichak River

Dillingham

Nushagak River

Manokotak

Nonvianuk L.

Bristol Bay Borough

Clarks Point

Ekuk

Naknek

King Salmon

South Naknek

Naknek Lake

Alaska Peninsula

Gulf of Alaska

Shelikof Strait

Bristol Bay

Egegik

Afognak Island

Becharof Lake

Port Lions

Kodiak Island

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Figure 15-2
Consolidated Study Program, 2004-2008
Expanded Study Area for Recreation (2007)

Legend

- Study Area
- Primary Study Area
- General Deposit Location
- Borough Boundary
- Existing Roads

Miles
0 15 30 45 60

Kilometers
0 30 60 90

N

Scale 1:1,620,000

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

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Version: 5	Author: RDI-LS

Pebble Project
Environmental Baseline Studies
2004 through 2008

CONSOLIDATED STUDY PROGRAM

16. LAND USE

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Figure 16-1, Consolidated Study Program, 2004-2008, Study Area for Land Use

ACRONYMS

ADOT&PF	Alaska Department of Transportation & Public Facilities
BLM	Bureau of Land Management
DNR	State of Alaska Department of Natural Resources

16. LAND USE

Kevin Waring Associates is the lead consultant for the baseline description of land use for the Pebble Project environmental baseline studies in portions of the Bristol Bay and Cook Inlet regions. This document describes the 2004 through 2008 study program for preparing the land use baseline description.

16.1 Objectives of Study

The overall objective of the land-use element of the environmental baseline description is to provide baseline information about existing land-use and tenure patterns, land-use and management plans, and land management regimes in the Pebble Project vicinity and other nearby areas. Specific objectives are as follows:

- Document the baseline land-use situation.
- Collect land-use data for input into studies by other disciplines.

16.2 Study Program

16.2.1 Study Area/Scope

The Pebble Project is located in the Lake and Peninsula and in the Kenai Peninsula boroughs. The area for land use studies focuses on this general project area, but includes areas in the immediate vicinity and other parts of the Lake and Peninsula Borough, Kenai Peninsula Borough (west side of Cook Inlet and, possibly, Homer), Bristol Bay Borough, and the area west of the deposit area to the Mulchatna and Nushagak rivers. Figure 16-1 depicts the study areas.

The scope of the land-use baseline study addresses both public and private lands. It includes local governmental land-use and coastal-management plans and related regulations, federal and state land-management plans, and land-management plans and activities of major private landowners (such as Alaska Native regional and village corporations, which are major landowners in the study area). It is the intention for the final land-use description document to reflect the latest information on land-use planning and management activities of federal and state governments, and of private ownership, so that the information will be current as of the time of the report.

The study considers all actual and allowed land uses, except subsistence land uses, which are addressed in the separate baseline study for subsistence and traditional knowledge (consolidated study program [CSP] 13). Because transportation systems are closely linked to land use, the land-use study also considers transportation plans as they relate to land use.

16.2.2 Methods/Approach

The methods and approach for the land-use study entail compiling and evaluating current and relevant official land-use and management plans, regulatory measures, relevant studies and documents, and transportation plans. As needed, documentary resources are supplemented with interviews with key public officials and private parties who have responsibility or authority for land-use plans and management in the study area. Existing land uses and planned and permitted land uses are being mapped for later assessment of project effects on land-use patterns. No field work has been proposed.

Several major initiatives are currently under way to develop updated or new land-use, coastal-management, and transportation plans. Of particular note at the time of this writing, the State of Alaska Department of Natural Resources (DNR) is revising the Bristol Bay Area Plan for state lands in the Bristol Bay region. Also, state legislation requires all participating local coastal-management districts to have revised their coastal-management plans by July 1, 2005, and that process, if not already completed, is under way. There are four coastal-management districts in the study area: Lake and Peninsula, Bristol Bay, Kenai Peninsula Borough, and Bristol Bay Coastal Service Area.

The results of these major initiatives are being added to the Pebble Project land-use information base as they become available. The planning documents include the following:

- DNR's Bristol Bay Area Plan (draft August 2004, final mid-2005).
- Kenai Peninsula Borough's Comprehensive Plan Update (April 2005) and Coastal Management Plan Update (July 2005).
- Lake and Peninsula Borough's Coastal Management Plan Update (draft late 2004, final July 2005).
- Alaska Department of Commerce, Community and Economic Development's Community Profile Maps for Lake and Peninsula Borough villages (Fall 2004).
- Alaska Department of Transportation and Public Facilities' (ADOT&PF's) Revised Southwest Alaska Transportation Plan (draft June 2004).
- ADOT&PF's Iliamna Airport Master Plan (draft late 2004).
- Bureau of Land Management's (BLM's) Ring of Fire Resource Management Plan and Environmental Impact Statement (September 2005, under review).

The general management plans for Lake Clark National Park and Preserve (1984) and Katmai National Park and Preserve (1987) are aged, but remain the primary management documents for those federal areas; therefore, they will be used as a reference in the land-use study.

16.2.3 Major Tasks/Activities

The major tasks and activities for the land-use baseline study follow an orderly process for collecting, evaluating, and presenting relevant information on existing land use and tenure, land-use plans and management regimes, and transportation plans in the study area.

Key tasks and activities for each year from 2004 through 2006 are summarized in Table 16-1. Land use studies were not conducted in 2007.

16.2.3.1 Tasks and Activities for 2004

Specific tasks and activities for land use were not developed in 2004. The discipline depended less on the 2004 summer season field work, which were the focus of the Pebble Partnership project management team at that time, than did other disciplines (e.g., hydrology, socioeconomics).

In fall 2004, the Pebble Partnership project managers worked on identifying experienced contractors to conduct a land use study, and providing them with an introduction to the Pebble Project, the land use study objectives, and a conceptual plan/scoping document for the land use study.

16.2.3.2 Tasks and Activities for 2005

In 2005, tasks and activities identified in the general scoping document prepared in 2004 were refined and implemented. Key tasks and activities included the following:

- Delineate/confirm the study area, including the project vicinity and other areas of land use in the general vicinity of the Pebble Project.
- Collect and critically review land-use and tenure information, public and private land-use and management plans, applicable land-use regulations and codes, land studies and reports, transportation plans, and other relevant documents.
- Identify and monitor ongoing land-use and transportation planning activities, incorporating new information as it became available.
- Interview local, state, and federal agencies that exercise land planning, management, or regulatory authority within the land-use study area.
- Interview representatives of major private landowners (e.g., Native regional and village corporations) on their land-use planning/management goals, policies, and practices for their landholdings.
- Map information on existing land-use patterns and tenure, and on planned and permitted land uses in the study area.
- As appropriate, integrate land-use information related to recreation use in the land-use study area and obtained for the recreation component of the environmental baseline studies.
- Coordinate with the geographic information system (GIS) study team to develop illustrative maps and geo-graphics.
- Prepare a draft baseline description of existing land tenure and uses in the land-use study area, with appropriate illustrative maps and graphics.

16.2.3.3 Tasks and Activities for 2006

The tasks and activities for the land-use description for 2006 continued to reflect the latest information on land use and ownership in the study areas. The status of ongoing land use planning and management

activities by federal and state governments was also updated. Most particularly, the 2006 study for the land use baseline description addressed the following:

- Recent revisions to state and local coastal management plans.
- The status of the BLM Ring of Fire and [Bristol] Bay area resource management plans (under review in 2006).
- Revisions to local governmental comprehensive plans and land use regulations.
- Ongoing state transportation plans.
- Recently published community profiles for communities in the Lake and Peninsula Borough.

16.2.3.4 Tasks and Activities for 2007

The tasks and activities for the land use study in 2007 continued to focus on gathering the most current land-use planning, management, and ownership information. The work included researching the following:

- Recent revisions to state and local coastal management programs.
- The status of the BLM's Rim of Fire and [Bristol] Bay area resource management plans.
- Changes, if any, to local government comprehensive plans and land use regulations.
- Changes and implementation of other state, local, and federal land-use and transportation plans.

Any changes or new information were integrated with the data collected in previous years into the land-use baseline description. In addition, land-use investigators provided land-use information to other members of the Pebble Partnership team, as necessary

16.2.3.5 Tasks and Activities for 2008

No new information was collected in 2008. Analysis and reporting of the land-use data collected from 2005 to 2007 continued during 2008.

.

TABLE

TABLE 16-1
Pebble Project Environmental Baseline Studies
Study Summary for Land Use, 2004-2008
Consultant: Kevin Waring Associates

2004 Data Collected or Tasks Completed	2005 Data Collected or Tasks Completed	2006 Data Collected or Tasks Completed	2007 Data Collected or Tasks Completed	2008 Data Collected or Tasks Completed
2004 Study Plan	2005 Study Plan	2006 Study Plan	2007 Study Plan Summary	2008 Study Plan Summary
Conduct preliminary assessment of available data and other study resources	Collect and review data on existing land ownership and use	Update previously compiled data to reflect any changed circumstances, (e.g., land ownership or use, coastal management program revisions, new comprehensive plans, BLM resource management plans)	Update previously compiled data to reflect any changed circumstances, e.g., land ownership or use, coastal management program revisions, new comprehensive plans, BLM resource management plans	Update previously compiled data to reflect any changed circumstances, e.g., land ownership or use, coastal management program revisions, new comprehensive plans, BLM resource management plans
	Review federal, state, and local land use and management plans and regulations			
	Review existing surface transportation plans and			
	Review local coastal management programs			
		Develop maps to display land ownership, use, and management status of land and waters	Develop maps to display land ownership, use, and management status of land and waters	Complete maps to display land ownership, use, and management status of land and waters
		Coordinate findings of land use baseline with recreation and regional transportation baselines	Coordinate findings of land-use baseline with recreation and regional transportation baselines	Coordinate findings of land-use baseline with recreation and regional transportation baselines
	Describe management status of land and water resources	Prepare draft land use baseline description	Prepare draft land use baseline description	Complete draft land-use baseline description

FIGURE

160°0'0"W 158°0'0"W 156°0'0"W 154°0'0"W 152°0'0"W

61°0'0"N 60°0'0"N 59°0'0"N 58°0'0"N

Matanuska-Susitna Borough

Lime Village

Beluga

Tyonek

Holokuna River

Nushagak Hills

Lake and Peninsula Borough

Kenai

Soldotna

Cook Inlet

Clam Gulch

Tustumena Lake

Port Alsworth

Clark Lake

Chulitna R

Kokhuh R

Mt. Iliamna

Ninilchik

Red Hills

Nondalton

Nushagak River

Mulchatna River

Kenai Peninsula Borough

Pile Bay

Iliamna

Pedro Bay

Williamsport

Koliganek

Newhalen

Homer

New Stuyahok

Iliamna Lake

Kokhanok

Seldovia

Aleknagik

Ekwok

Igiugig

Augustine Island

Kvichak River

Levelock

Kukaklek L.

Kamishak Bay

Dillingham

Nushagak River

Manokotak

Nonvianuk L.

Clarks Point

Ekuk

Bristol Bay Borough

Naknek

King Salmon

South Naknek

Naknek Lake

Alaska Peninsula

Gulf of Alaska

Shelikof Strait

Bristol Bay

Egegik

Afognak Island

Becharof Lake

Port Lions

Kodiak Island

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Figure 16-1
Consolidated Study Program, 2004-2008
Study Area for Land Use

Legend

- Study Area
- Primary Study Area
- General Deposit Location
- Borough Boundary
- Existing Roads

0 15 30 45 60 Miles

0 30 60 90 Kilometers

N

Scale 1:1,620,000

Alaska State Plane Zone 5 (units feet)
1983 North American Datum

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Environmental Baseline Studies
2004 through 2008

CONSOLIDATED STUDY PROGRAM

17. VISUAL AESTHETICS

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Figure 17-1, Consolidated Study Program, 2004-2008, General Study Area for Visual Aesthetics

ACRONYMS

GIS	geographic information system
LDN	Land Design North
LCNPP	Lake Clark National Park and Preserve
TIN	triangulated irregular network
USDA	United States Department of Agriculture

17. VISUAL AESTHETICS

This consolidated study program describes work completed during 2004 through 2008 for the visual resources analysis component of the environmental baseline studies for the Pebble Project. The work consisted of characterizing visual resources in the Bristol Bay region.

17.1 Objectives of Study

The objectives of the visual aesthetics study are as follows:

- Collect data concerning existing visual conditions and their context in the region.
- Provide the collected data for input into studies by other disciplines.

The primary outcome of the study is a baseline description that can be used to evaluate the sensitivity of residents and visitors ("constituents" in this document) to visual resources in this region.

17.2 Proposed Study Program

17.2.1 Study Area/Scope

The study area encompasses potentially viewed areas in the vicinity of the Pebble Deposit and transportation corridor study area in the Bristol Bay drainages. The eastern edge of the study area is the boundary between the Bristol Bay drainages and the Cook Inlet drainages. The study area extends westward through Chinkelyes Creek Valley and the Aleutian Range and includes portions of Iliamna Lake. The western edge of the study area is located in the lowlands west of Sharp and Groundhog mountains.

The northern edge of the study area is approximately the border of Lake Clark National Park and Preserve, except in the vicinity from Roadhouse Mountain to Hoknede Mountain where the study area boundary crosses into the park. The southern edge of the study area generally follows offshore of Iliamna Lake's northern shoreline and includes a complex archipelago of bays and islands, as well as a few settlement areas, including Pile Bay, Pedro Bay, Iliamna, and Newhalen. The study area also encompasses the Newhalen River drainage, Sixmile Lake, and the community of Nondalton.

Figure 17-1 depicts the general study area for visual aesthetics.

17.2.2 Methods/Approach

The study employs methods typically used by the U.S. Department of Agriculture (USDA), Forest Service, as described in *Landscape Aesthetics: A Handbook for Scenery Management* (USDA, 1995). This handbook describes methodology for defining landscape units based on landscape character types, evaluation of scenic integrity, and evaluation of scenic attractiveness. The methodology includes evaluating residents and visitors (i.e., constituents) to the study area. They are evaluated for their

sensitivity to changes in the landscape, and their location relative to specific viewed areas is determined in terms of landscape visibility or "distance zones."

The study methodology also includes computer-assisted analytical techniques. The landscape units and evaluation data are mapped using a geographic information system (GIS), and the data are correlated to mapped information with that of other studies.

17.2.3 Major Tasks/Activities

17.2.3.1 Tasks and Activities for 2004

A formal study plan for visual aesthetics was not fully developed in 2004. The discipline depended less on the 2004 summer season field work than did other disciplines (e.g. hydrology, socioeconomics, etc.); therefore, this study was not the focus of the Pebble Partnership project managers' efforts at that time.

Pebble Partnership managers, however, did introduce Land Design North (LDN) investigators to the Pebble Project, and provided a description of the objectives and a conceptual plan for a visual aesthetics study. Based on that input, LDN investigators drafted a preliminary tasked outline of the how the study work would be conducted, and began with the first three tasks. (The status of the work is shown in parentheses.)

Task 1: Baseline Information Collection (Completed, 2004)

Digital elevation model (DEM) information has been collected for the study area, and from that a triangulated irregular network (TIN) was constructed in an ARCView GIS format. The TIN will support the mapping and presentation of other landscape visibility information.

Task 2: Constituent Determination (Partially Completed, 2004)

LDN investigators interviewed Pebble Partnership personnel most familiar with the Pebble Project to gain an understanding of the sensitivities of individuals and groups within the study area. Key constituents included, but were not limited to, the following:

- Recreational visitors to Lake Clark National Park and Preserve (LCNPP).
- Recreational visitors to other areas potentially influenced by the Pebble Project.
- Communities within the potentially affected areas.
- Lodges operating in the area.
- Air traffic in the region.
- Boat traffic in the region.
- Subsistence users in the general study area.

In addition to discussions with Pebble Partnership personnel, LDN investigators contacted other resource analysts on the study team (such as socioeconomic and subsistence analysts) to identify constituents in these or other categories. The constituents were identified to gain an understanding of the sensitivities of individuals and groups within the study area.

Task 3: Site Visits and Documentation (Partially Completed, 2004)

Based on the key viewpoints and constituents identified in Tasks 1 and 2, LDN investigators flew throughout the study area to document existing features and key viewpoints. It was planned to conduct site visits by helicopter to the following locations:

- Nondalton/Iliamna roads at a height characteristically used by those traveling by airplane.
- The transportation corridor study area from the Newhalen River to the mine study area.
- Ridges overlooking the mine study area.
- Elevations above the mine study area.
- Upper and Lower Talarik creeks.
- The northern shoreline of Lake Iliamna at an altitude typically used by guides/sightseers.
- Pedro Bay.
- Islands south of Pedro Bay.
- The transportation corridor study area between Pedro Bay and Pile Bay.
- Pile Bay.
- The transportation corridor study area from Pile Bay to Williamsport.
- Portions of Iniskin and Iliamna bays.
- Ridge above the termination of Knutson Creek in LCNPP.
- Ridge between Canyon Creek and Chekok Creek in LCNPP.
- Unnamed ridge west of Chekok Creek in LCNPP.
- Roadhouse Mountain.

At each site, landscape character and views were documented.

17.2.3.2 Tasks and Activities for 2005

The main tasks and activities for the visual aesthetics baseline study in 2005 were to complete the tasks started in 2004, and to compile, map, analyze, and evaluate the data.

The additional tasks are described below. (The status of the work is shown in parentheses.)

Task 4: Evaluation and Mapping (Partially Completed, 2005)

The landscape of the study area and the constituencies were evaluated and mapped with respect to a number of criteria. The criteria used were based on USDA Forest Service (1995) methods. Evaluation was done for each landscape unit defined. The specific components of the analysis are described below.

A **landscape unit** is an area of land that has similar existing landscape attributes, including similar ownership and land use. Mapping reflects differences in attributes. The maps and their attributes are correlated with mapping of vegetation and habitat completed by other disciplines.

Scenic integrity refers to the condition of or deviations/alterations from the existing landscape character that is valued for its aesthetic appeal. A high scenic-integrity level is a landscape condition that is unaltered or is at a preservation level. Low or very low scenic integrity is a landscape condition that is heavily altered or has maximum modification.

Concern level refers to the degree of public importance placed on landscapes viewed from travel corridors and public-use areas. There are three numeric levels of concern: (1) represents the highest concern, (2) is of moderate concern, and (3) represents the lowest level of concern. Concern levels can also indicate the level of interest that people are likely to have in the surrounding landscape or setting.

Scenic attractiveness and **landscape visibility** are the two scenic classes.

Scenic attractiveness measures the scenic importance of a landscape based on human perceptions of the intrinsic beauty of a landform, vegetation pattern and cultural land use. There are three classes of scenic attractiveness: distinctive (A), typical or common (B), and indistinctive (C).

Landscape visibility (or "distance zone") refers to the distance from which a view can be seen. There are three distance zones: foreground (fg), middleground (mg), and background (bg). At the "immediate" foreground distance of 0 to 300 feet, people can distinguish individual leaves, flowers, twigs, bark texture, and small animals and can notice movements of vegetation in light wind. At the foreground distance of 0 to 0.5 mile, people can distinguish tree trunks, large branches, individual shrubs, wildflowers, medium-sized animals, and medium to large birds. At the middleground (0.5 to 4 miles), people can distinguish individual tree forms. At the background distance (4 miles to the horizon), people can distinguish groves or stands of trees, and the landscape is simplified. Landscape visibility can be evaluated to a large extent using computers and documenting seen and unseen areas and the distance zones from locations of sensitivity.

Task 5: Examination of Potential Changes to Affected Environment

The baseline TIN that was created from the digital elevation model can be modified to reflect changes as landscape changes occur. This allows LDN investigators to evaluate how changes to existing landscape features may or may not be seen by specific constituents.

Changes to the existing environment are described in terms of their visual context, examining issues of massing, color, contrasts, textures, and patterns. This includes evaluating both the existing landscape character and the potential facilities in these terms.

17.2.3.3 Tasks and Activities for 2006, 2007, and 2008

No further field investigations were conducted after 2005. The visual aesthetics baseline data collected during 2004 and 2005 was further analyzed and reported during 2006, 2007, and 2008.

17.3 References

U.S. Department of Agriculture (USDA). 1995. Landscape Aesthetics. A Handbook for Scenery Management. Agriculture Handbook No. 701, revised October 2000. USDA, Forest Service. Washington, D.C.

FIGURE

156°0'0"W
155°0'0"W
154°0'0"W
153°0'0"W
60°0'0"N
59°30'0"N

Port Alsworth
Tanalian River
Lake Clark
Lake Clark National Park
Lake Clark National Preserve
Mt. Iliamna
Chulitna R.
Koktuli River
N. Fork Koktuli R.
S. Fork Koktuli R.
Upper Talarik Cr.
Lower Talarik Cr.
Nondalton
Tazimina River
Newhalen River
Iliamna
Newhalen
Pedro Bay
Pile Bay
Williamsport
Iliamna Lake
Kokhanok
Igiugig
Kvichak River
Kukaklek Lake
Katmai National Preserve
Katmai National Park
Kamishak Bay
Cook Inlet
Augustine Island

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Figure 17-1
Consolidated Study Program, 2004-2008
General Study Area for Visual Aesthetics

Legend

- General Deposit Location
- Study Area
- Mine Studies
- Transportation Corridor Study Area
- National Park and Preserve
- Borough Boundary
- Existing Roads

0 5 10 15 20 25 Miles
0 5 10 15 20 25 Kilometers

N

Scale 1:600,000
Alaska State Plane Zone 5 (units feet)
1983 North American Datum

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18. SOCIOECONOMICS

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Table 18-1, Pebble Project Environmental Baseline Studies, Study Summary for Socioeconomics, 2004-2008

LIST OF FIGURES (following table)

Figure 18-1, Consolidated Study Program, General Area for Socioeconomic Studies, 2004-2008

18. SOCIOECONOMICS

The McDowell Group, supported by Kevin Waring Associates, is responsible for developing the description of the socioeconomic environment for the Pebble Project. As appropriate, their efforts are being coordinated with those of the consultants responsible for the subsistence and traditional knowledge, land use, and recreation baseline studies.

18.1 Objective of Study

The overall objective of the socioeconomic baseline study is to describe the baseline socioeconomic conditions in the study. Specific objectives include the following:

- Document the baseline socioeconomic environment.
- Collect socioeconomic data for input to studies by other disciplines (e.g., subsistence and traditional knowledge, land use, and recreation).

18.2 Study Program

18.2.1 Study Area/Scope

The socioeconomic environmental baseline studies were conducted in three study areas: the Iliamna Lake/Lake Clark Core study area, the Bristol Bay study area, and the Cook Inlet study area.

The seven communities in the localized region of Iliamna Lake/Lake Clark form the core study area and include the communities of Iliamna, Newhalen, Nondalton, Pedro Bay, Igiugig, Kokhanok, and Port Alsworth. Iliamna, Newhalen, Nondalton and Pedro Bay are nearest to the Pebble Deposit. The communities of Igiugig, Kokhanok, and Port Alsworth also are located in the core study area, and they currently are linked to the other four communities through existing roads and waterways. Therefore, they warrant the most extensive and detailed description and analysis in this socioeconomic baseline study.

The secondary study area encompasses the rural communities of the Bristol Bay region; specifically, those located in the Lake and Peninsula Borough (except the seven primary communities within the core study area), Bristol Bay Borough, and Dillingham Census Area. These communities and surrounding regions share definite institutional ties to the project vicinity through such regional entities as the Bristol Bay Native Association, the Bristol Bay Native Corporation, and the Southwest Alaska Municipal Conference. They are small in population, and have generally poorly developed community infrastructure. The economies of these communities and surrounding regions have also been adversely affected by recent trends in Alaska's commercial salmon fishing and processing industry. For these reasons, these communities and regions are assigned to the secondary study area.

The tertiary study area encompasses the Cook Inlet region; specifically the communities located in the Kenai Peninsula Borough, Municipality of Anchorage, and Matanuska-Susitna Borough.

The scope of the socioeconomic baseline description is designed to capture the major dimensions of past and existing socioeconomic effects in these three areas.

Communities in the core study area are being characterized in greater detail and depth than communities and regions in the secondary and tertiary study areas. Conversely, studies in the tertiary study area focus mainly on characterizing the general demographic and economic attributes of the associated communities and regions (rather than detailed studies).

Figure 18-1 depicts the core, secondary and tertiary areas, and their associated communities, within the overall socioeconomics study area.

18.2.2 Methods/Approach

Much of the information required for describing socioeconomic baseline conditions can be obtained from published and unpublished data sources, supplemented by interviews with local public officials and similar informants. The method of research for the Pebble Project makes full use of these available resources. Current detailed information about the employment, employability, and household incomes of residents of the core communities is lacking, but is needed to make a realistic assessment of their economic status. Up-to-date information about workforce availability and skills in communities in the secondary study area is similarly needed. The study program includes specific tasks and activities to assemble this essential information.

The following topics to be addressed in the baseline description:

- History and culture—culture and developmental history of the study area.
- Population—census and composition of population, migration patterns, and population trends and forecasts.
- Economy—traditional economic resources and economic structure, resident and non-resident workforce and workforce participation, employment and unemployment rates, workforce skills and mobility, wage and income levels, sources of cash and non-cash income, local suppliers of business goods and services, economic trends and forecasts, and outlook for traditional economy.
- Community infrastructure—community facilities and services, housing, etc.
- Governance—city, borough, and traditional/Tribal governments and non-profit service organizations; their legal status, powers, and finances; and their inter-relationships.
- Transportation—facilities and services for intra- and inter-regional transport of passengers and cargo by air, water, and overland.
- Community utilities—electric power, water/sewer systems, communications, etc.

18.2.3 Major Tasks and Activities

As feasible, certain of the tasks related to field-data collection identified below may be coordinated with field work undertaken as part of other project baseline studies (e.g., Alaska Department of Fish and Game, Division of Subsistence, household surveys, being conducted as part of the subsistence and

traditional knowledge study [consolidated study program 13]) or may be implemented in collaboration with appropriate local organizations.

Table 18-1 summarizes the work for the socioeconomic baseline study in 2004 through 2008.

18.2.3.1 Tasks and Activities for 2004

A specific plan for socioeconomic studies was not yet developed in 2004. Work focused on defining the objectives, study area, and scope of the study for socioeconomics; conducting a preliminary assessment of available data and other relevant resources; and searching for an experienced contractor to conduct the study.

18.2.3.2 Tasks and Activities for 2005

The tasks and activities for the baseline socioeconomic study in 2005 involved both critical distillation and analysis of information from existing bibliographic resources, plus field work geared to developing essential information not otherwise available. The work included the following:

- Compiling and critically reviewing published and unpublished data, including agency file data, for all socioeconomic topics.
- Interviewing local and agency officials and other informants to supplement published and unpublished data sources.
- Compiling socioeconomic profiles for the core communities and field-verifying community data for accuracy.
- Conducting household personal income/employment surveys for the core communities.
- Conducting manpower inventories and skills surveys for all core communities and some secondary communities.
- Organizing and analyzing the data collected in preparation for drafting the baseline description of socioeconomic conditions.

18.2.3.3 Tasks and Activities for 2006

The tasks and activities for 2006 were generally the same as those in 2005. The scope of the baseline description was revised, however, to reflect the most current socioeconomic conditions and to incorporate newly available annual data series.

The 2006 study updated the baseline information and analysis to incorporate the following:

- 2005 population and population trends.
- 2005 workforce, employment, and unemployment figures.
- Additional and more recent earnings and income data.
- 2005 commercial fishing activity.
- 2005 public assistance payments.

- 2005 household subsistence surveys.
- Current commercial fishing/seafood processing, visitor, and government sectors.
- Capital improvement spending for fiscal year 2005/2006.
- Recent changes in community infrastructure.
- Current local governmental organization, services, and finances.
- The most recent community energy and regional transportation services and costs.

The information collected was incorporated into a draft socioeconomic baseline description.

18.2.3.4 Tasks and Activities for 2007

The tasks and activities for 2007 study focused on updating the baseline information for the Bristol Bay study area (including Iliamna Lake/Lake Clark communities and Nushagak/Bristol Bay Borough communities) to incorporate the following:

- Senior review edits and recommendations for revisions, and new scope or data.
- 2006 population and demographic data and trends.
- 2006 workforce, employment, and unemployment figures.
- Most recent earnings and income data.
- Updated information on commercial fishing activity.
- 2006 public assistance payments.
- 2006 household subsistence-survey data related to demographics and economics (incorporating research performed by the Alaska Department of Fish and Game).
- Updated commercial fishing/seafood processing, visitor, and government sectors.
- Capital improvement spending for fiscal year 2006/2007.
- Recent changes in community infrastructure.
- Current local governmental organization, services, and finances.
- The most recent community energy and regional transportation services and costs.

The 2007 study also included developing a health-and-social-indicators baseline for the Iliamna Lake/Lake Clark communities. The baseline included a broad range of indicators, including deaths, births, health status, family violence, crime, and educational achievement.

The data collected in 2007 was integrated into the baseline socioeconomic description and was provided to other members of the Pebble Partnership team, as necessary.

18.2.3.5 Tasks and Activities for 2008

No new socioeconomics information was collected during 2008. Analysis and reporting of the data collected from 2004 through 2007 continued in 2008.

18.2.3.6 Tasks and Activities for 2009

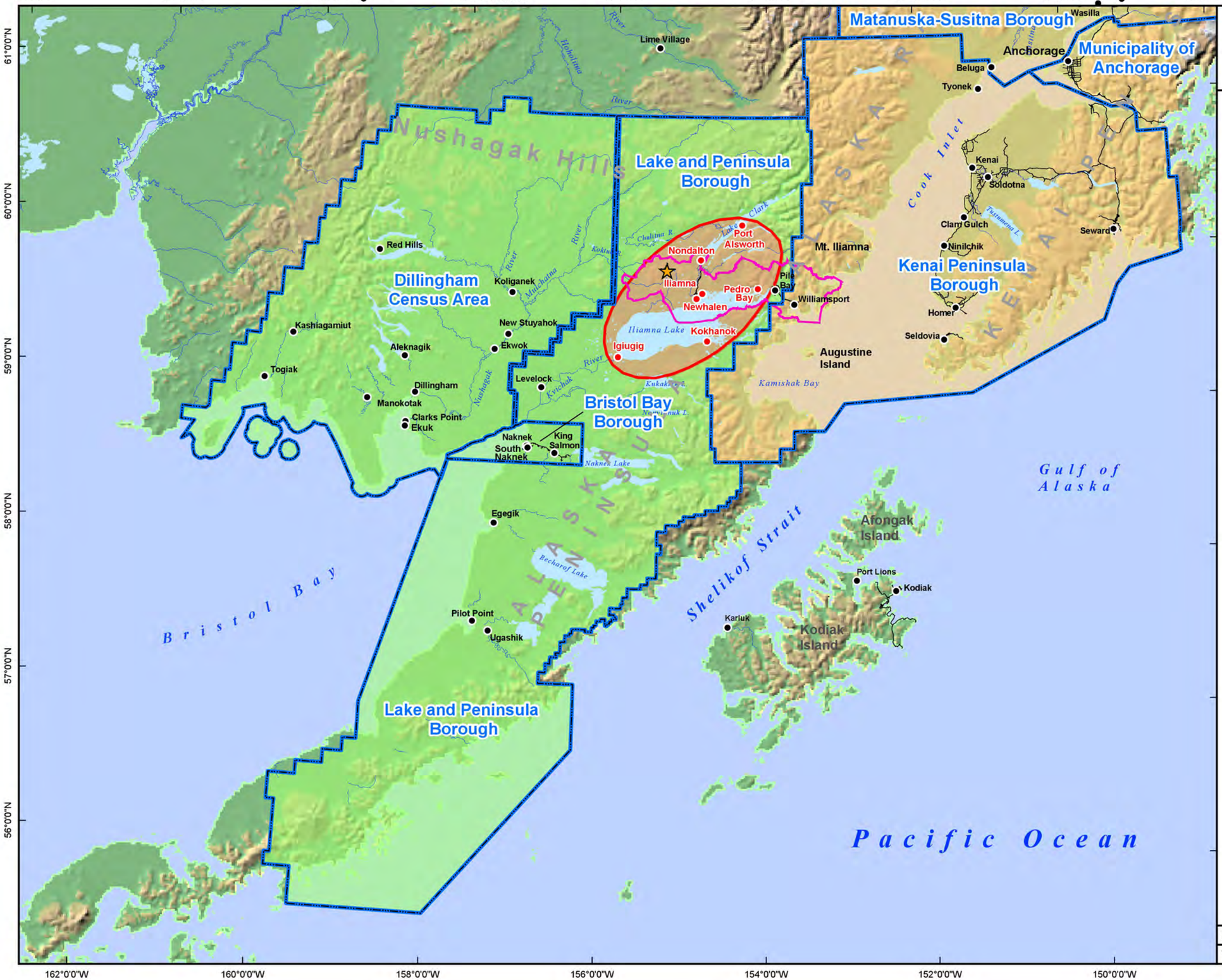
EBD chapters were updated to include recently published socioeconomic data.

TABLE

TABLE 18-1
Pebble Project Environmental Baseline Studies
Study Summary for Socioeconomics, 2004-2008
Consultant: McDowell Group, Kevin Waring Associates

2004 Data Collected or Tasks Completed	2005 Data Collected or Tasks Completed	2006 Data Collected or Tasks Completed	2007 Data Collected or Tasks Completed	2008 Data Collected or Tasks Completed	2009 Data Collected or Tasks Completed
2004 Conceptual Study Plan	2005 Study Plan	2006 Study Plan	2007 Study Plan	2008 Study Plan	2008 Study Plan
Conduct preliminary assessment of available data and other study resources	Compile and analyze information on population characteristics	Update baseline data to incorporate most current information and analysis into 2005 baseline data	Update baseline data to incorporate most current information and analysis into 2006 baseline data	Update baseline data to incorporate most current information and analysis into 2006 baseline data	Update baseline data to incorporate most recently published socioeconomic data
	Document historical and current economic conditions, including employment and unemployment, and earned and unearned income				
	Prepare profiles of major industries, including commercial fishing/processing, tourism, government				
	Design and conduct local labor-force survey of manpower skills, employment interest, and mobility				
	Collect information for profiles of community infrastructure				
	Describe the structure, powers, and finances of local governance institutions				
	Describe regional transportation facilities, services, and costs				
	Describe provisions for supply and cost of community electric power and petroleum fuels				
			Research, analyze, and incorporate health and social indicators baseline information		
		Prepare preliminary draft socioeconomic baseline description	Prepare draft socioeconomic baseline description	Complete draft socioeconomic baseline description	Complete draft socioeconomic baseline description

FIGURE



THE pebble PARTNERSHIP

Figure 18-1
Consolidated Study Program
General Area for Socioeconomic Studies 2004-2009

Legend

- Iliamna Lake/Lake Clark Core Study Area
- Pebble Project Vicinity
- Bristol Bay Secondary Study Area
- Cook Inlet Tertiary Study Area
- General Deposit Location
- Existing Roads

File: RDI_KW_SP_Fig18_1_11X17L_1of1_D05.mxd	Date: April 15, 2009
Version: 5	Author: RDI-LS

Pebble Project
Environmental Baseline Studies
2004 through 2008

CONSOLIDATED STUDY PROGRAM

19. DATA MANAGEMENT

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Table 19-1, Pebble Project Environmental Baseline Studies, Study Summary for Data Management, 2004-2008

ACRONYMS

ADF&G	Alaska Department of Fish and Game
CD	compact disc
COC	chain-of-custody
CQM	comment and question management
DLG	digital line graph
ERD	entity relationship diagram
EROS	Earth Resources Observation and Science
ESRI	Environmental Systems Research Institute
FGDC	Federal Geographic Data Committee
FTP	file transfer protocol
GIS	geographic information system
GPS	global positioning system
HDR	HDR Alaska, Inc.
HGM	hydrogeomorphic
JDS	jurisdictional field plot
NWI	National Wetland Inventory
RDI	Resource Data Inc.
Shaw	Shaw Environmental Inc.
SHP	shape (GIS file)
SOP	standard operating procedure
3PPI	Three Parameters Plus Incorporated
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey

19. DATA MANAGEMENT

Resource Data Inc. (RDI) is responsible for providing data management services to support the Pebble Project.

19.1 Objectives and Scope

The overall objectives of the data management support services are as follows:

- Provide a system for storing and accessing baseline environmental data collected for the Pebble Project.
- Ensure that data are accessible for input into studies by all disciplines.

The scientific data generated as part of the environmental baseline description are a valuable asset to the Pebble Partnership. The RDI team's scope of work is to make the Pebble Partnership data available to the environmental baseline project team.

19.2 Approach

The overall approach for data management is to proactively manage the data to ensure the data are readily available and integrated for multidisciplinary analysis. This approach calls for a process that is completely automated so that the data are accurate and can be accessed when needed. The plan is to specify to the project team clear requirements and standards for data deliverables and to provide the team with tools to verify compliance before delivery.

The approach has been to develop the project data management system and website concurrently. For the most part, data management is based on a geographic information system (GIS), using the ArcInfo software developed by Environmental Systems Research Institute (ESRI). GIS coverages are created with ArcInfo, which are output as shape (SHP) files. This is the most expedient method to process data, and SHP files are the preferred format for the environmental team. The SHP files also are used to load an ArcSDE/Oracle database. This database supports the website GIS. Cartographic (mapping) products are generated in ArcGIS.

Most data that will be loaded into the GIS are available in digital format. Data available in hardcopy only are digitized for uploading. Distribution is accomplished by transfer media such as compact discs (CDs) and portable hard disk drives. Smaller files are published on the project website for download.

19.3 Study Program

The data management support provided by the RDI team has three components:

- GIS.

- Integrated support for the wetlands study being conducted by Three Parameters Plus Incorporated (3PPI) and HDR Alaska, Inc. (HDR).
- Data and website management.

Each component is discussed separately in this document.

Table 19-1 summarizes the data management work completed for the Pebble Project for 2004 through 2008.

19.3.1 Geographic Information System

The GIS component covers managing all the mapping data collected during the baseline studies, creating and loading basemap and Pebble Project-specific data, and providing cartographic and GIS services to support the project.

19.3.1.1 Objectives and Scope

The objectives for the GIS component are as follows:

- Develop standards for spatial data, including datum, projection, and accuracy.
- Compile the basemap data for the Pebble Project study areas.
- Compile study data.
- Distribute data to all investigators for all environmental disciplines.

The scope of services includes developing GIS standards, building a GIS framework to support permitting, uploading basemap and project-specific data, and providing GIS support to all team members.

19.3.1.2 Tasks and Activities

Tasks and Activities for 2004

The primary tasks and activities for 2004 were those required to develop the GIS environment.

Task 1: GIS Management. The first task was to develop GIS data-management standards for the Pebble Project. These included projection information, required formats for data distribution, documentation requirements, and schema for naming revisions. The standards were documented and distributed to the project team.

After data-management standards were developed, a GIS data repository was developed. The repository was developed using an ArcSDE/Oracle geodatabase. Map templates and ESRI layer files were developed to ensure that all maps have a consistent appearance.

Finally, a process for facilitating the exchange of spatial data between team members was developed. Some data can now be exchanged through the file transfer protocol (FTP) site, and other data are distributed on CDs or portable hard drives.

Task 2: Compile Basemap Data. The next task was to create the GIS basemap layers for the Pebble Project area. These layers consist of features that make up a typical United States Geological Survey (USGS) quadrangle, map including topographic features such as rivers, lakes, and contours, and cadastral features such as place names, townships, section, and range lines.

Task 3: Load Pebble Project Data. Once the basemap layers had been prepared, RDI technicians loaded the Pebble Partnership data to the GIS. The information included claim block data, drill hole and geotechnical location data, and other existing baseline study data that had been collected by previous investigators (e.g., Cominco) and more recently by the Pebble Partnership project team.

Task 4: Load Environmental Data. Existing environmental data sets obtained from government agencies were digitized, as necessary, and loaded. Data sets included the following:

- Alaska Department of Fish and Game (ADF&G) anadromous fish stream catalog.
- U.S. Fish and Wildlife Service raptor nest data.
- National Marine Fisheries Service critical habitat data for fish, marine mammals, and stellar sea lions.
- ADF&G fish and game habitat information.

Task 5: Cartographic Services. Maps of data collected by the project team and produced by the GIS were provided for use in meetings with agencies. Maps also were developed to be suitable for final documents.

Tasks and Activities for 2005

Tasks and activities for 2005 focused on refining/maintaining the GIS environment set up in 2004, and adding additional layers of data.

Task 1: Extended Mapping. Public data sets were gathered and translated into ESRI ArcGIS format to support the addition of new study areas in the Cook Inlet study area. The following activities were required to complete this task:

- Creating and processing hydrography data from USGS digital line graph (DLG) data.
- Acquiring and processing all existing Alaska Department of Environmental Conservation habitat mapping for the study area addition.
- Processing borough boundaries, Native corporation boundaries, and township/range/section data for the study area addition.
- Acquiring and processing the USGS Earth Resources Observation and Science (EROS) digital land-cover data.
- Incorporating digital raster graphics (DRG), digital orthophoto quadrangle (DOQ) data into the GIS.
- Processing the existing National Wetland Inventory (NWI) fish and wildlife data for the study area addition, including adding long species name to the data set.

- Acquiring soundings for Cook Inlet and process the soundings into bathymetric contours.
- Processing any other additional layers that had not been identified into the GIS.

Task 2: Generate Accurate Native Allotment Data. The Native allotment data that the project team members were using were approximate and were not considered accurate for location purposes. The data are published by the Bureau of Land Management simply to show that allotments exist in the general area, not to provide accurate location information. The only source of accurate location information for the allotments is the original survey notes. To resolve this issue, the team completed the following activities:

- Gathered the survey notes.
- Converted the lot bearings and distances from the notes into coordinate geometry.
- Tied the allotment boundary data to known control points.
- Projected the data to Alaska State Plane Zone 5, North American Datum of 1983 (NAD83).
- Created metadata for the new accurate allotments.

Tasks and Activities for 2006, 2007, and 2008

Tasks and activities for GIS in 2006, 2007, and 2008 included refining data sets, and general database and software maintenance.

Task 1: Annual Software Maintenance. Annual software licensing and network connections renewals were required. These included renewals for the following:

- ESRI ArcIMS software license.
- ESRI ArcView software license.
- Oracle Maintenance software license.
- Digital subscriber line (DSL) network connections.
- Domain name registration.
- Secured socket layer (SSL) protocol licenses.

19.3.2 Wetlands Project Support

The second component of work, support for the wetlands study, includes creating and loading basemap and Pebble Project-specific data; managing all the mapping data collected by 3PPI, HDR, and other investigators for the wetlands study; providing GIS support; and providing cartographic services.

19.3.2.1 Objectives and Scope

The specific objectives for data management activities in support of the wetlands program are as follows:

- Support the wetlands mapping team.

- Support the ongoing field season work.
- Maintain the wetlands-study website and software.

The scope of services includes maintaining the GIS environment established as part of the RDI team's GIS services, adapting it for use as a wetlands-data repository, providing professional GIS services to the wetlands and habitat-mapping team and other related disciplines, and developing and maintaining a wetlands website.

19.3.2.2 Tasks and Activities

Tasks and Activities for 2004

Task 1: Data Acquisition. Existing data relevant to wetland mapping were acquired for uploading to the GIS. These data sets were in addition to those loaded under previous GIS-related activities and included the following:

- NWI data.
- Natural Resource Conservation Service data.
- Bristol Bay Land Cover Map Data from USGS EROS
- Permit layer from United States Army Corps of Engineers (USACE).

Task 2: Support for Wetlands Mapping. RDI personnel have supported the wetlands team throughout the wetland mapping process. The following activities were required in 2004:

- Create wetland layer files.
- Produce preliminary field maps and photo reports.
- Process photos and photo locations.
- Scrub digitized wetlands data (close polygons, remove slivers, etc.).
- Support analysis of wetland mapping, sorted by vegetation type and hydrogeomorphic (HGM) classification.
- Prepare preliminary plots for the environmental baseline report.

Tasks and Activities for 2005

Task 1: Ongoing Support for Wetlands Mapping. Ongoing support was provided to the wetlands team for wetland determinations and habitat mapping. The following activities were required for this task:

- Continue with data scrubbing (close polygons, remove slivers, etc.).
- Support analysis of wetland mapping, jurisdictional wetland mapping, vegetation type, and HGM classification.
- Maintain the master data set throughout the mapping process.

- Provide ongoing documentation of GIS data sets and upload to the website at www.pebbleproject.com. Ensure documentation was compliant with current Federal Geographic Data Committee (FGDC) standards.

Task 2: Field Season Support. Wetland field work proposed during the 2005 field season included the following:

- Field options to include 120 more jurisdictional field plots (JDS) with associated functional assessment data.
- Up to 1,050 more rapid functional assessment sites (one-page form with the global positioning system [GPS] camera data).
- Additional camera data.
- Up to 120 more JDS in willow thickets.

The following data management activities were required to support this work:

- Creating two additional GPS camera scripts to support the additional wetland data-collection effort.
- Creating field maps and photo reports to support the wetland field surveys and data analyses.
- Processing photos and photo locations and creating a single-point data set that linked each digital photo to its sample location.

Task 3: Website and Data Maintenance. General maintenance was conducted to keep the wetlands website environments (development, test, and production) running and in good working order and to protect the integrity of the data contained within the database and website. Activities required to complete this task included:

- Applying necessary security patches and performance tuning of servers.
- Performance tuning and maintenance of the Oracle 9i database.
- Minor website source code changes.
- Migration efforts—transferring the website source code from development to test and finally to production.
- Documentation—updates to database entity relationship diagrams (ERDs), updates to website diagrams, and creation/modification of technical-support documents.
- Creating a series of administration screens to help administrative users update the site in a more efficient manner. Administration-screen types included “User Manager,” “Application Manager,” “Role Manager,” and “Site Configuration Manager.”

Tasks and Activities for 2006

Task 1: Ongoing Support for Wetland Mapping. RDI personnel continued to provide ongoing support to the wetlands team in their wetland-determination and habitat-mapping efforts. The following activities were required for this task:

- Continuing with data scrubbing (close polygons, remove slivers, etc.).
- Supporting the analysis of wetland and habitat mapping, jurisdictional wetland mapping, vegetation type, and HGM classification.
- Maintaining the master data set throughout the mapping process.
- Providing ongoing documentation of GIS data sets, compliant with FGDC standards, and uploading to www.pebbleproject.com.
- Providing agency-meeting support for the wetlands-mapping team (agency meetings to be held in October or November); attending meetings and providing reports.
- Providing printing services.

Task 2: Field Season Support. Support for the wetland mapping team continued during the 2006 field season. The following activities were required for this task:

- Modifying GPS camera scripts to the specifications developed by the wetlands/habitat-mapping team, supporting the additional wetland data-collection effort.
- Creating field maps to support the wetlands field surveys and data analysis.
- Processing photos and photo locations and creation of a single-point data set that linked each digital photo to its sample location.
- Producing photo reports for the wetlands/mapping-habitat team as needed.

Task 3: Functionality Consistent with USACE Wetland Delineation Manual. The Pebble Project's wetland website that had been in place up to 2006 was converted into a site capable of using either the original wetland determination method, which the site was using at the time, or the new method outlined in the Alaska supplement to the USACE's *Wetland Delineation Manual* (USACE, 2007). The following functionality was added:

- Dominance test for hydrophytic vegetation.
- Prevalent index calculation.
- Wetland cryptogam calculation.
- Morphological adaptation indicator.
- Determination changes.
- Hydrology changes.

Task 4: Website and Data Maintenance. General maintenance was conducted to keep the wetland website environments (development, test, and production) running and in good working order and to protect the integrity of the data contained in the database and website. Activities required for the task included the following:

- General site maintenance.
- Modifications to the wetlands application as specified by the wetlands and habitat-mapping team, including the following:

  - Modifications to the plant community report.
  - Functional assessment data updates and modifications.
  - Updates to the soils report.
- Performance tuning and maintenance of the Oracle 9i database.
- Minor website source-code changes.
- Documentation—updates to database ERDs, updates to website diagrams, and creation/modification of supporting technical documents.

Tasks and Activities for 2007

Task 1: Ongoing Support for Wetlands Mapping. The following activities were performed in 2007 to support the wetlands team:

- Continuing with data scrubbing (close polygons, remove slivers, etc.).
- Providing analysis of wetlands mapping, jurisdictional wetland mapping, vegetation type, and HGM classification.
- Maintaining the master data set throughout the mapping process.
- Providing ongoing documentation of GIS data sets, compliant with FGDC standards, and uploading to the Pebble Project website.
- Providing support for the wetlands mapping team for agency meetings (to be held in October or November); attending meetings and providing reports.
- Modifying GPS camera scripts to the specifications developed by the wetlands mapping team, supporting the collection of additional wetland data.
- Creating field maps to support the wetlands field survey crews and subsequent data analysis.
- Processing photos and photo locations and creating a single-point data set that linked the digital photos to the associated sample location.
- Producing photo reports for the habitat team as needed.
- Providing printing services.

Task 2: Field Season Support. The following activities were conducted in support of the 2007 field season for the wetlands project:

- Shipping and installing computers for mapping (digitizing) of wetlands by wetlands technical personnel in Iliamna.
- Training wetlands technical personnel in digitizing wetland boundaries.

Task 3: Website and Data Maintenance. General maintenance was conducted to keep the wetlands website environments (development, test, and production) operating properly and to protect the integrity of the wetlands data contained in the database and website. The following activities were performed:

- Modified the wetlands application as specified by the wetlands mapping team, including the following:
  - Modifications to the plant community report.
  - Functional assessment data updates and modifications.
  - Updates to the soils report.
- Instituted minor changes in the wetlands website source code.
- Maintained documentation:
  - Updated the wetlands database ERDs.
  - Updated wetlands website diagrams.
  - Created/modified supporting technical wetlands documents.
- Set up access to wetlands data for statisticians.

Tasks and Activities for 2008

The approach and scope of work for the data management and GIS program in 2008 are the same as described for 2007, except as noted below.

The following additional activities will be performed to support the wetlands team:

- Modify camera scripts for new cameras to be used during field season.
- Produce maps to support wetlands field work and data compilations developed in support of wetlands determinations.
- Provide printing services for mapping team.
- Set up a computer network in Iliamna for wetlands field investigators.
- Assist wetlands field team in Iliamna in support of GIS data development.
- Maintain wetlands website and data to keep the wetlands website environments (development, test, and production) operating properly and to protect the integrity and security of the wetlands data contained in the database and website.

19.3.3 Website and Data Management

Website and data management includes building and maintaining a central data repository for the Pebble Project, providing web-based tools to enter and report on project data, and providing tools to allow the project team to upload their data into the project database. The website and database are designed to provide long-term storage of and access to baseline data.

The project website has been proven effective in facilitating project communications, document sharing, and data acquisition and management. Data quality and availability is ensured through the automated data acquisition strategy. The website will be further developed over the life of the project with added functionality in uploading, storing, and analyzing data. For example, in 2007, functionality was added to the project website to manage comments and responses, web mapping, and analysis tools; support

increased weather stations; produce maps for use in reporting and presentations; cross-reference field and laboratory data; and increase security of the Pebble Project data.

19.3.3.1 Objectives and Scope

The specific objectives of the website and data management activities are as follows:

- Enhance the functionality for managing Pebble Project comments from agencies and private individuals.
- Support web-based mapping, data analysis, and reporting.
- Increase the security of the Pebble Project data.
- Maintain the website, database, and software.

The general scope of work includes the following:

- Establishing standards for data format, content, and transfer.
- Supporting field operations through the development of web-based software for data entry, document management, project management (calendar, logistics tools, etc.), and mapping.
- Creating a process for managing the sampling process.
- Creating field forms for capturing field data.
- Creating cartographic map products (aside from those related to wetlands).
- Managing documents.

Proactively managing the data ensures accuracy and availability when needed. Data sources are provided with clear requirements for data deliverables, and software has been provided to verify compliance before delivery. Using this strategy, data are ready to load when transferred to the database team. Further, the RDI team uses the website to facilitate transmittals and to load data when they are detected by the system. The goal is to eliminate, or at least to minimize, manual data management activities.

RDI's data management and website maintenance approach is based on the methods and approach described in Section 19.2. In addition, the RDI team is able to develop new functionalities, as necessary, using the technology for the existing GIS database and website. For example, processes to facilitate capturing data in the master Pebble Partnership repository can be refined. Cartographic products can be generated in ArcGIS and be made available in digital format through the project website. Finally, GIS capabilities are built into the website to provide support for spatial query and analysis from any known user with Internet access.

19.3.3.2 Main Tasks and Activities

A wide range of tasks and activities are necessary to support and enhance the Pebble Partnership's data management system and website. The tasks and activities are described below.

Tasks and Activities for 2004

Task 1: Develop Website Framework. This task involved designing and implementing the core framework for the website. It included all website-design activities that take place before any coding occurs, including establishing the technology framework of servers, identifying software and standards for coding, and implementing details of this design.

Task 2: Create Data Access and Storage Systems. The data access and storage task involved creating a single database to house all required application information. The task included creating and implementing an "access layer" that all system components use to connect to and manipulate the database in a consistent, secure manner.

Task 3: Create Field Forms. Once the framework and data access/storage systems were in place, RDI technicians developed some high-priority applications to support field operations. These applications included a logistics form, contact list, and document repository. Of equally high priority was the sample-tracking application. After the first four applications were developed, the sample tracking application was developed. The latter application was designed to integrate with the data access/storage system created as part of Task 2, above.

Web-based field input forms serve as the input mechanism of the field crews into the central database of the data access/storage system. The forms to support water sampling (including sample labels, chain-of-custody (COC) forms, etc.) were a high priority. Additional forms have been created since 2004 to support other sampling efforts and types as the project has proceeded. Hardcopy field forms necessary for capturing input data were reconstructed from their paper form into a digital representation.

Task 4: Develop Document Repository. The document repository serves as a central location for the storage of all documents in the system. This repository is held in the project database and can be accessed and updated through an FTP site and through a comprehensive web-based search/retrieval mechanism. The work in 2004 included developing a search-retrieval mechanism for finding and downloading documents and data.

Task 5: Create Project Applications. This task consisted of creating project applications, as required. Project applications are any applications that have been predefined to be project-wide and accessible by all project members.

Task 6: Data Acquisition and Management. This task consisted of acquiring and managing data. It included designing and creating all necessary components for acquiring data from the project team and agencies, and for managing the data in a centralized database. Several components were developed, such as data source identification, analytical methods identification, deliverable compliance software, data delivery process, data source training, etc.

Data that cannot be entered from the field are delivered to the data management team for incorporation into the project database.

Task 7: Site Administration. Site administration involves creating an application control structure allowing administrative users access to configurable site elements. These include user management screens and database connection strings.

Task 8: Migrations. A migration plan was developed, which involved a comprehensive strategy for scheduling rollouts and testing during the early stages of the project.

Task 9: Website GIS. The GIS portion of the website is an ArcIMS-designed site capable of showing all portions of the study area. It also performs analysis based on spatial selections.

Tasks and Activities for 2005

In 2005, a main goal of the RDI team was to develop new functionality on the same technology as the existing Pebble Project website. Processes were developed to facilitate capturing the data in the master Pebble Partnership data repository. Cartographic products were generated in ArcGIS and were made available in digital format through the project website.

A wide range of tasks were conducted to add this functionality, as described below.

Task 1: E-Chain Integration. The project website was integrated with the E-Chain product. This integration resulted in management-level reporting capabilities, which could be used to provide an audit trail for tracking the Pebble Partnership's sampling process. The following activities required to complete the task:

- Developing a standard operating procedure (SOP)—collaborating with Shaw Environmental Inc. (Shaw) to write an SOP that defined how electronic COC forms and the Pebble Partnership database were to be integrated into sampling, shipping, and laboratory reporting.
- Modifying the project website to store E-Chain-generated data.
- Developing management-level reports for tracking the analytical data—creating a Chain of Command List Report and a Chain of Command Standard Report.

Task 2: Modify Field Forms. Additional field forms were added to the project website, and forms created during 2004 were modified. The following activities required to complete the task:

- New field form implementation—developing three new field forms for the Pebble Project website, including Habitat Survey Field Form, Habitat Morphology Data Card, and Transportation Corridor Survey Form.
- Existing field form management—coordinating with the 2004 field crews to update and refine the existing field forms used in 2004 to more closely match data that were actually tracked during the season.

Task 3: Modify Data Analysis Tools. Activities required to complete this task included developing a data-set report tool, to be driven by custom views created for outputting data sets needed for analysis.

Task 4: Cartographic Services. Maps and graphics were generated and provided as needed for use in meetings with agencies. Maps also were developed to be suitable for attaching as figures to the final documents.

Tasks and Activities for 2006

The RDI team continued to develop new functionality on the existing Pebble Project website. Processes developed to facilitate capturing the data in the master Pebble Partnership repository were refined. Cartographic products were generated in ArcGIS and were made available in digital format through the project website.

A wide range of tasks was conducted to develop this functionality, as described below.

Task 1: Enhance Document Repository. The following requested enhancements to the document repository were made:

- Add ability to move documents between folders.
- Add ability to rename folders.
- Improve upload and download speeds.

Task 2: Modify Analytical Data Loader. The following functionality was added to the data loader:

- The ability to upload .ZIP files, which facilitated the loading of very large files and improved performance for loading smaller data files.
- The ability to modify data without reloading data sets, which was accomplished by adding a new web module called a "Data Changer."
- Developing a standard environmental baseline document report, which included developing standard templates for use with the data extractor to ensure that report tables are output in a standard format for all contractors.

Task 3: Other Environmental Data. This task consisted of preparing the database to manage environmental data identified by Pebble Partnership and Shaw project managers. Project managers determined which data sets needed to be managed. After this step, reporting formats that define how the identified data sets must be formatted for database uploading were developed.

Task 4: Cartographic Services/GIS Data Management. Maps and graphics continued to be provided as needed for use in meetings with agencies and for preparing the final environmental baseline documents. The collection and distribution of GIS data from the consultants were also managed. Printed maps were provided.

Tasks and Activities for 2007

Additional refinements were made to the Pebble Project website and to the data management system in 2007.

Task 1: Comment and Question Management (CQM) System. The following requested enhancements were made to the CQM system:

- Create a user manual and an administrator's manual.

- Train Pebble Partnership personnel in use of the system.

Task 2: Web Mapping Analysis Tool. Under the guidance of the Pebble Partnership, the existing wetlands and other location-based information (sample locations) were refined.

Task 3: Pebble Project Data Security. A detailed security report and plan to increase the security of all data and documents were developed under the guidance of the Pebble Partnership.

Task 4: Cross-referencing for Field and Sample Data. All GPS data for samples and locations that have been collected by various contractors throughout the years were captured, and the ability to reference these to the analytical laboratory data was verified.

Task 5: Cartographic Services and GIS Data Management. Maps and graphics were provided as needed for use in meetings with agencies and for use in project documents. The collection and distribution of GIS data from the consultants also was managed. Map printing was provided.

Task 6: General Website and Data Maintenance. In addition to the tasks described above, the following maintenance activities were performed:

- Instituted minor changes in non-wetlands website source code.
- Conducted performance tuning and maintenance of the Oracle 9i database.

Tasks and Activities for 2008

The general approach and scope of work for data and website management program in 2008 are the same as those described for 2007, except as noted below.

The following additional activities were performed to support the environmental program:

- Audit GIS data management of all contractors, continued from 2007.
- Provide printing services to produce maps, as requested.
- Make enhancements to the CQM system.
- Continue training and support of staff for the CQM system.
- Modify website and database to reflect any weather data collection changes made by Hoefler Consulting Group.
- Support fisheries studies by providing GIS analysis and report compilation.
- Share management (RDI and Pebble Partnership) of data throughout 2008.
- Upgrade system and security, including replacing an old server with a new one.
- Continue data validity checks, software maintenance, and modifications in 2008.

19.4 References

United States Army Corps of Engineers. 2007. Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Alaska Region (Version 2). Wetlands Regulatory Assistance Program, Engineer Research and Development Centre (ERDC/EL TR-07-24). Washington, D.C.

TABLE

TABLE 19-1
Pebble Project Environmental Baseline Studies
Study Summary for Data Management, 2004-2008
Consultant: Resource Data, Inc.

Data Management Discipline	2004 Tasks Completed	2005 Tasks Completed	2006 Tasks Completed	2007 Tasks Completed	2008 Tasks Completed
GIS	Compile and Load Basemap Data				
	Load Pebble Project Data				
	Load Environmental Data				
		Extended Mapping	Extended Mapping	Extended Mapping	Extended Mapping
		Generate Accurate Native Allotment Data			
	Provide Cartographic Services	Provide Cartographic Services	Provide Cartographic Services	Provide Cartographic Services	Provide Cartographic Services
			Annual Software Maintenance	Annual Software Maintenance	Annual Software Maintenance
	General GIS Management Services	General GIS Management Services	General GIS Management Services	General GIS Management Services	General GIS Management Services
Wetlands Project	Acquire and Load Existing Wetlands Data				
	Wetlands Mapping Support (create layers,	Wetlands Mapping Support (load data, scrub	Wetlands Mapping Support (load data,	Wetlands Mapping Support (load data, scrub	Wetlands Mapping Support (load data,
		Wetlands Field Support (create field maps, photo reports, process data)	Wetlands Field Support (modify camera scripts, habitat mapping analysis)	Wetlands Field Support (installing computers for digitizing, training personnel, habitat mapping analysis)	Wetlands Field Support (installing computers for digitizing, training personnel, habitat mapping analysis)
		Design and Create Wetland Data Acquisition & Management Applications	Modify Wetland Data Applications	Modify Wetland Data Applications	Modify Wetland Data Applications
			Revise Website Functionality Consistent with USACE Wetland Delineation Manual: Alaska Region	Create Wetland Delineation COE Manual	Modify Camera Scripts.
	Initial Wetlands Website Framework / Application Design	General Wetlands Website Maintenance	General Wetlands Website Maintenance	General Wetlands Website Maintenance	General Wetlands Website Maintenance
Database & Website Management	Develop Website Framework				
	Create Data Access and Storage System	Database Support	Database Support	Database Support	Database Support
	Design Field Input Forms	Modify Existing Field Forms, Add New Forms	Field Form Modifications, Add New Forms	Field Form Modifications, Add New Forms	Field Form Modifications, Add New Forms
	Design Document Repository		Enhance Document Repository	Enhance Document Repository	Enhance Document Repository
	Design Initial Project Applications				
	Design and Create Data Acquisition & Management Applications	Modify Data Management / Data Analysis Applications	Modify Analytical Data Loader	Enhance Comment and Question Management System	Enhance Comment and Question Management System
	Site Administration	Site Administration	Site Administration	Site Administration	Site Administration
	Design Migration Plan		Acquisition of Additional Environmental Data / Develop Report Formats		
	Design Website GIS / Map			Refine Web Mapping Applications	Refine Web Mapping Applications
		Data Scrubbing	Data Scrubbing	Data Scrubbing	Data Scrubbing
		E-Chain Integration			
				Improve Cross-Referencing Between Field and Analytical Data	Improve Cross-Referencing Between Field and Analytical Data
Project Management	Project Planning	Senior Analysis	Senior Analysis	Senior Analysis	Senior Analysis
		Staff Meetings, Staff Management	Staff Meetings, Staff Management	Staff Meetings, Staff Management	Staff Meetings, Staff Management
		Status Reporting	Status Reporting	Status Reporting	Status Reporting