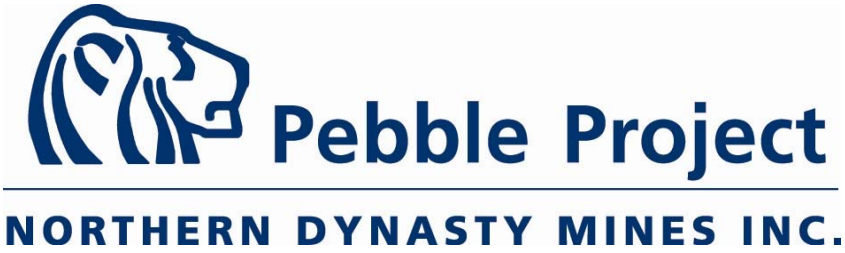

DRAFT ENVIRONMENTAL BASELINE STUDIES
2005 STUDY PLANS

CHAPTER 6. WATER CHEMISTRY

NOVEMBER 2005

TABLE OF CONTENTS

LIST OF TABLES

ACRONYMS

AASHTO	American Association of State and Highway Transportation Officials
ABA	acid-base accounting
ACHP	Advisory Council on Historic Preservation
ACL	alternative cleanup level
ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
ADNR	Alaska Department of Natural Resources
agl	above ground level
AHRS	Alaska Heritage Resource Survey
AKNHP	Alaska Natural Heritage Program
ANOVA	analysis of variance
APE	area of potential effect
AS	alpine rock and dwarf scrub habitat
ASCI	Alaska Stream Condition Index
ASTM	American Society for Testing and Materials
BEESC	Bristol Environmental & Engineering Services Corporation
BMR	baseline monitoring report
°C	degrees Celsius
CAD	computer-aided drafting
CC	comprehensive stations with continuous-stage monitoring
CIR	color infrared
CQ	continuous discharge
CWOC	comprehensive stations without continuous-stage monitoring
DECD	Alaska Department of Economic and Community Development
DEM	digital elevation model
DNR	Alaska Department of Natural Resources
DO	dissolved oxygen
DOT&PF	Alaska Department of Transportation & Public Facilities
DQOs	data quality objectives
EBD	environmental baseline document
EC	environmental consequences
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
FAA	Federal Aviation Administration

FHWA	Federal Highway Administration
FSP	field sampling plan
GIS	geographic information system
GPS	global positioning system
HDR	HDR Alaska, Inc.
HGM	hydrogeomorphic
IEE	Initial Environmental Evaluation
IM	initial monitoring station
L	liter(s)
LCNPP	Lake Clark National Park and Preserve
LDN	Land Design North
LM	lowland wet graminoid, moss meadow habitat
LS	lowland low and tall alder/willow scrub habitat
m	meter(s)
MCHTWG	Mulchatna Caribou Herd Technical Working Group
MDC	mine development concept
mg	milligram(s)
ML/ARD	metal leaching/acid rock leaching
mm	millimeter(s)
MODIS	moderate resolution imaging spectroradiometer
MRL	method reporting limit
µm	micrometer(s)
NASA	National Aeronautics and Space Administration
NDM	Northern Dynasty Mines Inc.
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NOAA	National Oceanic & Atmospheric Administration
NPS	National Park Service
NRCS	Natural Resources Conservation Service
NRHP	National Register of Historic Places
NWI	National Wetlands Inventory
ORP	oxidation reduction potential
PJD	preliminary jurisdictional determination
PSD	prevention of significant deterioration
psi	pounds per square inch
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control

RS	riverine willow scrub habitat
SHPO	State Historic Preservation Officer
SLR	SLR Alaska
SOP	standard operating procedure
SRB&A	Stephen R. Braund & Associates
SS	subalpine dwarf, low, and tall scrub habitat
SWE	snow/water equivalent
TIN	triangulated irregular network
TOC	total organic carbon
TPH	total petroleum hydrocarbons
UF	upland dwarf scrub, lichen flats habitat
US	upland dwarf, low, and tall scrub habitat
USACE	United States Army Corp of Engineers
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WMC	Water Management Consultants
WMP	water monitoring plan
WQ	water quality

6. WATER CHEMISTRY

HDR Alaska, Inc. (HDR), will lead the seep and surface water-quality data collection on the mine site; SLR Alaska Inc. (SLR) will collect the groundwater-quality data at the mine site, and Bristol Environmental and Engineering Services Corporation (BEESC) will collect the water-quality data for the road and port.

6.1 Mine Site

6.1.1 Objectives of Study

Water-quality baseline studies at the mine site will include collection and analysis of surface water, groundwater, and water from seeps. The main objectives of this study are as follows:

- Collect baseline data to provide defensible documentation of the naturally occurring levels and variability of trace elements in surface water, groundwater and sediments.
- Evaluate sources that could be used for mine make-up water.
- Provide a database for the site water-chemistry and site loading models for project design and environmental impact assessment.
- Develop the baseline for the evaluation of potential environmental impacts from construction, operation, and closure of the mine and associated facilities.

These studies will provide data on the surface-water and groundwater systems that can be linked with the physical flow data to provide estimates of baseline surface-water and groundwater load from the mineralized area to downgradient groundwater and surface-water systems.

The water-quality results will be used in the evaluation of the site geochemistry described in Chapter 8. This information is key to understanding current conditions and will provide a baseline for the evaluation of future potential environmental impacts during operation and closure. The baseline water-quality data are also important for determining if site-specific water-chemistry standards are required for waterbodies in the project area.

6.1.2 Proposed Study Plan

6.1.2.1 Study Area/Scope

The project area, including the deposit area and potential mine, mill, and tailings-disposal facilities, is drained by the north and south forks of the Koktuli River, Upper Talarik Creek, and tributaries of these waterbodies. The Kaskanak Creek watershed is located to the southwest of the project area and will also be monitored to identify potential interbasin transfer from the South Fork of the Koktuli River.

6.1.2.2 Methods/Approach

Water-quality monitoring will be conducted for surface water, groundwater, and seeps. Surface-water stations were selected to characterize the surface-water system for geochemical parameters, to establish baseline water chemistry, to provide data for fish habitat and resources studies, to document water chemistry in waterbodies in areas of water supply, and to document water chemistry in potential receiving waters.

To meet the project objectives, the following activities will be conducted:

- Sampling and analysis of naturally occurring constituents in surface water from each waterway to characterize the signature of natural conditions.
- Characterization of the natural statistical variance of the concentrations of naturally occurring elements in each system.
- Characterization of surface-water and groundwater baseline systems throughout the year under a range of hydrologic conditions to understand the seasonal changes throughout the year.
- Surface water-chemistry sampling under different hydrologic conditions to document variability of water chemistry with flow.

Northern Dynasty Mines Inc. (NDM) has appointed an Analytical QA/QC (quality assurance/quality control) Manager who is responsible for quality management for all laboratory programs. This will ensure both consistency among the various programs within the baseline study and that data-quality objectives are met for the program.

The sample collection and handling protocols for environmental baseline studies at the mine site are outlined in the *Draft Environmental Baseline Studies, 2005 Final Quality Assurance Project Plan* (QAPP; NDM, 2005) and the 2005 field sampling plans (FSPs) for surface-water quality, hydrology, sediment, and groundwater quality (HDR, in press; SLR, in press).

6.1.2.3 Major Activities

Major activities will include:

- Water-quality data from previous studies in the project area will be compiled and reviewed to evaluate the suitability of the existing data for planning purposes and to determine if it can be used to supplement the data that will be collected under the current program.
- Field studies will include collection of water-quality data for surface water, groundwater, and seeps and the collection of sediment-quality data.
- Data will be reviewed as part of the analytical QA/QC program and will be incorporated into the project database as discussed in Chapter 19.
- Evaluation of the water- and sediment-quality data will then be conducted.

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

Sample Site Selection

The selection of the sampling sites for water chemistry was done in conjunction with the selection of sites for surface-water hydrology sampling (Chapter 4), groundwater hydrogeology studies (Chapter 5), and aquatic studies (Chapter 11). A preliminary definition of alternative sites for the mine site, milling facilities, and associated waste-management facilities was provided by the engineering team for consideration in sample-site selection. This was used to locate stations that would be useful both for baseline characterization and, in the appropriate areas, to be maintained for operations and closure monitoring.

Field Studies, Surface-water Quality

The surface water-quality sampling is designed to quantify the water chemistry throughout the year and under a range of different hydrologic conditions at key surface-water locations. The surface water-quality sampling is designed to occur during breakup and six times in the summer when there is the greatest potential variation in water chemistry. As hydrologic conditions change (i.e., flows vary due to breakup and storm events), there is greater potential for varying water chemistry. During the winter, flows will gradually decrease as winter progresses and sampling is planned three times during this period. Late winter surface-water sampling is important because this represents minimum flows, which are most representative of base flow due to groundwater discharge. This results in nine planned surface-water monitoring events for the 12-month period from April to March.

Samples will be collected at 30 surface-water monitoring stations which are identified in Chapter 4, Surface-water Hydrology (Figures 4-3 through 4-7). Depth-integrated water-chemistry samples will be collected with a DH-81 sampler when possible. A detailed description of sampling procedures is presented in the FSP for surface water and sediment at the mine site (HDR, in press).

Surface water will be tested in the field for select parameters, and samples will be collected and sent to the selected independent external laboratory for chemical analyses. Field parameters include dissolved oxygen (DO), conductivity, pH, temperature, turbidity, and oxidation reduction potential (ORP). Laboratory samples will be analyzed for the water analytes listed in Table 6-1.

Samples will be collected from select monitoring stations during the two sampling events in August and October to be analyzed for organic constituents, including pesticides, volatile compounds, and semi-volatile compounds.

Field Studies, Sediment Sampling

Sediment will be collected in July from the following six lake locations:

- Frying Pan Lake and Big Wiggly Lake.
- Two new lake sites in the southern portion of the mine-site area and co-located with newly proposed fish-monitoring sites. Final locations to be determined.
- Two lake sites considered prime moose pond habitat and co-located with aquatic-vegetation sampling sites. Final locations to be determined.

TABLE 6-1
Surface-water and Sediment Analytes for Laboratory Determination

Water Analytes	
• Aluminum, total and dissolved	• Thallium, total and dissolved
• Antimony, total and dissolved	• Tin, total and dissolved
• Arsenic, total and dissolved	• Selenium, total and dissolved
• Barium, total and dissolved	• Silicon
• Beryllium, total and dissolved	• Vanadium, total and dissolved
• Bismuth, total and dissolved	• Zinc, total and dissolved
• Boron, total and dissolved	• pH
• Cadmium, total and dissolved	• Specific conductance
• Calcium, total and dissolved	• Alkalinity
• Chromium, total and dissolved	• Acidity
• Cobalt, total and dissolved	• Ammonia
• Copper, total and dissolved	• Chloride
• Iron, total and dissolved	• Cyanide-total
• Lead, total and dissolved	• Cyanide-WAD
• Magnesium, total and dissolved	• Fluoride
• Manganese, total and dissolved	• Hardness
• Mercury, total and dissolved	• Nitrate + Nitrite
• Molybdenum, total and dissolved	• Phosphorus-total
• Nickel, total and dissolved	• Sulfate
• Potassium, total and dissolved	• Total Dissolved Solids
• Silver, total and dissolved	• Total Suspended Solids
• Sodium, total and dissolved	• Thiocyanate
Sediment Analytes	
• 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	
• Hg	
• Total Cyanide	
• Chloride	
• Fluoride	
• Sulfate	
• Ammonia as N	

Lake samples will be collected from a boat in locations which are most likely for sediment deposition. Sediment will be collected using a dredge or core-sampling techniques.

Sediment samples will be collected from up to ten seep locations in July and October. Sediment samples will be located at a subset of the seeps where water-quality samples are collected in 2005.

Field Studies, Groundwater Quality

The groundwater-chemistry sampling goal is to quantify the water chemistry under seasonal hydrologic conditions at key locations in the project area. Four seasonal sampling events (March, May, August, and October) will be conducted for groundwater monitoring wells. Sampling events have been timed to include high groundwater levels in the spring and early fall, and low groundwater levels in summer and late winter. This approach is standard for baseline studies for other projects in Alaska.

The baseline groundwater samples will be collected from all monitoring wells installed in 2004 plus all wells installed in 2005 (as they become available). The selection of the locations of these wells is discussed in Chapter 5. Groundwater samples from the wells will be obtained using dedicated sampling pumps. Sample- and data-handling procedures will be the same as for surface water with the exception that groundwater samples for dissolved metals will be filtered with in-line filters immediately after collection in the field. The field parameters pH, specific electrical conductance, temperature, turbidity, and dissolved oxygen will be measured each time groundwater samples are collected (Table 6-2).

TABLE 6-2
Parameters for Field Determination

Parameter	Method (range)	Units	Detection Limit	Sensitivity	Precision	Accuracy
Depth to water	Electric sounder (0 to 100)	feet	NA	0.001	0.01	± 0.02
pH	pH meter (0 to 14)	pH units	NA	0.1	0.1	± 0.2
Electrical Conductance	Conductivity meter (0 to 100)	mS/cm	0.001	0.001	0.001 to 0.1 (range dependant)	± 0.5% + 0.001
Temperature	Thermometer (-5 to 45)	^{o}C	NA	0.1	0.1	± 0.15
Dissolved Oxygen	DO meter (0 to 50)	mg/L	0.2	0.01	0.01	± 2 % to 20 mg/L
Turbidity	Turbidity meter	NTU	0.01	0.01	0.01 to 1 (range dependant)	±2% of reading or ±1 least significant digit; ±3% of reading at 500 to 1000 NTU

All samples will be analyzed for a wide range of cations and anions (Table 6-3). Samples also will be analyzed for organic constituents, including pesticides/polychlorinated biphyenlys, volatile compounds, and semi-volatile compounds.

TABLE 6-3
Groundwater Analytes for Laboratory Determination

Analytes	
• Aluminum, total and dissolved	• Silver, total and dissolved
• Antimony, total and dissolved	• Sodium, total and dissolved
• Arsenic, total and dissolved	• Thallium, total and dissolved
• Barium, total and dissolved	• Tin, total and dissolved
• Beryllium, total and dissolved	• Vanadium, total and dissolved
• Bismuth, total and dissolved	• Zinc, total and dissolved
• Boron, total and dissolved	• pH
• Cadmium, total and dissolved	• Specific Electrical Conductance
• Calcium, total and dissolved	• Acidity
• Chromium, total and dissolved	• Hardness
• Cobalt, total and dissolved	• Alkalinity
• Copper, total and dissolved	• Sulfate
• Iron, total and dissolved	• Chloride
• Lead, total and dissolved	• Fluoride
• Magnesium, total and dissolved	• Ammonia
• Manganese, total and dissolved	• Phosphorus-total
• Mercury, total and dissolved	• Nitrate + Nitrite
• Molybdenum, total and dissolved	• Cyanide-total
• Nickel, total and dissolved	• Cyanide-WAD
• Potassium, total and dissolved	• Total dissolved solids
• Selenium, total and dissolved	• Total suspended solids

These analytical parameters have been selected to fulfill two purposes:

- To provide baseline values for possible contaminants.
- To provide general information on groundwater quality that can help with natural-attenuation assessments and the site-wide water balance.

The analytical method and MRL for each analyte are summarized in the 2005 quality assurance project plan (NDM, 2005).

Field Studies, Seep-water Quality

The objective of conducting a seep-sampling program is to document the water chemistry of water discharging from seeps or springs throughout the study area. These data are useful for interpreting the groundwater regime and assessing groundwater/surface water interaction. Eleven seep locations were sampled in 2004, but a seep survey will be conducted in January, March, and May 2005 to identify and map a more representative number of seeps and measure water chemistry and flow. This inventory will be reviewed to identify approximately 20 sampling sites for July 2005 and up to 40 sites for August and October 2005. Field parameters, water-chemistry, and flow measurements will be collected at these seep locations. Water-chemistry data will be used to establish geochemical signatures of the seeps.

Seep water will be tested in the field for select parameters, and samples will be collected and sent to the selected independent external laboratory for chemical analyses. Sample- and data-handling procedures and sample analyses will be the same as for groundwater.

Quality Management

The quality management program is defined in the QAPP (NDM, 2005) and in associated FSPs (HDR, 2005; SLR, 2005).

Data Evaluation

Data presentation and evaluation will include tabulating water-chemistry data and summarizing statistics of water-chemistry data, preparing plots of key analytical parameters and comparing results to water-chemistry criteria, presenting the spatial distribution of key analytical parameters, and evaluating flow and quality relationships where appropriate. These data will also be used as input data for the site baseline water-balance and water-chemistry (loading) models.

6.1.3 Deliverables

The results of the 2005 data collection effort will be compiled and presented to the agencies in the form of an environmental baseline document which will include tabulated data and interpretation of the results.

6.2 Groundwater Quality—Road/Port

6.2.1 Objectives of Study

The objective of the groundwater-quality studies in the road and port areas is to define the chemical characteristics of project area groundwater used for drinking water. At the port site, where ore concentrates may be temporarily stored and handled, there is potential for environmental impact to groundwater. The objective at the port site is to establish background concentrations of trace elements in groundwater.

6.2.2 Proposed Work Plan

6.2.2.1 Study Area/Scope

The study area will include the proposed road corridor between the Newhalen River and Cook Inlet, and the area surrounding the port site. More specifically, groundwater samples will be collected from existing water-supply wells in Iliamna, Newhalen, Nondalton, and Pedro Bay and possibly at other existing groundwater-well locations along the road corridor, if any exist.

6.2.2.2 Methods/Approach

One drinking water well from each village along or near the road corridor has been selected for groundwater sampling. Four wells were identified from discussions with local village corporations and governments. In each case, a well in the community with high usage was chosen. The following four

wells, shown on Figure 4-9 in Chapter 4, were sampled in July and October 2004 and will be sampled quarterly in 2005:

- Nondalton City Well
- Newhalen Public Well #2
- Iliamna Weathered Inn
- Pedro Bay Tribal Council Well

For each sample, water will be collected from a tap after running the water for several minutes. For the Nondalton and Newhalen wells, the water will be sampled from where it first leaves the wellhead, prior to chlorination. Water from the Iliamna and Pedro Bay wells is not treated. Groundwater will be tested for the same laboratory parameters as for surface water (Table 6-1). QA/QC protocols will follow procedures outlined in the QAPP (NDM, 2005). Temperature, pH, conductivity, dissolved oxygen, turbidity, and ORP will be measured in the field at the time the sample is collected.

6.2.2.3 Major Activities

Major activities include the following:

- Research, compile, document, and review existing groundwater data for the area.
- Select one well from each community as an indicator well.
- Collect quarterly groundwater samples from each well.
- Report results in an environmental baseline document.

6.2.3 Deliverables

An environmental baseline document will be prepared and will include a discussion of results, trends, and variations.

6.3 Surface-water Quality—Road/Port

6.3.1 Objectives of Study

The objective of the surface water-quality studies is to define the chemical characteristics of fresh-water surface streams that could be potentially impacted by the future road and port facilities. The baseline data will be used to evaluate and monitor potential impacts associated with construction, operation, and maintenance of road and port facilities.

6.3.2 Proposed Work Plan

6.3.2.1 Study Area/Scope

The study area will include the preferred road corridor—as identified by the Alaska Department of Transportation and Public Facilities—between the Newhalen River and Cook Inlet, and the area surrounding the port site (Figure 4-9 in Chapter 4).

6.3.2.2 Methods/Approach

In 2004, 16 sampling stations were established on stream crossings along the road corridor. Streams near villages and anadromous streams were targeted in particular for regular sampling. Sample locations were determined in coordination with locations chosen for fish studies. The water-sampling locations coincided with monitoring stations used for the hydrology study and included most streams listed in the State's Title 41 anadromous stream catalogue.

For 2005, eight of these stations will be sampled on a monthly basis beginning in February and continuing through October. Water-sampling procedures will remain the same as those used during 2004 and will be coordinated to ensure consistency between sampling at the mine site and along the road corridor.

Surface water will be tested in the field for dissolved oxygen, conductivity, pH, ORP, temperature, and turbidity. Surface-water samples will be collected as composite samples using a DH-81. Detailed sampling procedures are outlined in the FSP for surface-water studies in the road/port areas (BEESC, 2005).

Surface water samples will be tested for the laboratory analytes presented in Table 6-1. QA/QC protocols will follow procedures outlined the QAPP (NDM, 2005) and in the FSP for surface-water studies in the road/port areas (BEESC, 2005).

6.3.2.3 Major Activities

Major activities are as follows:

- Research, compile, document, and review existing surface-water data for the area.
- Collect monthly surface-water samples from each established surface-water sampling location between February and October.
- Report results in an environmental baseline document.

6.3.3 Deliverables

An environmental baseline document comparing all monthly data will be prepared and will include analysis and discussion of results, trends, and variations.

6.4 References

Bristol Environmental and Engineering Services Corporation (BEESC). 2005. Surface-water and Sediment Studies, Road/Port, 2005 Field Sampling Plan. Prepared for Northern Dynasty Mines Inc.

HDR Alaska Inc. (HDR).2005. Surface-water Quality, Hydrology, and Sediment, Mine Area, 2005 Field Sampling Plan. Prepared for Northern Dynasty Mines Inc.

Northern Dynasty Mines Inc. (NDM). 2005. Draft Environmental Baseline Studies, 2005 Final Quality Assurance Project Plan.

SLR Alaska (SLR). 2005. Groundwater Studies for Mine Area, 2005 Field Sampling Plan. Prepared for Northern Dynasty Mines Inc.