Pebble Project

NORTHERN DYNASTY MINES INC.

DRAFT ENVIRONMENTAL BASELINE STUDIES
2004 PROGRESS REPORTS

CHAPTER 4. SURFACE WATER HYDROGEOLOGY

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ACRONYMS

AASHTO	American Association of State and Highway Transportation Officials
ABA	acid-base accounting
ac-ft	acre-feet
ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
ADNR	Alaska Department of Natural Resources
agl	above ground level
AHRS	Alaska Heritage Resource Survey
ALS	ALS Environmental Laboratory
ANCSA	Alaska Native Claims Settlement Act
AP	acid potential
APE	area of potential effect
ASCI	Alaska Stream Condition Index
ASTM	American Society for Testing and Materials
ASTt	Arctic Small Tool tradition
BBNA	Bristol Bay Native Association
BEESC	Bristol Environmental & Engineering Services Corporation
bgs	below ground surface
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
BP	before present
BTEX	benzene, toluene, ethylbenzene, and xylenes
ºC	degrees Celsius
^{14}C	Carbon 14
CEMI	Canadian Environmental and Metallurgical Laboratory
cfs	cubic feet per second
CIRCAC	Cook Inlet Regional Citizens Advisory Council
cm	centimeter(s)
CPUE	catch per unit effort
CQ	continuous flow
CRM	cultural resources management
CUEQ%	copper equivalent grade
DEM	digital elevation model
DI	deionized
DOT&PF	Alaska Department of Transportation and Public Facilities

DRO	diesel-range organics
EBD	environmental baseline document
EIS	environmental impact statement
EPT	Ephemeroptera, Plecoptera, or Trichoptera
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FL	fork length
fps	feet per second
FR	Federal Register
ft	foot (feet)
ft^2	square foot (feet)
g	gram(s)
GIS	geographic information system
GLM	general linear model
GMU	Game Management Unit
gpm	gallons per minute
GPS	global positioning system
GRO	gasoline-range organics
GS	gauging station
HC-3	high-gradient, contained channel
HDR	HDR Alaska, Inc.
HGM	hydrogeomorphic
HWM	high-water mark
ICP	inductively coupled plasma
IIE	Iniskin/Iliamna Estuary
IQ	instantaneous flow
KC	Kaskanak Creek
kg	kilogram(s)
km^2	square kilometers
KP	Knight Piesold
KR	Koktuli River Main Stem
L	liter(s)
LC-1	low-gradient, contained channel
LIDAR	light detection and ranging
m	meter(s)
m^2	square meter(s)
M.A.	Master of Arts

MC-1	moderate-gradient, narrow, shallow, contained channel
MCHTWG	Mulchatna Caribou Herd Technical Working Group
MDC	mine development concept
MDL	method detection limit
me-Hg	methyl-mercury
MEND	mine environment neutral drainage
mg	milligram(s)
mi^2	square mile(s)
ml	milliliter(s)
ML/ARD	metal leaching/acid rock drainage
MLLW	mean lower low water
mm	millimeter(s)
MM-1	moderate-gradient, mixed-control channel
MMS	Minerals Management Service
MODIS	moderate resolution imaging spectroradiometer
mph	miles per hour
MRL	method reporting limit
m/s	meters per second
µg	microgram(s)
µL	microliter(s)
µmhos	micromhos
NASA	National Aeronautics and Space Administration
ND	non-detect
NDM	Northern Dynasty Mines Inc.
NEPA	National Environmental Policy Act
ng	nanogram(s)
NK	North Fork Koktuli River
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NP	neutralization potential
NPS	National Park Service
NRCS	Natural Resources Conservation Service
NRHP	National Register of Historic Places
Nv	calculated variance
NWR	National Wildlife Refuge
OCSEAP	Outer Continental Shelf Environmental Assessment Program
OHMP	Office of Habitat Management and Permitting
OHW	ordinary high water

PA-1	narrow, placid-flow habitat
PA-3	shallow-ground, water-fed slough
PA-5	palustrine beaver habitat
PAG	potentially acid-generating
PJD	preliminary jurisdictional determination
PSD	Prevention of Significant Deterioration
PVC	polyvinyl chloride
Q	discharge
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
RBP	Rapid Bioassessment Protocols
RRO	residual-range organics
SHPO	State Historic Preservation Officer
SK	South Fork Koktuli River
SLR	SLR Alaska
SRB&A	Stephen R. Braund & Associates
SRK	SRK Consulting (Canada) Inc.
SVOC	semivolatile organic compound
SWE	snow/water equivalent
3PP	Three Parameters Plus
TDS	total dissolved solids
TOC	total organic carbon
TSS	total suspended solids
UAF	University of Alaska Fairbanks
USACE	U.S. Army Corps of Engineers – Regulatory Branch
USC	United States Code
USDA	United States Department of Agriculture
USDI	United States Department of Interior
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UT	Upper Talarik Creek
VHF	very high frequency
VOC	volatile organic compound
WMC	Water Management Consultants Inc.
WRIR	water-resources investigations report
WY	water year

4. SURFACE-WATER HYDROLOGY

4.1 Mine Site Surface Water

This section presents the findings of the 2004 surface-water hydrology study at the Pebble Project mine site. It summarizes data collected in 2004 as part of the baseline study program and evaluates future needs based on data gaps that are noted. Hydrologic data were also collected by Cominco, Ltd., for the Pebble Project for various periods between 1991 and 1993. These data are expected to be integrated into a future environmental baseline document, but are not included in this discussion of the 2004 data collection effort.

4.1.1 Introduction

Surface-water data were collected from April to October 2004. The study results will be included in the environmental baseline document and are expected to be used for design of and permit applications for construction, operation, and closure of the proposed long-life, large-scale, open-pit gold-copper mine and related infrastructure.

The information presented is the result of a combination of data-collection efforts by CH2M Hill, Inc.; HDR Alaska, Inc. (HDR); and the U.S. Geological Survey (USGS). The USGS data are considered *provisional* until published by the USGS. Similarly, HDR will perform additional quality assurance checks on the remainder of the data before considering the results final in the environmental baseline document.

4.1.2 Study Objectives

Objectives of the baseline surface-water hydrology study include data collection for the following:

- Characterization of current surface-water resources.
- Project design, including water-management and water-supply structures.
- Evaluation of potential environmental impacts during mine construction, operation, and closure.
- Support for assessments of aquatic resources, fish resources, and wetlands habitat.

This baseline study provides physical flow information for surface-water systems in the vicinity of the proposed mine, mill, and tailings-disposal facilities. The surface-water hydrology study is interfacing with a concurrent groundwater baseline study (discussed in Section 5) to assist with the evaluation of gaining and losing reaches of the various drainages. Surface-water flow data will be used by the surface-water-quality program to provide estimates of baseline surface-water load from the mineralized area to down-gradient surface-water systems. Surface-water flow data will also be used in the water balance model being developed for the project area. This information will allow description of current conditions and will provide a baseline for the evaluation of potential future impacts during operation and closure.

Groundwater monitoring and water-quality monitoring are addressed in separate sections (Section 5 and Section 6, respectively) of the 2004 progress report.

4.1.3 Study Area

Northern Dynasty Mines Inc. (NDM) is proposing to develop the Pebble Project, located in southwestern Alaska, about 18 miles northwest of the town of Iliamna. The project-area watersheds are shown in Figure 4-1. The project study area, including the ore body and potential mine, mill, and tailings-disposal facilities, is drained by the north and south forks of Koktuli River, Upper Talarik Creek, and tributaries of these waterbodies. These drainages are shown in Figure 4-2. The Kaskanak Creek watershed is southwest of the ore body and was monitored to identify potential interbasin transfer from the South Fork of Koktuli River. Kaskanak Creek drains to the Kvichak River below Iliamna Lake. These streams within the project-area drainage are part of the Nushagak or Kvichak river watersheds. The project-area watersheds encompass 361 square miles, including the mineralized area, and are shown in Figure 4-2. The long-term mean annual precipitation in the mine-site area is estimated to be 34.1 inches (87 centimeters), of which approximately 30 percent falls as snow (Knight-Piesold, 2004).

4.1.4 Scope of Work

The research and field work for this study were conducted during 2004. Most of the study (April through September) was conducted by CH2M Hill, Inc.; HDR completed the study tasks during the remainder of the 2004 calendar year. The following field work was performed in 2004:

- Installation of pressure transducers and dataloggers at 11 stations in July 2004 on the Koktuli River, north and south forks of Koktuli River, Upper Talarik Creek, and Kaskanak Creek. (The USGS installed three stations in August 2004.)
- Measurement of instantaneous discharge at most of the 29 stations (including 11 continuous stations) during monthly field visits between April and October 2004. Some instantaneous measurements could not be made because of dangerous high-water conditions. The USGS measured instantaneous discharge on its three stations between August and October 2004.

Data collected during the 2004 field season were assembled for the following purposes:

- To develop a stage-discharge relationship at each continuous recording station and to calculate a continuous discharge record.
- To evaluate results of the discharge record and other field observations.

4.1.5 Methods

4.1.5.1 Site Selection and Nomenclature

Data were collected in accordance with the *Draft Environmental Baseline Studies, Proposed 2004 Study Plan* (NDM, 2004b), and the *Field Quality Assurance Plan for Baseline Environmental Studies* (NDM, 2004a). Surface-water-hydrology monitoring stations were selected with consideration of a number of hydrologic criteria, including the following:

- Surface waterbodies that have the potential to be affected by project activities.
- Locations upstream and downstream of potential mine facility locations.

- Major water courses that may be crossed with streams of hydrologic importance (stations to provide data on groundwater and surface-water interactions).
- Streams that could be potential receiving waters for releases from the project.
- Stations that coincide with historical (Cominco) monitoring stations and the information obtained from those studies and related literature.
- Waterbodies in areas of potential water supply.

Additionally, selection and development of station locations was a coordinated process involving the engineering design team and other monitoring program teams, including those studying water chemistry, fisheries and aquatic resources, and sediment and trace metals. Through this process, 14 sites were selected for continuous flow monitoring. The USGS installed its standard stream-gauging equipment at three of these 14 sites. The conceptual-level understanding of surface and groundwater regimes and the preliminary project alternatives for facilities were used to help define the surface-water monitoring program. The locations of the surface-water monitoring stations and their associated watersheds are shown in Figure 4-3 through 4-7 and are listed in Table 4-1.

Surface-water-site nomenclature is as follows:

- KC = Kaskanak Creek
- KR = Koktuli River Main Stem
- NK = North Fork of Koktuli River
- SK = South Fork of Koktuli River
- UT = Upper Talarik Creek
- Main stream channels are designated as 100, and each tributary stream is numbered sequentially starting at the mouth and moving upstream (101, 102, . . . 135, 136, etc.).
- Each stream identification number was followed by a sequential (from mouth moving upstream) sample-site identifier letter (A, B, C, etc.).

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

TABLE 4-1
2004 Available Data from Surface-water Monitoring Sites

Location ID	USGS Site	Type	Rationale	Datalogger Installed
North Fork Koktuli River				
NK100C	—	CQ	NK "basin" integrator for NK headwaters	July 2004
NK119A	—	CQ	Downstream of G tailings site	July 2004
NK119B	—	INITIAL	Drains "back side" of ore body	
NK100A	yes	CQ	Lower main stem NK near SK confluence	August 2004
NK100B	—	IQ	Downstream of mine development concept (MDC) Option G; integrates NK100C and NK100A.	
South Fork Koktuli River				
SK136B	—	INITIAL	Drains ore body	
SK136A	—	INITIAL	Drains ore body	
SK134A	—	INITIAL	South of ore body (control)	
SK133A	—	INITIAL	South of ore body (control)	
SK100G	—	CQ	Upper main stem; integrates mine/mill; outside MDC Options A and J; upstream of Frying Pan Lake; same reach as Cominco Stations 6 and 14	July 2004
SK131A	—	IQ	Drains Koktuli Mountain; control stream	
SK100F	—	CQ	Main stem downstream of Frying Pan Lake (poss. sink); same Reach as Cominco CQ Station 17	July 2004
SK100D	—	INITIAL	Main stem downstream of flow loss; Cominco Station 5	
SK100C	—	CQ	Main stem downstream of MDC Options A and J; upstream of flow gain; Cominco CQ Station 16	July 2004
SK119A	—	CQ	Tributary downstream of MDC Options A and J; flow to aquifer recharge-discharge area; Cominco Stations 18 and 20	July 2004
SK100B	yes	CQ	Main stem downstream of MDC Options A and J; downstream of flow gain	August 2004
SK100A	—	CQ	Lower main stem South Fork Koktuli near confluence with North Fork Koktuli	July 2004
Upper Talarik Creek				
UT100E	—	CQ	Upper reach of Upper Talarik Creek; downstream of potential flow gain from North Fork Koktuli; upstream of drainage from ore body; control for MDC options; same reach as Cominco Station 8	July 2004
UT146A	—	IQ	Drains ore body; headwaters in mineralized zone	
UT141A	—	INITIAL	Low point for new drainage north of MDC Options A5 and J5, mine area; added Q to UT	
UT100D	—	CQ	Integrates all Upper Talarik Creek from mine, mill, embankment impacts for MDC Option A5; Cominco CQ Station 13	July 2004
UT138A	—	IQ	Drains "Pig"	
UT135A	—	INITIAL	Major Upper Talarik Creek tributary near confluence with main stem of Upper Talarik; winter flow contribution; Cominco CQ Station 19	

Location ID	USGS Site	Type	Rationale	Datalogger Installed
UT119B	—	INITIAL	Downstream of flow gain from South Fork Koktuli and MDC J-Options sites	
UT119A	—	CQ	Integrates mine/mill groundwater impacts on Upper Talarik Creek from reduced flow from South Fork Koktuli for MDC J Options; water-quality and biological sampling.	July 2004
UT100B	yes	CQ	Lower reach of Upper Talarik Creek; downstream of UT-1.190 impacts; downstream of mineralized zone	August 2004
UT100A	—	INITIAL	Downstream of mineralized zone; integrates all of Upper Talarik Creek	
Kaskanak Creek				
KC100A	—	CQ	Evaluate potential interbasin transfer of water from South Fork of Koktuli River	July 2004
Main Stem Koktuli River				
KR100A	—	IQ	Integrates north and south forks of Koktuli River; lowest watershed site	

CQ = continuous flow
IQ = instantaneous flow
INITIAL = selected for specific monitoring purposes, and may or may not continue to be sampled

The 11 sites where CH2M Hill installed dataloggers were SK100A, SK100C, SK119A, SK100F, SK100G, NK100C, NK119A, KC100A, UT100D, UT100E, and UT119A. The three sites for the USGS installations (SK100B, NK100A, and UT100B) were determined during the May 2004 field trip. Table 4-2 provides details about these three stations.

TABLE 4-2
Local USGS Stream-gauge Locations

USGS Station Number	NDM Site ID	Datalogger Installed	Parameter
15302250	NK100A	August 2004	Stage discharge
15302200	SK100B	August 2004	Stage discharge
15300250	UT100B	August 2004	Stage discharge

4.1.5.2 Equipment and Installation

Dataloggers used for this project were MiniTROLL units manufactured by In-Situ, Inc. Each datalogger was designed to record water depth and water temperature. A 5-pound-per-square-inch (psi) pressure transducer within the MiniTROLL unit recorded changes in water surface elevation and has an accuracy rating to 0.01 feet. The units were set to observe water depth and temperature on a one-minute interval. One-minute observations were recorded only for changes in water depth of 0.01 foot or greater; however, observations were recorded every 10 minutes, regardless of changes in water depth. Temperature was recorded for every depth recording. The units were installed by driving a steel angle iron into the streambed until the angle was solidly anchored. In most cases, this depth constituted approximately two feet. A prefabricated polyvinyl chloride (PVC) housing shell was connected to the angle at the channel bottom with steel clamps. PVC conduit was then installed above the housing, and the MiniTROLL unit was placed in the housing with the cable secured in the conduit. A junction box to protect the cable connection was installed at the top of conduit. The top of the PVC housing remained open, and holes were drilled in the sides of the PVC to allow free water pressure over the sensors.

4.1.5.3 Field Methods

A channel cross-section was surveyed at each datalogger installation. Two or three temporary benchmarks were established at each site to provide local datums for vertical control. A minimum of one temporary benchmark on each bank defining the cross-section was established. Cross-section distances were measured with a survey tape, and a survey level was used for vertical measurements. The datalogger was tied to the surveyed cross-section by surveying the elevation of the top of the steel of the angle post and the water-surface elevation at the angle post.

Instantaneous discharge measurements were collected monthly at each sampling location. Exceptions to this process occurred because of high water, which was considered too dangerous to wade. In a few cases, measurements were not collected because of equipment malfunctions. Instantaneous measurements were collected based on the procedures defined by the USGS (Rantz et al., 1982) and the *Field Quality Assurance Plan for Baseline Environmental Studies* (NDM, 2004a). Both Price AA- and Marsh McBirney-type flow meters were used, depending on stream depths and velocities. All measurements were taken by using top-setting wading rods. During the spring of 2004, snow and ice were removed from banks as required to provide a suitable cross-section for measurement.

4.1.5.4 Data Analysis

The USGS has analyzed its data and converted it into provisional discharge for use in this report. The procedures described below were used to analyze the data collected by CH2M Hill and HDR.

The raw data were downloaded from the dataloggers during monthly trips to the sites. The values reported from the dataloggers were date, time, elapsed time (seconds), channel temperature, and channel pressure (feet of water) for the periods between trips to the sites.

The date, time, and channel pressure for each period of record were copied and pasted into a single file for data analysis and adjustment. “Adjusted stage” was created by adding the datalogger depth value recorded at the time of installation to each channel-pressure reading, thereby ensuring that all stage readings would be positive values.

As is typical for electronic dataloggers, the continuously recorded data experienced an electronic drift or shift in measurements over time. The magnitude of drift was calculated by comparing the transducer-elevation values recorded during each monthly site survey with the value recorded on the installation date. According to accepted industry practice, the total drift was divided by the number of days, and an estimated shift in the datalogger for each day was established. This daily shift was added to each of the adjusted-stage data readings and recorded as a shifted-stage value.

The date and time of the monthly instantaneous discharge measurement corresponded, within a few minutes, to a channel-pressure reading recorded by the datalogger. In this way, the pressure readings from the datalogger could be compared to the actual flow of the stream. For each field trip in July, August, September, and October, the instantaneous discharge measurement was plotted on the Y axis of a logarithmic graph, and the stage (the shifted-stage value corresponding to that measurement) was plotted on the X axis of a logarithmic graph. For the majority of the gauges, this plot resulted in four points. These four points were used to develop a logarithmic trend line, or stage-discharge rating curve, through the data. The equation of the logarithmic trend line was calculated for application to the continuous-stage data. The equation was applied to the continuous shifted-stage values to find Q, or discharge, at every time step.

Once the Q for every datalogger reading was established, the data were separated into monthly groups. In this format, the daily and monthly means for each continuous surface-water station were calculated and graphed. This analysis followed the accepted practice for displaying hydrologic data by separating the data into water years (WY). 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 facilitate comparison of flows at different stations or of flow regimes between watersheds, it is useful to normalize the flow by dividing by drainage area upstream of the station. Minimum mean daily discharge per unit area was calculated by finding the lowest mean daily value, which was accomplished with the use of a geographic information system (GIS) to find drainage areas of surface-water stations and lengths of stream segments between stations.

4.1.6 Results and Discussion

4.1.6.1 Results

This analysis focuses on the farthest downstream continuous stations on each drainage (NK100A, SK100A, UT100B, and KC100A), although other upstream gauges also demonstrated important results that are discussed below. Mean daily discharge graphs are provided in Figures 4-8 through 4-11.

The data from two gauges installed by CH2M Hill in July, at SK100A and KC100A, show a fairly flat and continuously decreasing hydrograph until an event in mid- to late September 2004 (Figures 4-9 and 4-11, respectively). Data from two gauges installed by the USGS in August, at NK100A and UT100B, also show the same decreasing hydrograph until mid- to late September (Figures 4-8 and 4-10, respectively). The instantaneous discharge measurements at all stations show this same trend toward decreasing stream discharges in the summer months. In late September, the data from continuous gauges show a large spike in the hydrograph. Most gauge data show a 100 to 700 percent increase in discharge, although SK100A only shows a 20 percent increase (Figure 4-9). The rest of the period of record is indicative of minor storms throughout October, and these data sustain the hydrographs well above the summer level. During the preparation of the draft environmental baseline document, precipitation data will be correlated with the 2004 surface-water hydrology data.

Field crews were unable to measure instantaneous discharge during dangerous high-water conditions and because of equipment malfunctions, which in some cases, limited the number of points on the rating curve. In future field work and when safe to do so, field crews will obtain high-water instantaneous discharge measurements from a boat. Backup instrumentation has been added to the field program to avoid future data gaps resulting from equipment failure.

The mean monthly discharge (in cfs) graphs, Figures 4-12 to 4-15, generally show values for July and August that are lower than those for September and October. The September means were influenced by one large event in the later part of the month, whereas several lesser events occur throughout October.

Mean monthly runoff (in acre-feet [ac-ft]) was calculated for each farthest downstream station in each watershed (Figure 4-16). These data also present a trend of lower runoffs reported in July and August, and substantial increases in runoff in September. Data for Kaskanak Creek (KC100A) are consistently the lowest values, a result that was expected because the Kaskanak Creek watershed is the smallest of those studied. The mean monthly runoff values at SK100A, shown in Figure 4-16, for August and September for the South Fork of Koktuli River are relatively similar in magnitude. These data from the lower reaches of the South Fork Koktuli do not reflect an increase in discharge similar to that which is evident for the lower reaches of the North Fork Koktuli River and Upper Talarik Creek. The data collected from the South Fork Koktuli River create a more stable hydrograph for the period of record and show a very small response to the precipitation event in late September. However, the reader should note that this statement is weakened by the fact that 2004 rating curve at SK100A does not contain a measurement of peak flow. The absence of peak flow values for the rating curve may be responsible for an underestimation of discharge—and a reported attenuated discharge at SK100A—during the fall freshet. Field measurements of peak flows, which should clarify these results, are expected to be obtained during the 2005 field season.

The analysis of minimum mean daily discharge per unit area shows a normalized discharge from the headwater station to the farthest downstream station (Table 4-3 and Figures 4-17 to 4-19). The results show that each watershed demonstrates a unique pattern of normalized discharge, and these patterns indicate the location and magnitude of gaining and losing surface-water reaches under baseflow conditions. The North Fork Koktuli River exhibits similar unit discharge from the downstream station NK100A to NK100B (Figure 4-17). A spike is seen in the area of NK119A, indicating a gaining reach. Upper Talarik Creek is relatively steady to station UT100B, at which point a downward trend indicates a losing reach until upstream of UT100D (Figure 4-19). UT100C discharge was calculated by subtracting the discharge from UT119A (tributary) from UT100B. Data for the South Fork Koktuli River produce the most dynamic graph (Figure 4-18), in which the discharge per unit area varies greatly between reaches. Only at SK136A does the graph indicate a value near that of SK100A; all other stations indicate more of a losing pattern. Losing reaches are most prominent between the outlet of Fying Pan Lake (SK100F) and SK100C.

TABLE 4-3
Analysis of Discharge per Unit Area

Station	Minimum Mean Daily Discharge (cfs)	Drainage Area (mi^2)	Discharge Per Unit Area (cfs/mi^2)	Distance Upstream (ft)
NK100A	62.0	110.30	0.56	0
NK100B	22.0	39.27	0.56	91,877
NK119B	5.0	4.06	1.23	95,842
NK119A	5.0	8.57	0.58	100,148
SK100A	98.0	114.79	0.85	0
SK100B	38.0	77.08	0.49	64,462
SK100C	0.0	36.87	0.00	92,964
SK100D	2.04	16.46	0.12	97,441
SK100F	6.75	11.97	0.56	118,036
SK100G	2.07	5.32	0.39	128,456

Station	Minimum Mean Daily Discharge (cfs)	Drainage Area (mi^2)	Discharge Per Unit Area (cfs/mi^2)	Distance Upstream (ft)
SK136A	0.9	1.32	0.68	136,718
SK136B	0.23	0.59	0.39	143,245
UT100A	114.0	101.6	1.12	0
UT100B	94.9	85.89	1.10	31,225
UT100C (calc)	69.7	82.07	1.16	32,525
UT100D	7.9	17.16	0.46	108,438
UT100E	3.9	2.71	1.44	131,280
KC100A	17.3	28.65	0.60	

cfs = cubic feet per second

mi^2 = square mile(s)

ft = feet

4.1.6.2 Discussion

The flat and decreasing hydrographs suggest that snowmelt sources of runoff had a decreasing influence on the hydrograph or all snowmelt had occurred before gauge installation. They also indicate that there was little or no precipitation from the time of installation until mid- to late September. During these summer dry periods, it is assumed that the streams studied approach a base flow condition in which the only contributing flows are from groundwater interception.

The large spike shown in mid- to late September allows a comparison of different watershed responses to precipitation events. As noted above, the data from most gauges show a 100 to 700 percent increase in discharge, but data from SK100A only show a 20 percent increase (Figure 4-9). This result suggests either a convective thunderstorm that had decreased intensity in the watershed of the South Fork Koktuli River or the presence of a drainage basin morphometry or lithology that lends itself to lower-peak, longer duration events. In late July to late September, the mid-section of the South Fork Koktuli River, around SK100C, was reported to be dry with no surface-water discharge. Upstream (at SK100D) and downstream (at SK100B) of this reach, the channel was flowing with low flows, suggesting a losing reach in the mid-section of the South Fork Koktuli River, near SK100C. These data may help explain the lower peak of the SK100A hydrograph. As precipitation fell on the South Fork Koktuli River watershed, the peak was diminished by losing reaches in the water course from headwater to mouth. This losing reach is expressed again in the relevant graph of minimum mean daily discharge per unit area (Figure 4-18). Upstream of, and relative to SK100A, the stream is losing and reaches its lowest normalized discharge at SK100C. The data indicate that the water course between SK100F and SK100C presents a possible location of interbasin transfer; the losing reach may be contributing water to the Kaskanak Creek watershed or the Upper Talarik Creek watershed.

4.1.7 Summary

The project study area, including the mineralized area and potential mine, mill, and tailings-disposal facilities, is drained by the north and south forks of Koktuli River, Upper Talarik Creek, and tributaries of these waterbodies. The Kaskanak Creek watershed was included as part of the study area to determine if there is interbasin transfer of water from the South Fork Koktuli River drainage. This baseline hydrology study provides physical flow information for surface-water systems in the project study area. Continuous data were collected with pressure transducers and dataloggers at 14 stations on the north and south forks of Koktuli River, Upper Talarik Creek, and Kaskanak Creek, including at three stations operated by the USGS. Instantaneous discharge was measured at 29 stations (including the 14 continuous stations) during monthly field visits between April and October 2004. Stage-discharge relationships were developed at each continuous station to calculate a continuous-discharge record. Mean daily and mean monthly discharge, mean monthly runoff, and minimum mean daily discharge per unit area were calculated at each continuous station to demonstrate the different characteristics and potential interaction of these watersheds.

Some interesting phenomena were observed during an initial analysis of the 2004 data; most significantly, the location and characterization of gaining and losing reaches was documented. The watershed of the South Fork Koktuli River is unique in that it includes reaches with a dry surface channel in late summer. The presence of the dry channels signifies the presence of losing reaches, and future efforts will focus on understanding this scenario

The stage-discharge relationship that was developed from the 2004 data was weakened by the absence of instantaneous discharge data during high-flow periods. Future studies of surface-water hydrology will attempt to fill this data gap during both spring freshets and storm-discharge events.

4.2 Mine Area Snow Distribution Surveys

4.2.1 Introduction

This section presents the findings of the 2004 snow survey and distribution-mapping study conducted by ABR, Inc. This information should be treated as preliminary. The final results and modeling for the survey will be presented at a future date.

4.2.2 Study Objectives

This study is designed to compliment concurrent surface-water hydrology studies by characterizing the distribution, snow/water equivalent (SWE), and ablation rates of late-season (pre-breakup) snow across the landscape of the mine region. This information on winter precipitation and its contribution to surface water in the area will be critical for the design of tailings-storage areas and water-management plans for the mine. Specific objectives of this study include the following:

- Produce a map of late-season snow distribution using data from field surveys, terrain characteristics, and MODIS (moderate resolution imaging spectroradiometer) satellite imagery.
- Produce a map of snowpack ablation rates from field-survey data, terrain characteristics, and climate data.
- Provide paired field measures of snow depths and densities at meteorological stations to compare with automated precipitation-gauge measures.

- Evaluate records from proximal snow-survey sites administered by the Natural Resources Conservation Service (NRCS) and Federal Aviation Administration (FAA) as appropriate proxies for historical snowpack data.

4.2.3 Study Area

The study area includes the three major catchments that occur in the mine survey area (Figure 4-20).

4.2.4 Scope of Work

The research and field work for this study were conducted during 2004. The study was conducted by Erik Pullman (Senior Scientist) with assistance from Matt Macander (GIS Specialist), and Tim Cater and Wendy Davis (Research Biologists), all of ABR, Inc., Fairbanks, Alaska. The study was conducted according to the approach described in the Draft Environmental Baseline Studies, Proposed 2004 Study Plan (NDM, 2004b). Field snow surveys were conducted in the three major drainage basins in and around the proposed mine site. Field surveys, data analysis, and reporting were performed by scientists from ABR, Inc., in consultation with surface-water-hydrology project leaders and project design engineers from Knight-Piesold.

The scope of work included the following:

- Performance of field surveys during April to determine the general distribution of snow across the local landscape.
- Additional surveys to be performed in early May to document the rate of ablation (melting and sublimation) of the snowpack during breakup.
- Comparison of field measurements with a selection of downloaded MODIS satellite imagery.
- Development of a preliminary digital elevation model (DEM) of the local area from USGS data sets.
- Use of the preliminary terrain model to test assumptions of snow distribution.

While landscape position (slope, aspect, and elevation) explained a portion of the variance in field measurements, it was clear that a more detailed terrain model that identified canopy structure and potential separation zones would be required to adequately map late-season snow distribution due to the extensive wind redistribution that occurs in the area. We expect to obtain this information from the recently processed LIDAR information.

4.2.5 Methods

The approach to mapping spring snow distribution will rely on a combination of detailed field surveys and a terrain model that incorporates the predominant variables that influence snow accumulation (elevation, aspect, slope, and vegetation-canopy and wind-shelter indices). To determine the spring snow distribution across the study site, snow depths and density were measured along 14 slope/aspect transects and two permanent snow courses (Figure 4-20). Sampling along the slope/aspect transects extended from ridge tops to valley bottoms with snow depths and densities measured at 100-foot-elevation intervals. At each measurement location, SWE was determined from three replicate measures of snow depth and snow density using a standard federal snow sampling tube and scale. Percent snow cover was visually estimated at each measurement site. Slope and aspect also were measured at each sample site for use in the snow-distribution model. Slope/aspect transects ranged from 0.6 to 1.9 miles in length and covered the predominant elevation spans and aspects present in the major drainage basins in the study area. Additional field measurements were made at the proposed location of meteorological stations. At each of these locations, snow depth and density were measured at five locations situated in a 10-foot radius around the proposed station location.

Two permanent snow courses were located to provided data suitable for comparison with existing NRCS snow-course sites and to provide precise inter- and intra-annual comparison of SWE. One snow course was located at 2,000 feet elevation on a shoulder of Groundhog Mountain, and the other at 1,200 feet elevation on an isolated hill in the headwaters of Upper Talarik Creek. Each snow course comprised a one- to two-mile circuit around a small ridge or knob with 10 to 16 stations located to cover all slope aspects. Repeated measures of snow depth and density were performed on May 2 and 3 and May 15 and 16, 2004, along the two snow-course transects to provide estimates on spring snowpack-ablation rates. The additional spring field surveys will be used with calibrated MODIS snow data to estimate snowpack ablation and provide runoff estimates.

4.2.6 Results and Discussion

The snow distribution survey was conducted April 13 through 18, 2004. Our sampling effort was concentrated in the three major drainage basins within the claim area: the North Fork Koktuli River, the South Fork Koktuli River, and Upper Talarik Creek. Sample transects were performed along slopes with at least two transects per major aspect category (north, south, east, west, and flats). In addition, we measured depth and density along two circular snow courses (located at 2000 feet and 1,200 feet elevation). The three meteorological-station locations also were surveyed. Measurements were made at a total of 107 locations throughout the mine survey area (Figure 4-20).

Locally, 2003-2004 was a high snow year, with the Port Alsworth snow station reporting snow depth 124 percent of normal as of April 1, 2004 (NRCS, 2004). Mean snow depth across the mine survey area was 34 inches and ranged from 0 to more than 95 inches. Mean SWE ranged from 0 to more than 53 inches. Mean SWE across the claim was 13.8 inches. Some melting and loss of water from the snowpack was apparent in the majority of sample stations by mid-April. Evidence of snowpack-melt included damp or wet duff layers below the snowpack and areas of bare, wet ground. Determination of ablation rates was confounded by precipitation events that occurred between and during ablation sampling trips. Since the meteorological station had not been established, we were not able to accurately account for additional precipitation that occurred following the initial distribution surveys in mid-April. Ignoring these sources of error, snowmelt ranged from 0 to 2 inches of SWE per day with a mean of 0.75 inches per day from April 18 to May 3. This is an underestimate, because there were a number of significant precipitation events at the site between measurements. The snowpack was largely gone by the time of the May 15-16 survey (Figure 4-21).

Variability in the field results was partitioned by elevation, slope, aspect, and vegetation-canopy structure using a general linear model (GLM). While the variables were significantly related to SWE, they only explained a small portion of the total variance observed in the field. Since wind redistribution plays a dominant role in late-season snow distribution, we are planning on deriving an upslope wind-field layer that will identify relative degrees of shelter and exposure in winds of a given direction (Winstral and Marks, 2002). This layer will be derived from the recently completed LIDAR data for the mine survey area. In addition, vegetation-canopy information may be available from the LIDAR data. We also expect to be able to derive vegetation canopy information from the habitat mapping that is scheduled to be completed in 2005.

4.2.7 Summary

Based on information from NRCS snow surveys, 2004 was a high snow year representing 125 percent of the average level for April. The snowpack in the mine survey area averaged 34 inches deep with a mean SWE of 13.8 inches in mid-April. The snowpack in wind-sheltered areas often exceeded 94 inches. The snowpack melted rapidly and was largely gone a month later (May 15). These ground observation were confirmed by MODIS data. Direct measurements of ablation rates ranged from 0 to 2 inches per day with a mean of 0.75 inches per day.

4.3 Road/Port

4.3.1 Introduction

This section presents the preliminary findings of the 2004 baseline surface-water hydrology studies conducted by Bristol Environmental & Engineering Services Corporation (BEESC) for the road/port areas for the Pebble Project. The road-corridor and port-site alternatives were developed by the Alaska Department of Transportation and Public Facilities (DOT&PF).

All baseline data were collected using guidelines established by DOT&PF, the Federal Highway Administration (FHWA), the USGS, and the American Association of State and Highway Transportation Officials (AASHTO). The magnitude and frequency of streamflows were computed in accordance with USGS Bulletin #17B (USGS, 1982) and procedures established by DOT&PF, FHWA, and the USGS.

The observations and conclusions presented in this report are based on less than one year of data for most streams in the study area. Additionally, 2004 was an extremely dry year, and observations may not be representative of typical flow conditions in these streams.

4.3.2 Study Objectives

The objectives of the surface-water hydrology studies along the road corridor and at the proposed port site are to:

- Identify and describe the existing surface-water hydrological characteristics near the proposed road crossings and port site,
- Identify and describe the processes that control the hydrologic balance within the project watersheds, and
- Provide baseline information to be used in evaluating the potential impacts the proposed road will have on the upstream and downstream environment.

Activities completed in 2004 focused on compiling physical drainage-basin characteristics, collecting streamflow measurements on selected streams in the corridor, and evaluating applicability of existing hydrologic models for predicting streamflows.

4.3.3 Study Area

The study area includes the preferred road corridor as identified by the DOT&PF between the Newhalen River and Cook Inlet, including the area surrounding the proposed port site as shown on Figure 4-22. The corridor considered for developing the study program was presented in the *Draft Iliamna Regional Transportation Corridor Analysis* (PN&D, 2004). At the time the 2004 field studies were conducted, the port location and configuration of upland facilities had not been determined. All watersheds that are intersected by the preferred road corridor were considered in the study design.

The proposed road corridor extends from Iniskin Bay approximately 55 miles to the Newhalen River and encompasses a variety of distinct topographic and climatic regions. The eastern end of the study area experiences a maritime climate with a mean annual precipitation of 80 inches. The area is characterized by steep rugged mountains with little or no vegetation or soil cover. Topographically, the elevations vary from sea level to in excess of 4,000 feet, in many instances covering this change in a span of a few miles. Drainage basins have little storage in the form of ponds or lakes, if any. By contrast, climate in the western half of the study area is considered transitional between the maritime climate of the coast and the continental climate of the interior. The area has a mean annual precipitation of approximately 20 inches. Drainage basins in the western portion of the study area are characterized by gentler slopes, significant vegetation, and numerous ponds and lakes which provide basin storage. Elevations over this section of the road corridor range from the Iliamna Lake level of 57 feet to approximately 500 feet. Variations in topography and climate are presented on Figure 4-23.

4.3.4 Scope of Work

The baseline study was designed and implemented by Mr. William F. Barber, Hydrologist, and was conducted according to the approach described in the proposed 2004 study plan (NDM, 2004b). The study was designed to account for the wide range in climatic conditions and stream types encountered in the study area. Work completed in 2004 included researching existing data and aerial photography, preliminary statistical flood-frequency analysis, and field data collection.

4.3.5 Methods

4.3.5.1 Stream Gauge Station Locations

The project area currently has eighteen “Title 41” streams as designated by Alaska Statute (AS) 41.14.870 and managed by the Alaska Department of Natural Resources (ADNR), Office of Habitat Management and Permitting (OHMP). Title 41 streams are so designated because they support anadromous fish. The focus of the surface-water baseline study for the road is to document the existing surface-water conditions in critical habitat streams as part of the EIS process. To meet this objective, gauges were installed on all accessible Title 41 streams.

Prior to actual field data collection, an intense review of available information from sources including the Alaska Department of Fish and Game (ADF&G), ADNR-OHMP, DOT&PF, U.S. Fish and Wildlife

Service, National Oceanographic and Atmospheric Administration River Forecast Center, and existing aerial photography from 1978, 2002, and 2003 was used to plan the proposed gauging network. Because the preferred alignment for the road corridor had not been defined during the study design phase, gauges were sited below the most probable corridor alignment to ensure that the surface-water data collected would be relevant to the final selected road corridor. Once the final preferred alignment is defined by the DOT&PF, the gauging network will be evaluated on a case-by-case basis to verify that gauging stations are representative of conditions at the proposed crossings.

4.3.5.2 Basin Characteristics

Basin characteristics files were created for each watershed in the project area that catalogued information on the physical and climatic nature of the basin. Drainage basin areas were defined for each stream in the study area using USGS topographic maps imported into AutoCAD 2002 format. The maps were enhanced with watershed boundary regions from the Alaska Watershed and Stream Hydrologic Enhanced Datasets (USGS, 2002). Watersheds included in this study are presented on Figure 4-24.

Watersheds were further delineated by BEESC using full and partial boundary areas to define the local drainage-basin tributary to each gauging location. A typical watershed map (for Gauging Station [GS] 17a) is shown in Figure 4-25. USGS topographic information was supplemented by aerial photography (1978, 2002, and 2003) to create basin characteristics files for each proposed gauging station which included information summarized in Table 4-4. The basin characteristics files are used in the statistical streamflow analysis to predict flows from each stream in accordance with Water-Resources Investigations Report (WRIR) 03-4188 (USGS, 2003b). Basin characteristics data are presented in Appendix 4-B, Table 4B-1.

TABLE 4-4
Basin Characteristics File Data

Parameter	Variable	Unit
Drainage area	Da	mi^2
Storage area (lakes and ponds)	St	mi^2
Glacier area	Gl	mi^2
Forested area	Fr	mi^2
Mean basin elevation	El	ft
Main channel slope	Sl	%
Main channel length	C	miles
Mean annual precipitation	Pr	inches
Mean minimum January temperature		°F

4.3.5.3 Gauge Station Installation

Field data was collected in accordance with the standards set forth in the *National Handbook of Recommended Methods for Water-Data Acquisition* (USGS, 1977-plus updates). Crest gauges were installed at each selected gauging location to record high water levels occurring between monitoring events. A crest gauge is designed to measure the maximum instantaneous flood crest under conditions of transitory or transient flow.

Crest gauges installed on this project were constructed of two-inch galvanized pipe containing a wooden staff held in a fixed position relative to a datum (in this project an assumed datum of 100 was used on all crest gauges). Proper placement of intake holes in the bottom of the pipe to minimize the non-hydrostatic drawdown or super elevation was taken into account in the placement of each crest gauge. A typical crest-gauge installation is shown in Figure 4-26.

The crest gauge is a simple device intended to measure peak flow stages. The gauge includes granulated cork, stored in the bottom of the capped pipe. As a transitory flood wave passes, the water rises in the pipe and the cork floats on the water surface. As the water recedes, the cork adheres to the staff inside the pipe thereby retaining a record of the crest stage of flood. The height of the flood peak is obtained by measuring the elevation of the flood mark relative to an established reference point on the pipe.

During installation of the gauge, stream cross-sections were surveyed starting at a rebar driven into the bank just beyond the ordinary-high-water mark and proceeding across the river perpendicular to the stream channel. Survey measurements upstream and downstream were taken to record the stream channel slope at the crest gauge. Photographic documentation upstream and downstream of the crest gauge was also collected. High-water marks from past flood events were identified and photographed. Data collected during installation of the gauges is summarized in Table 4-5.

TABLE 4-5
Gauge-station Installation Data

Parameter	Description	Method
Location	Latitude and longitude	Global Positioning System
Stream cross-section	Hydraulic cross-section perpendicular to flow	Rod and transit survey
Skew of flow	Cosine of the perpendicular to the hydraulic cross-sections	Rod and transit survey
Gauge datum	Elevation of reference point on crest gauge	Assumed datum of 100 feet except for Iliamna River station with USGS-established datum
Crest gauge reading	Flow height above datum	Measured by gauge
Mean velocity	Average velocity through wetted cross-section	In-streamflow meter and area average method
Hydraulic slope	Average slope of right and left banks up and downstream of gauging station, or slope between high-water marks used slope area method of computing peak discharge	Rod and transit survey
High-water marks	Evidence of major flood events at a given site	Visual observation
Ordinary high water	Legally defined by AS 16 and Title 41as the line on the bank established by fluctuations of water and indicated by physical characteristics such as clear, natural line impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, the presence of litter and debris, or other appropriate means that consider the characteristics of the surrounding areas	Visual observation
Water temperature	Degrees Fahrenheit	Hand-held thermometer
Photographic documentation	Upstream and downstream conditions, stream bed materials	Digital camera

Stream data were collected on a monthly basis. For each collection event, the current water-surface elevation, stream discharge, and hydraulic slope up and downstream were measured at each gauging location. The crest-gauge reading was also collected to determine peak flow stages between monitoring events. Types of data collected are summarized in Table 4-6.

TABLE 4-6
Summary of Monthly Hydrology-data Parameters

Gauging station number	Date
Width of channel (ft)	Hydraulic slope (ft/ft)
Total area (ft^2)	Mean velocity (fps)
Mean depth (ft)	Wetted parameter (Wp)
Number of sections	Sections greater than 5%
Sections greater than 10%	Total discharge (Q) in cfs

fps = feet per second

The stream velocities were measured using a Marsh-McBirney Flo-Mate Model 2000. For small streams less than 20 feet in width, velocity was measured at 1-foot intervals across the channel. For the larger streams, the width of the channel was divided into 20 sections controlled by changes in the hydraulic cross-section and changes in velocities. Velocity measurements were taken at the center of each section. Point velocities for all discharge measurements are taken at 0.6 of the measured flow depth unless the depth was greater than two feet. Where stream depths were greater than two feet, two measurements were recorded—one at 0.2 and one at 0.8 of the total depth. The mean velocity of the two depths was then used as the velocity for that section.

At most gauging stations, streams could be safely waded during low-flow events (Figure 4-27). During high-flow events at some gauging stations it was necessary to use a boat with a fathometer to obtain the discharge measurement. The Iliamna River, Pile River, and Knutson Creek required a boat to conduct the velocity measurements for all events. The first attempt to collect measurements on the larger streams used a skiff with jet outboard motor, as this was the only craft that could navigate the shallow water. The skiff was difficult to maneuver and hold in position long enough to collect the measurement in the swift water. Beginning with the September sampling event, the standard boat method, using a small inflatable boat outfitted with a tag-line and powered with a propeller outboard motor (Figure 4-28), was used on all streams which could not be waded safely.

4.3.5.4 Field Data Reduction

Stream discharges were calculated from field notes using methods described in the *National Handbook of Recommended Methods for Water-data Acquisition* (USGS, 1977 plus updates).

The mid-section method of computing a cross-section area was used to compute discharges. This method assumes that the velocity measured at each sampling point across the stream represents the mean velocity in the partial rectangular cross-sectional area. The partial area extends laterally from half the distance from the preceding velocity-measurement location to half the distance to the next, and vertically from the water surface to the sounded depth. This method is described in the *Discharge Measurements at Gaging Stations* (USGS, 1969). Figure 4-29 shows a sample spreadsheet used for discharge computations.

Table 4-7 presents a summary of the monthly peak discharges at gauge sites in the study area. Discharge-measurement summaries of all 2004 measurements are provided in Appendix 4-B, Table 4B-2.

TABLE 4-7
Peak Monthly Discharges, Road Corridor, 2004 Water Year[1]

Gauge #	Name:	July 2004 (cfs)	Aug 2004 (cfs)	Sept 2004 (cfs)
3a	Iliamna River [2]	5690	898	522
4a	Pile River	1533	1277	65
4b	Long Lake Creek	(3)	(3)	0.07
6a	No-Name Creek near Dumbbell Lake	4	2	0.02
7a	No-Name Creek at Pedro Bay Apt Rd	0	0	0
8a	Knutson Creek	129	135	21
11a	Canyon Creek	218	53	19
12a	Chekok Creek	76	43	36
14a	No-Name Creek (East Fork Chekok Bay Tributary)	20	13	36
14b	No-Name Creek (West Fork Chekok Bay Tributary)	7	4	20
17a	No-Name Creek (West Fork of Eagle Bay Creek)	7	5	4
18a	No-Name Creek (Eagle Bay Tributary)	1	1	1
20	Lower Roadhouse Creek	15	9	11
20a	Upper Roadhouse Creek	1	1	2
21	No-Name Creek near Port Site	(3)	27	6

Notes:

1. The water year is October 1st through September 30th.
2. Continuous-recording gauge.
3. Gauge was not installed.

All discharge data sheets are formatted and recorded as part of the gauge station's permanent record. The permanent record will include stage-discharge curves. The summer of 2004 was an extremely dry gauging season. Because of the consistently low flows observed, it was impossible to establish a stage-discharge curve except for the low-flow events. Assuming more typical flows are experienced in 2005, these curves will be developed for each gauging station.

4.3.5.5 Statistical Analysis

The intent of the surface-water baseline study is to document existing conditions using existing gauged data, field measurements such as high-water marks, and actual discharge measurements. Actual flow data were collected for streams with existing gauge data. These data were used to check flood-frequency predictions using USGS WRIRs 03-4114 (USGS, 2003a) and 03-4188 (USGS, 2003b). The regression equations from these publications were adjusted as needed and used to develop flood-frequency predictions for all ungauged streams.

4.3.6 Results and Discussion

The 2004 program developed limited data on streamflows and basin characteristics. The standard regression equations for predicting high and low flows on ungauged streams were evaluated to determine their applicability for predicting flow characteristics for all streams in the project corridor. Analyses to date have been limited to this evaluation.

4.3.6.1 Review of Available Data and Statistical Analysis

In the study design it was assumed that statistical methods presented in USGS WRIRs 03-4114 (USGS, 2003a) and 03-4188 (USGS, 2003b) would provide reliable methods for determining the magnitude of flood flows for the entire project area from Iniskin Bay to the Newhalen River. The regression equations from these publications for estimating peak streamflows, annual high flow, and monthly and seasonal low-flow statistics used in this preliminary report were developed using methods described in USGS Bulletin #17B (USGS, 1982). Bulletin #17B is mandated by federal regulation as the guiding methodology to determine the magnitude of flood flows in the United States.

Because little or no actual surface-water data are available for the project area, an initial task was to determine if the methodologies described in WRIRs 03-4114 and 03-4188 (USGS, 2003a and 2003b, respectively) could be used for this project by comparing predictions from these equations with data from established gauging stations in the region. Only three USGS streamflow gauges have historically recorded data within the study area; Iliamna River (USGS Gauge No. 15300300, also known as GS 3a in this report), Roadhouse Creek (No. 15300200, also known as GS 20 in this report), and Newhalen River (No. 153000000). The Iliamna River gauge station is currently the only operational gauge in the study area.

The Iliamna River has a nine-year period of record, starting in 1995. Figure 4-30 shows the peak discharges for this gauging station. As can be seen, the river is subject to relatively large peak flow events which occur on a nearly annual basis. During the nine years of record, six events exceeding 10,000 cfs and one event exceeding 20,000 cfs have been recorded. Figure 4-31 shows the Iliamna River Bridge during the October 2003 flood event. The bridge was designed for a 50-year flood event. Interviews with the USGS personnel who maintain the gauging reveal that at least three times when they were at the site taking a discharge measurement the water was at or above low steel on the old Iliamna River Bridge.

A Log Pearson Type III analysis was performed for the Iliamna River using the existing nine years of record and the methodologies mandated in Bulletin #17B (USGS, 1982). Prior to the analysis, the flow record was reviewed according procedures in Bulletin #17B to identify any recorded peaks (high or low) that were not consistent with other measurements in the data set and that could abnormally skew the data analysis. No outlier values were identified. The Log Pearson Type III analysis was performed using the full gauging record for the Iliamna River gauging station. Figure 4-32 is a graphical representation of the Log Pearson Type III analysis using the various steps outlined in Bulletin #17B.

Figure 4-32 also shows a comparison of the 2003 peak discharge in relation to the discharge predicted by Log Pearson Type III analysis. The curve titled “17b without adjustment” is an evaluation of the Iliamna River data as recorded. The systematic record curve presents the results of the analysis, with corrections to account for variability in the recorded data. The expected probability estimate also includes factors for regional skew; curves representing the 95 percent confidence interval suggested by this method are also presented. According to Bulletin #17B (USGS, 1982), the expected probability estimate provides the best estimate to determine the magnitude of flood flows for the Iliamna River based on the USGS's gauging records. The Log Pearson Type III analysis indicates that the October 1, 2003, peak discharge of 22,000 cfs was a Q12 Recurrence Interval or has an 8.33 percent exceedance probability. Considering that, in its nine years of record, the Iliamna River has six peak events which exceed discharges of 10,000 cfs, it appears that the Log Pearson Type III analysis accurately represents the magnitude of floods for the Iliamna River using the nine years of record.

4.3.6.2 Comparison of Log Pearson Type III Analysis and Regression Equations for the Iliamna River

Flow predictions from the Log Pearson Type III analysis for the actual gauging record for the Iliamna River were compared to flow predictions for floods developed using the methodology described in the WRIR 03-4188 (USGS, 2003b) to gauge the validity of the latter method for predicting flows in ungauged streams in the study area. Comparison of predictions from these methods is presented in Figure 4-33. As can be seen, there is a significant difference between the flood magnitudes predicted by the Log Pearson Type III analysis and those predicted by WRIR 03-4188 for the Iliamna River. For the purposes of our analysis we also show WRIR 93-4179 (USGS, 1994), which was the method of computing floods of magnitude for this area prior to publication of WRIR 03-4188 and which was used in the design of the Iliamna River Bridge.

After a review of the methods that were used in developing WRIR 03-4188 (USGS, 2003b), the following factors appeared to have skewed the equations, lowering the predicted magnitude of flood flows for the area:

- The equations in WRIR 03-4188 assume precipitation similar to that observed in Iliamna over this entire subregion of Alaska. As noted above, the mean annual precipitation ranges from 20 inches at the community of Iliamna to 80 inches in the upper Iliamna River basin.
- The WRIR 03-4188 analysis did not include the Iliamna River gauging records in their computations.
- There was a significant difference in the general basin characteristics between those used in WRIR 30-4188 and those generally found in the area from Iniskin Bay to Canyon Creek.
- With the exception of the no-name creek at Dumbbell Lake (GS 6a), basins are generally very steep with little or no storage in any of the streams between Iniskin Bay and Canyon Creek

Computations using regression equations found in WRIR 03-4188 (USGS, 2003b) were compared with high-water marks and other gauging information on drainage basins with similar basin characteristics to determine if the equations are valid. Ordinary-high-water marks and high-water marks were collected at each crest gauging station during the 2004 season. Discharge volumes were estimated for all streams based on observed high-water marks using the slope-area method. Differences between discharges estimated from high-water marks and those predicted by WRIR 03-4188 provide further indications that the publication does not reliably predict the magnitude of flood flows for the area between Iniskin Bay and Canyon Creek.

With little or no exception, flow predictions based on actual streamflow data and a Log Pearson Type III analysis are considered to be more reliable than those developed strictly from a regression equation. The large discrepancy between observed high-water marks, expected probability using actual gauged data from the Iliamna River, and the flows predicted by regression equations in WRIR 03-4188 indicates that calibration of regression equations to be used on the ungauged streams will provide more defendable predictions of flood magnitudes for the area. Therefore, the Log Pearson Type III analysis for the Iliamna River will be used as a model to calibrate the regression equations described in WRIR 03-4188 (USGS, 2003b) for all streams east of Canyon Creek.

4.3.6.3 Calibration of Regression Equations for Iliamna River Area

The methodology used to calibrate or adjust the equations used in WRIR 03-4188 (USGS, 2003b) are described in WRIR 78-129 (USGS, 1979). Using the guidelines established in Bulletin #17B (USGS, 1982), and WRIR 78-129, modifications were made to the regression equations in WRIR 03-4188 to reflect the Log Pearson Type III analysis using the expected probability estimate for the Iliamna River as our standard. The regression equations were modified until predictions from these equations were within 5 percent of the predictions presented by the expected probability curve in Figure 4-33. The calibrated regression equations developed from this analysis are presented in Figure 4-34. After the 2004-2005 gauging season, the calibrated equations will be reviewed to verify that these equations provide a defendable method of computing the magnitude of floods for the area from Iniskin Bay to just west of Canyon Creek.

4.3.6.4 Comparison Between WRIR 03-4188 and Calibrated Equations

The preliminary calibrated equations in Figure 4-34 were applied to basin characteristics of selected streams in the subregion from Iniskin Bay to just west of Canyon Creek. Table 4-8 shows the differences in flood flows predicted by WRIR 03-4188 (USGS, 2003b) and the flood predictions generated using the revised regression equations discussed above for four streams in the eastern subregion of the project for the predicted 50-year and 100-year recurrence-interval floods. Figure 4-34 graphically presents this comparison over the full range of flood frequencies for the Pile River.

TABLE 4-8
Comparison of Flood Predictions by WRIR 03-4188 and by Calibrated Regression Equations

Gauge #	Stream Name	WRIR 03-4188 (Q_{50}/Q_{100})	Calibrated Regression Equations (Q_{50}/Q_{100})
3a	Iliamna River	9,040 / 10,189	24,600 / 26,840
4a	Pile River	3,709 / 4,238	10,093 / 11,165
8a	Knutson Creek	1,730 / 1,993	4,707 / 5,250
11a	Canyon Creek	1,531 / 1,763	4,166 / 4,645

4.3.6.5 Other Observations

The Iliamna River GS 3a is a continuous-recording gauging station which is maintained by the USGS in cooperation with the DOT&PF as part of their small-streams gauging network. Figure 4-36 presents the maximum, minimum, and means flows at the gauging station for June through September 2004. The gauging record indicates that flows in the river respond very rapidly to precipitation inputs, with flows rising rapidly in response to events and dropping off rapidly almost immediately after the event.

4.3.7 Recommendations for 2005 Gauging Season

After a review of all of the information collected during the 2004 gauging season, the following are recommended for the 2005 field program and data analysis:

- Re-establish the USGS Roadhouse Creek gauge as a recording gauging station. The information from this gauging station will provide the needed information to calibrate the low flows for the area from Canyon Creek to the Newhalen River. It appears that the WRIR 03-4188 (USGS, 2003b) regression equations can be used to reliably predict the magnitude of floods for the area between west of Canyon Creek to the Newhalen River. However, there are no actual data that can be used to determine if the WRIR 03-4114 (USGS, 2003a) regression equations will provide realistic low-flow durational flows. The USGS Water Resources Branch will be contracted to install the recording gauge at the old site.
- Continue monitoring and maintaining the existing crest-gauging network on a monthly basis.
- Generate stage discharge curves for all crest gauges using the discharge measurements taken during the 2004-2005 water year (October 1 through September 30). Because the summer of 2004 was an extremely dry year we were unable to get any points on the stage-discharge curve for higher flows. In fact, all of the flow measurements collected in 2004 were below ordinary high water. In order to dependably create a stage-discharge curve, it is necessary to have discharge measurements at the higher flows.
- Further refine the subregion regression equations in this report after the end of the 2004-2005 water year. A total of 10 years of record will be available for the Iliamna River gauging station, which will increase the reliability of the Log Pearson Type III analysis.
- Conduct a comparison between the actual gauging records for the Iliamna River and the WRIR 03-4114 (USGS, 2003a) regression equations to determine the low-flow durational flows at the conclusion of the 2004-2005 water year.
- Continue to collect the information needed to review the relationship between the hydraulic slope and the Mannings Roughness Coefficient “n” to see if there is a relationship that can be used in the EIS process. Because all of the discharge measurements taken to date have been at low flows, it is impossible to determine if there is a defendable relationship between hydraulic slope, Mannings “n,” and discharge. If there is a defendable relationship then this information can be used in the EIS process.
- Complete the basin characteristics files for all crest-gauging stations. This information will be used in the evaluation of the WRIR 03-4114 (USGS, 2003a) methods to determine durational low flows for the project area. These equations will be used in the EIS process.
- Continue to collect the information to perform indirect and/or slope-area computations on all high-water marks at crest-gauging stations. This information will be used to further verify the magnitude of floods for all Title 41 streams. This information will ultimately be used in the EIS process.

4.4 References

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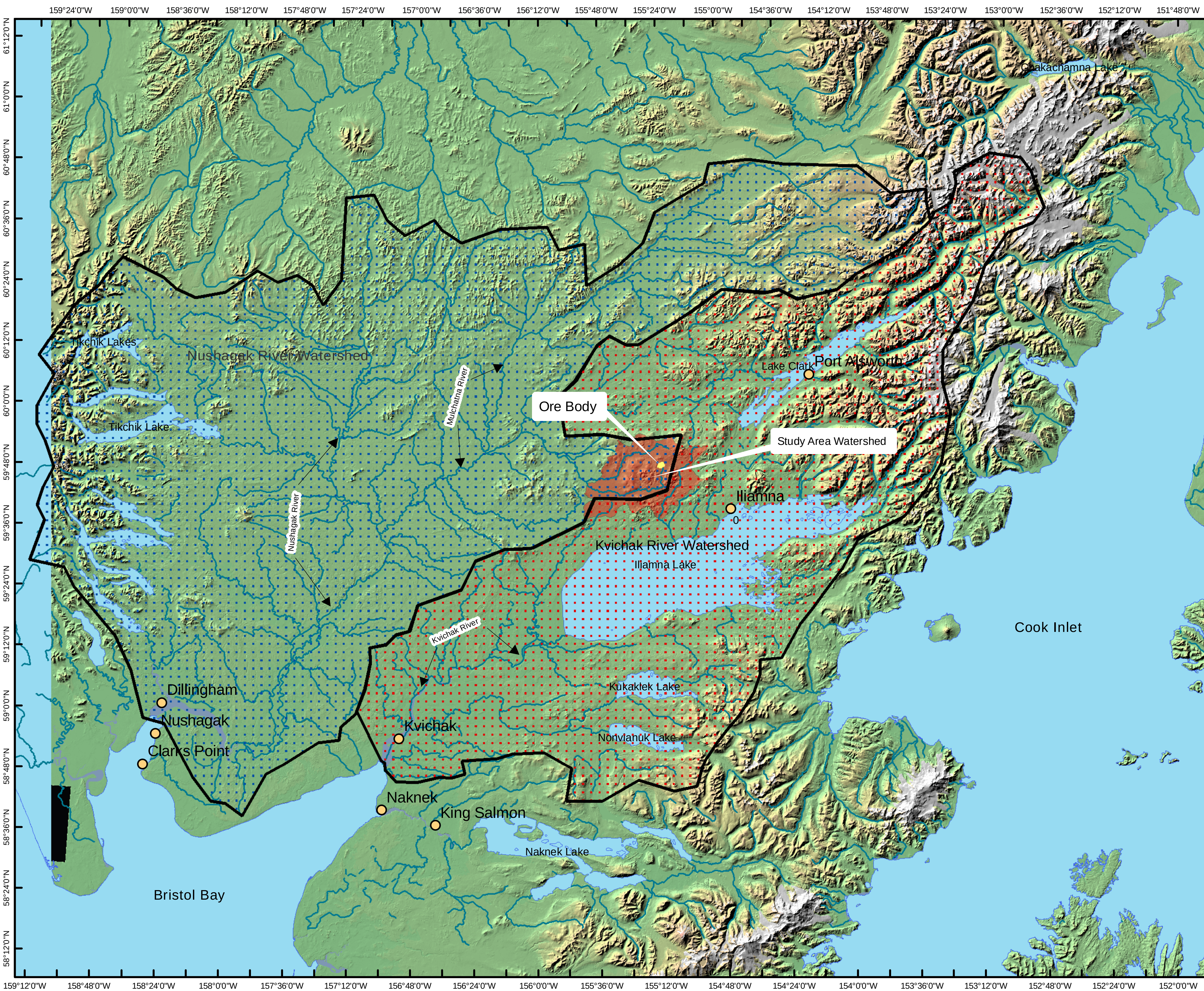
FIGURES



Northern Dynasty Mines Inc.

Pebble Project

Project Area Watersheds
Figure: 4-1

Legend

- Villages
- Kvichak Watershed
- Nushagak Watershed
- Project Study Area

Sites from HDR, file date 02/03/2005

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Pebble Project Area

0 5 10 20 30 40 Miles

0 10 20 40 60 80 Kilometers

Scale 1:1,427,778

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

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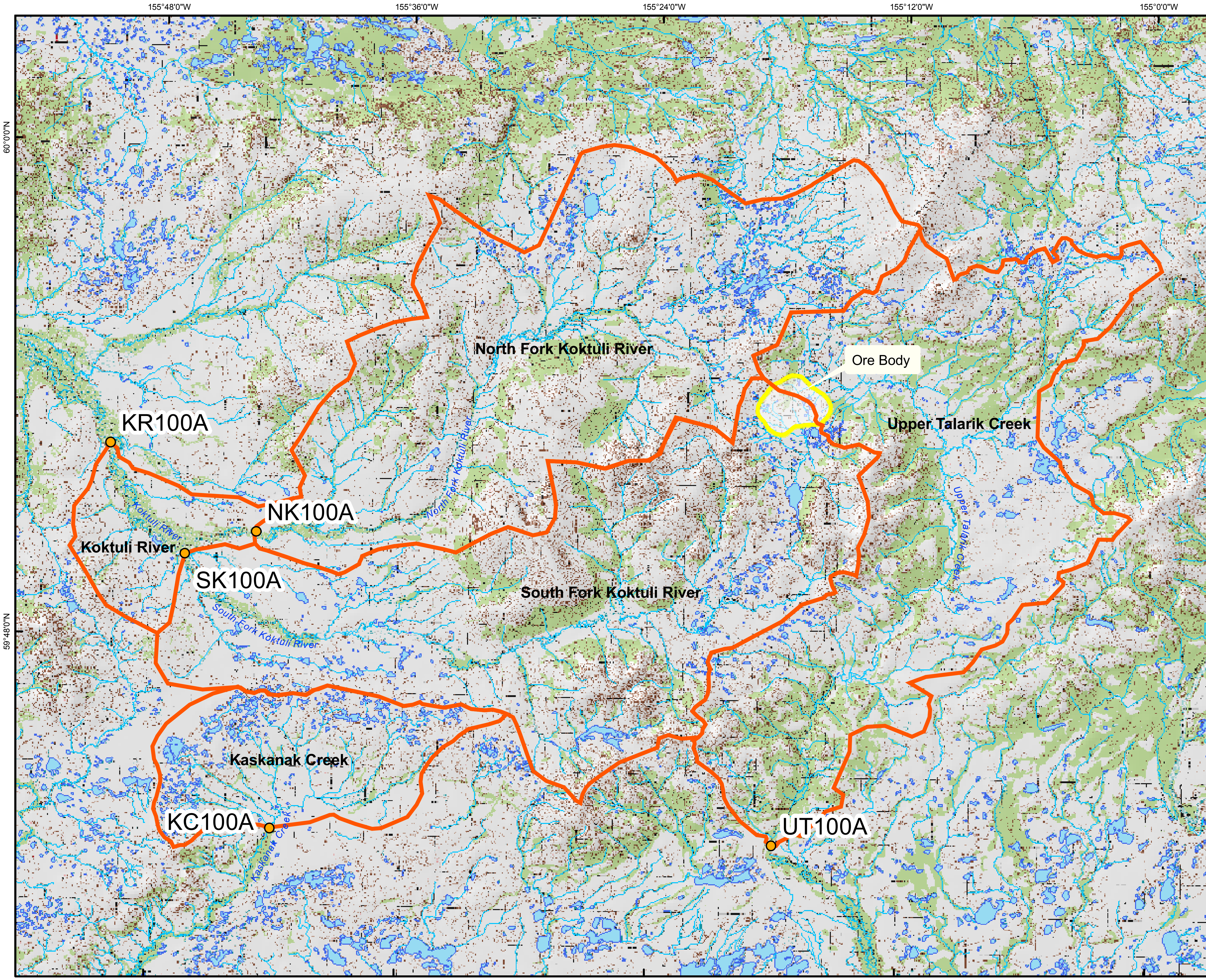


Northern Dynasty Mines Inc.

Pebble Project

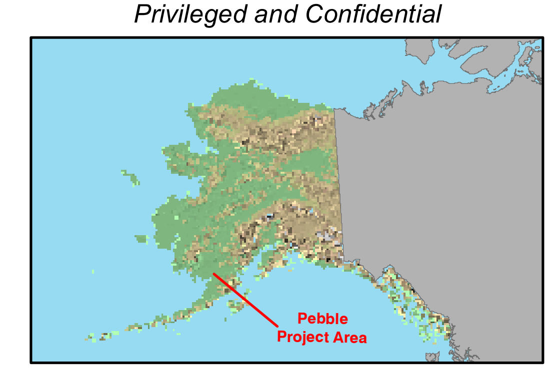
Monitoring Site Drainages, Mine Area Ore Body
Figure: 4-2

Legend

- Most Downstream Monitoring Site in Drainage
- Ore Body
- Monitoring Site Drainages

Sites from HDR, file date 02/03/2005

Privileged and Confidential



N

0 0.5 1 2 3 4 Miles

0 1 2 4 6 8 Kilometers

Scale 1:175,754

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

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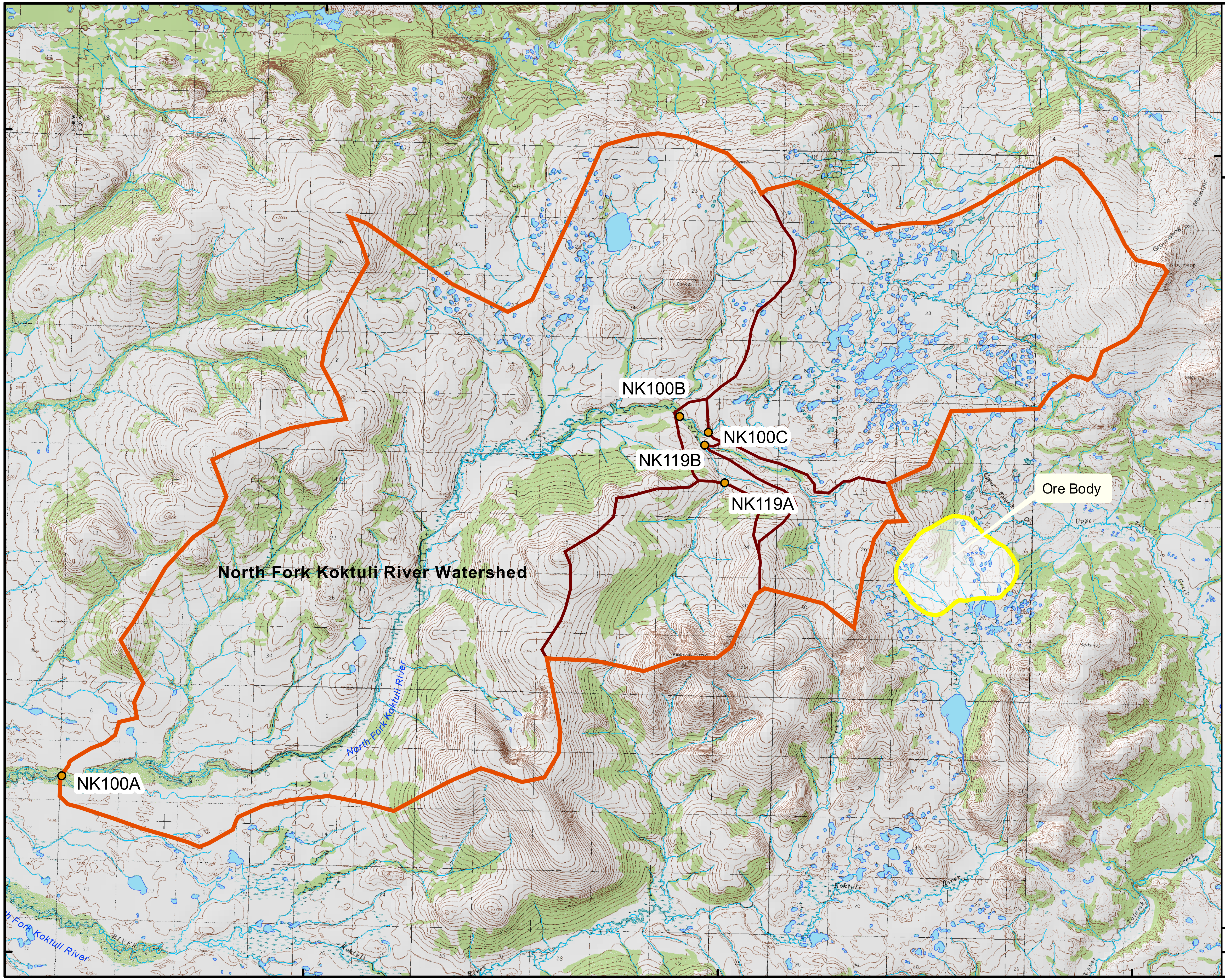


Northern Dynasty Mines Inc.

Pebble Project

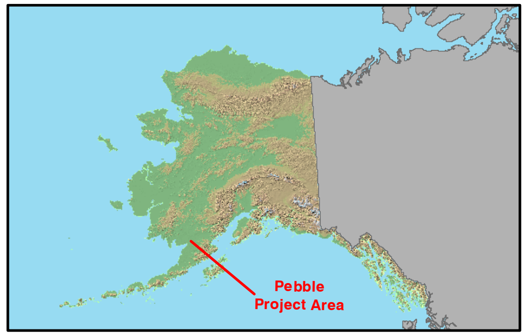
North Fork Koktuli River Watershed
Figure: 4-3

Legend

- North Fork Koktuli River Monitoring Sites
- Ore Body
- Monitioring Site Drainage Basins
- North Fork Koktuli River Watershed

Sites from HDR, file date 02/03/2005

Privileged and Confidential



0 0.4 0.8 1.6 2.4 3.2 Miles

0 0.5 1 2 3 4 Kilometers

Scale 1:107,132

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

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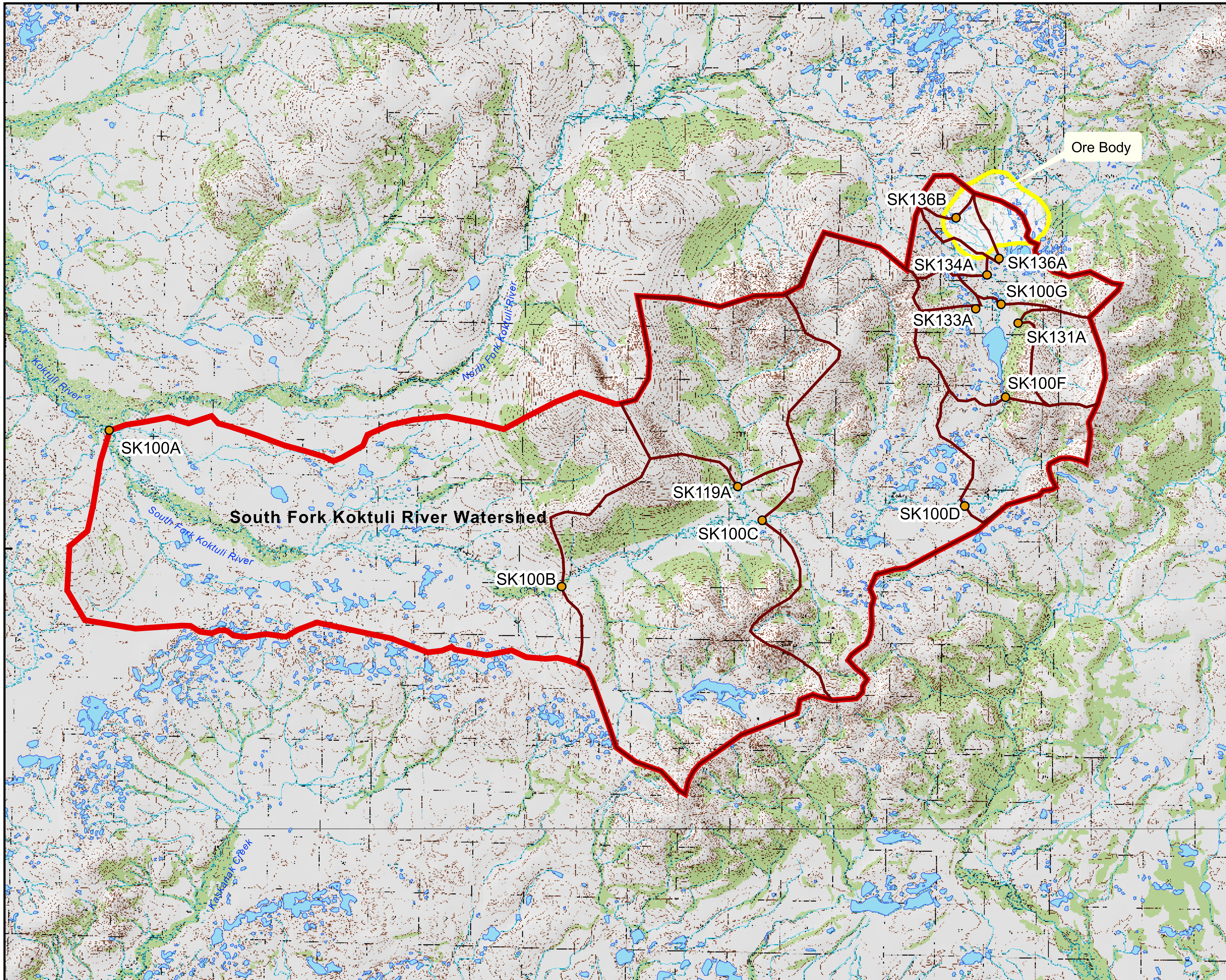

Northern Dynasty Mines Inc.

Pebble Project

South Fork Koktuli River Watershed
Figure: 4-4

Legend

- South Fork Koktuli River Monitoring Sites
- Ore Body
- Monitoring Site Drainage Basins
- South Fork Koktuli River Watershed

Sites from HDR, file date 10/05/2005

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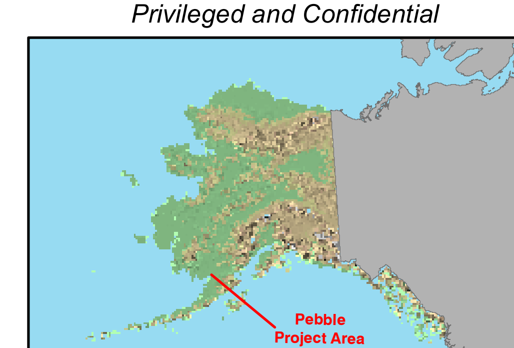

N

0 0.5 1 2 3 4 Miles

0 1 2 4 6 8 Kilometers

Scale 1:123,998

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

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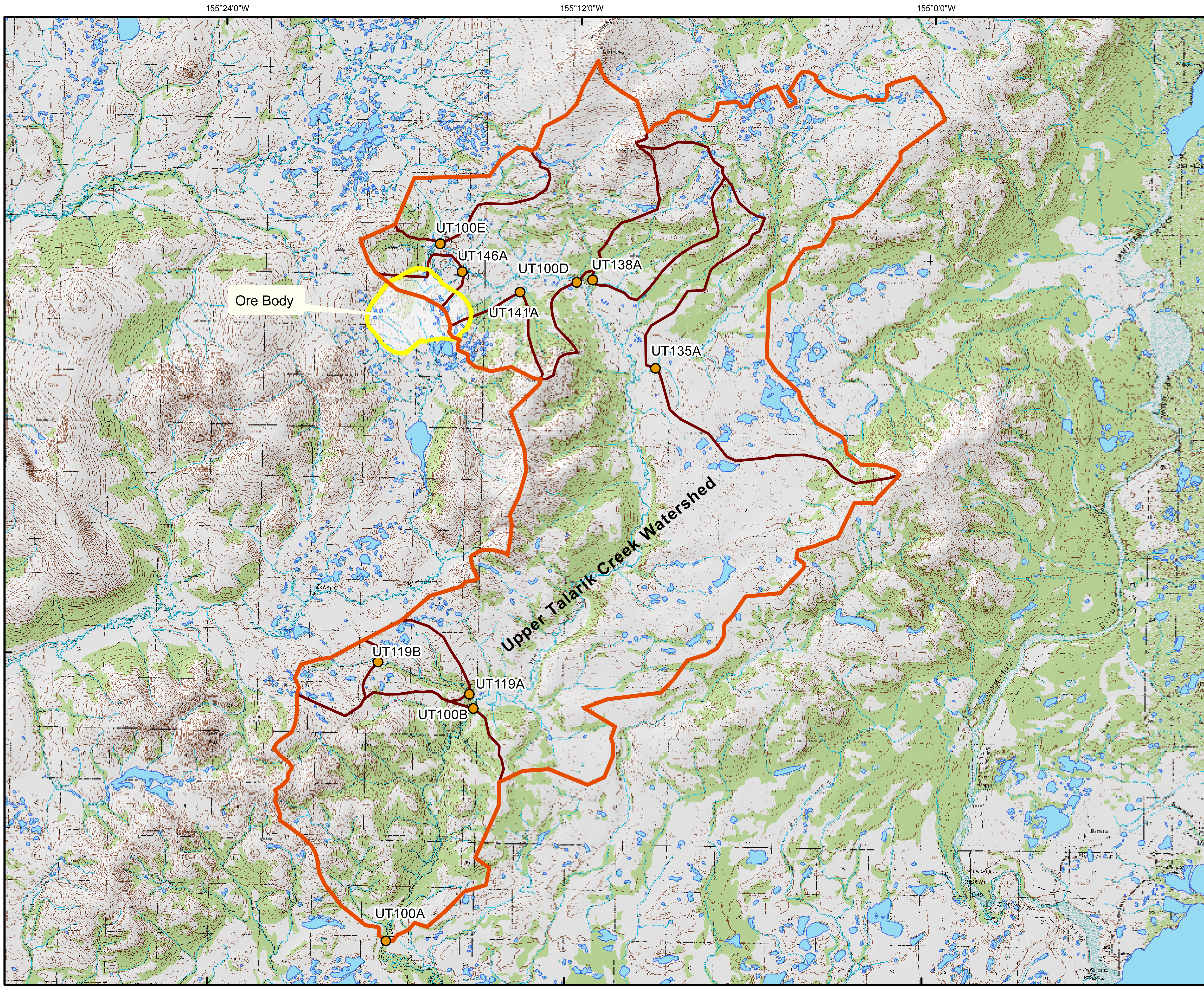

Northern Dynasty Mines Inc.

Pebble Project

Upper Talarik Creek Watershed
Figure: 4-5

Legend

- Upper Talarik Creek Monitoring Sites
- Ore Body
- Monitoring Site Drainage Basins
- Upper Talarik Creek Watershed

Sites from HDR, file date 02/03/2005

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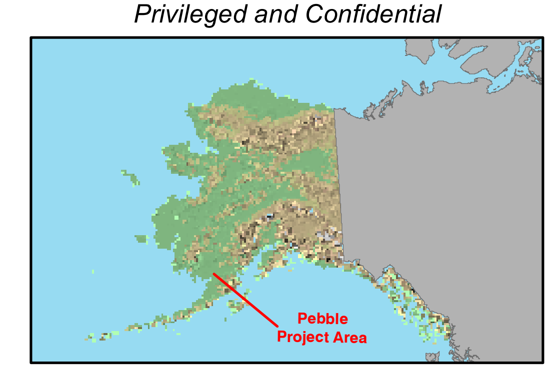

N

0 0.4 0.8 1.6 2.4 3.2 Miles

0 1 2 4 6 8 Kilometers

Scale 1:123,654

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

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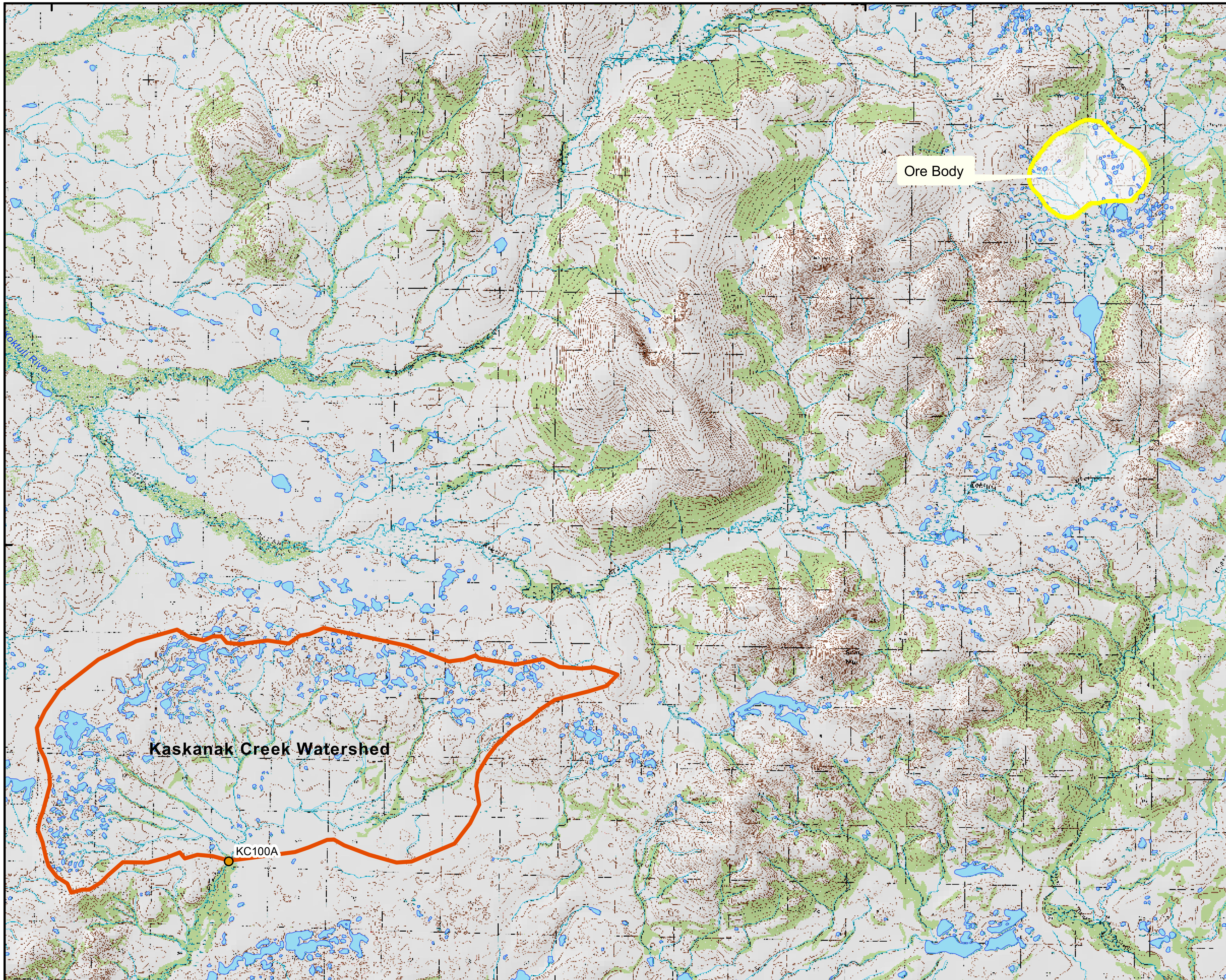
155°48'0"W 155°36'0"W 155°24'0"W



59°48'0"N

155°48'0"W 155°36'0"W 155°24'0"W

Northern Dynasty Mines Inc.

Pebble Project

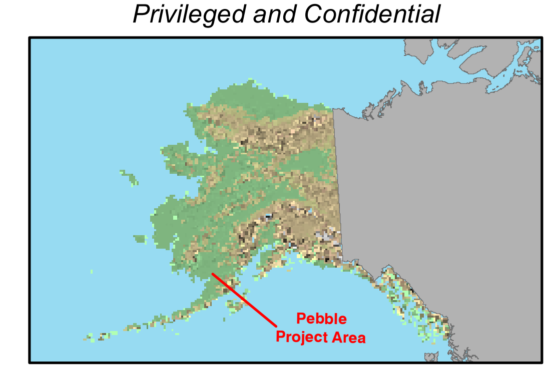
Kaskanak Creek Watershed
Figure: 4-6

Legend

- Kaskanak Creek Monitoring Site
- Ore Body
- Kaskanak Creek Watershed

Sites from HDR, file date 02/03/2005

Privileged and Confidential



N

0 0.5 1 2 3 4 Miles

0 0.5 1 2 3 4 Kilometers

Scale 1:109,976

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

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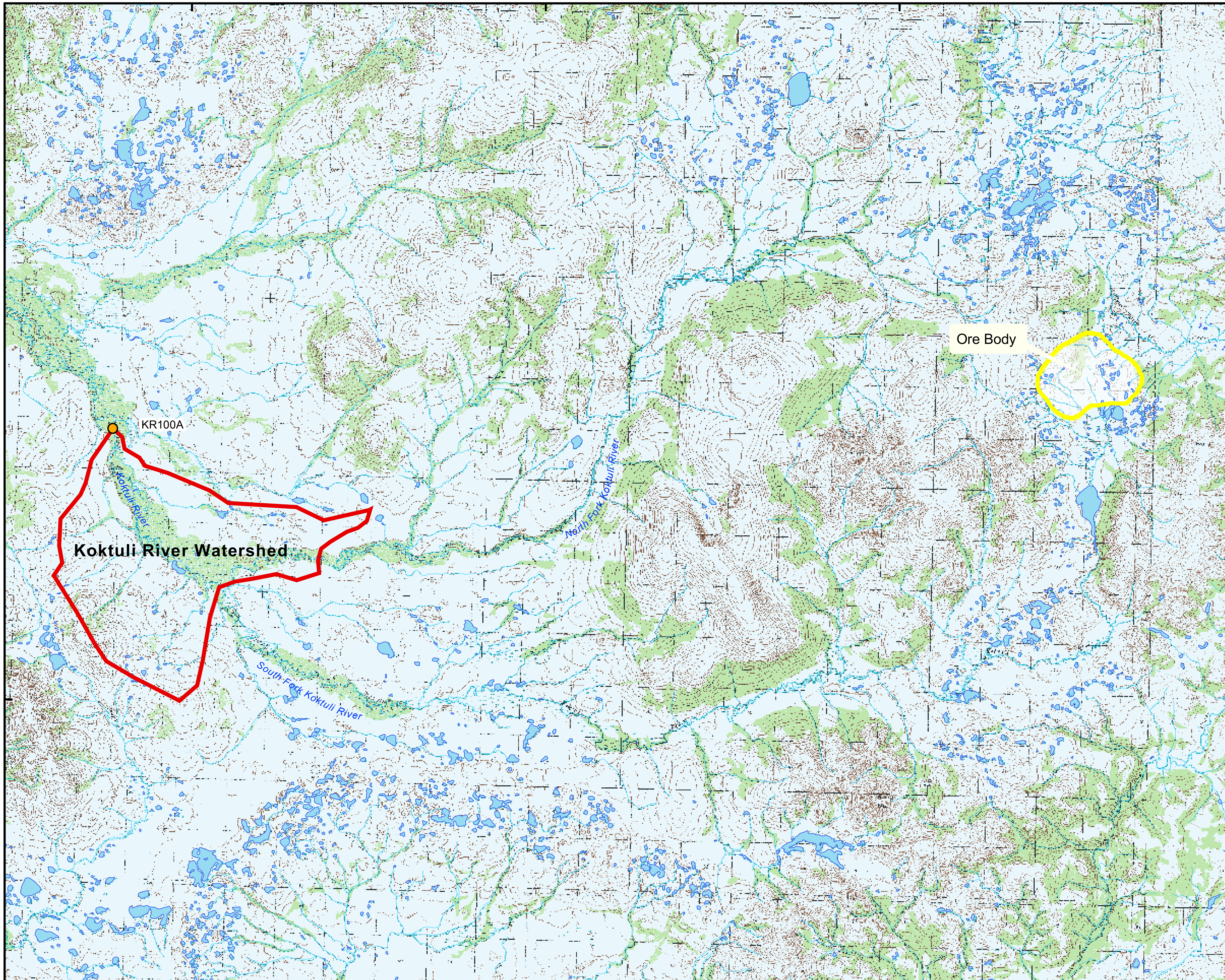

Northern Dynasty Mines Inc.

Pebble Project

Main Stem Koktuli River Watershed
Figure: 4-7

Legend

- Koktuli River Monitoring Site
- Ore Body
- Koktuli River Watershed

Sites from HDR, file date 02/03/2005

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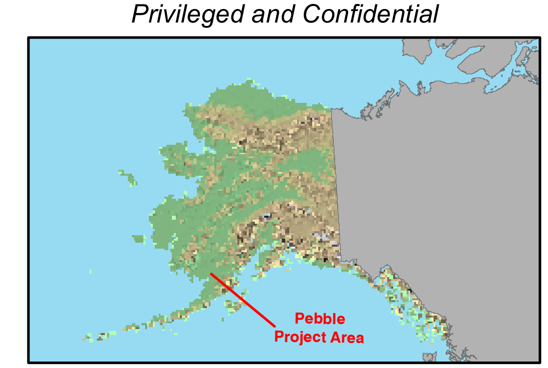

N

0 0.5 1 2 3 4 Miles

0 1 2 4 6 8 Kilometers

Scale 1:126,095

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

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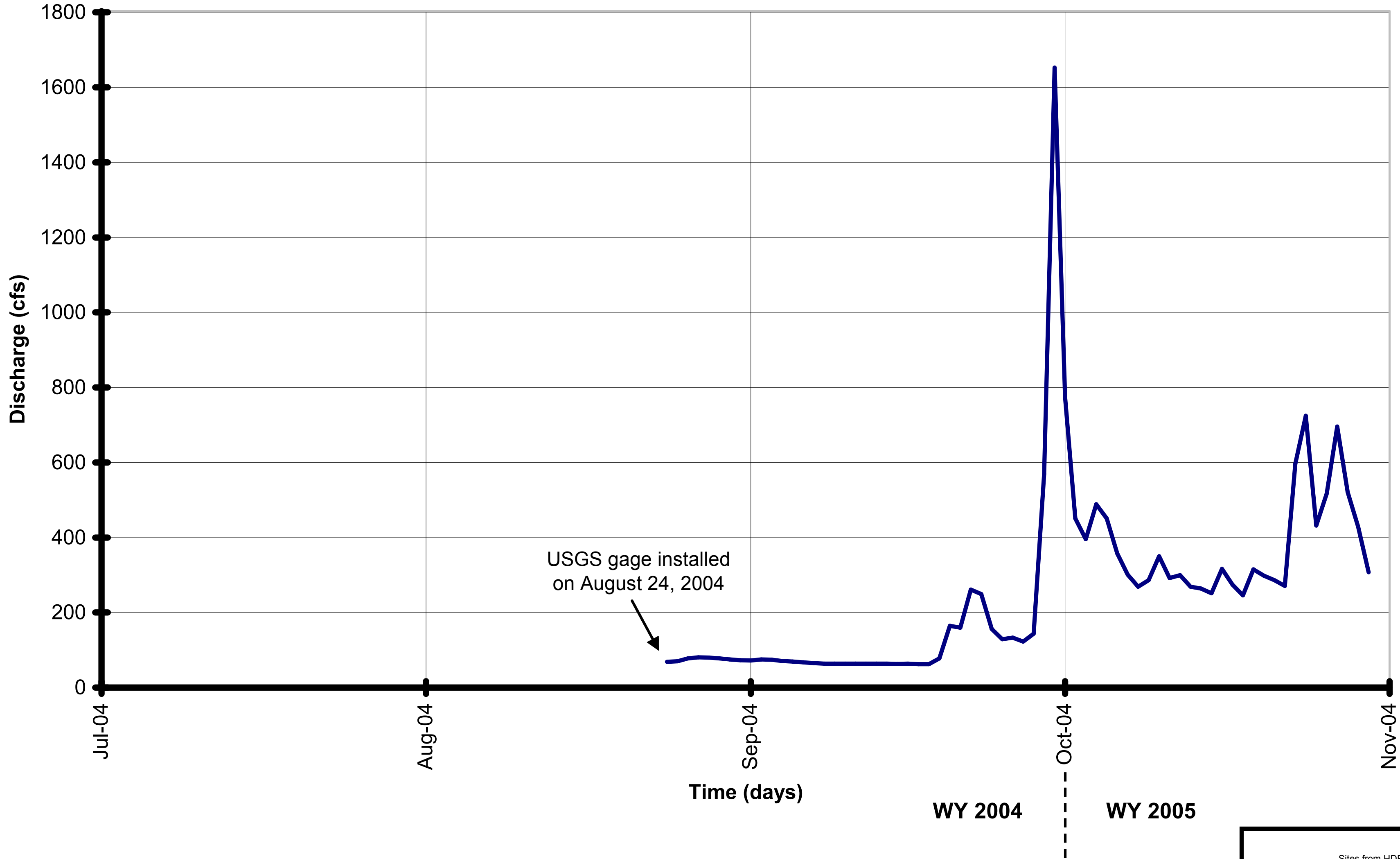
Mean Daily Discharge - North Koktuli River

NK100A, USGS Station 15302250



See Figure 4-3 for site location.
WY: Water Year (October 1 - September 30)

Sites from HDR, file date 02/07/2005

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Northern Dynasty Mines Inc.

Pebble Project

Mean Daily Discharge
North Fork Koktuli River
Figure: 4-8

File: Fig4-8.mxd	Date: October 10, 2005
Version: 1	Author: HDR-DS/JC

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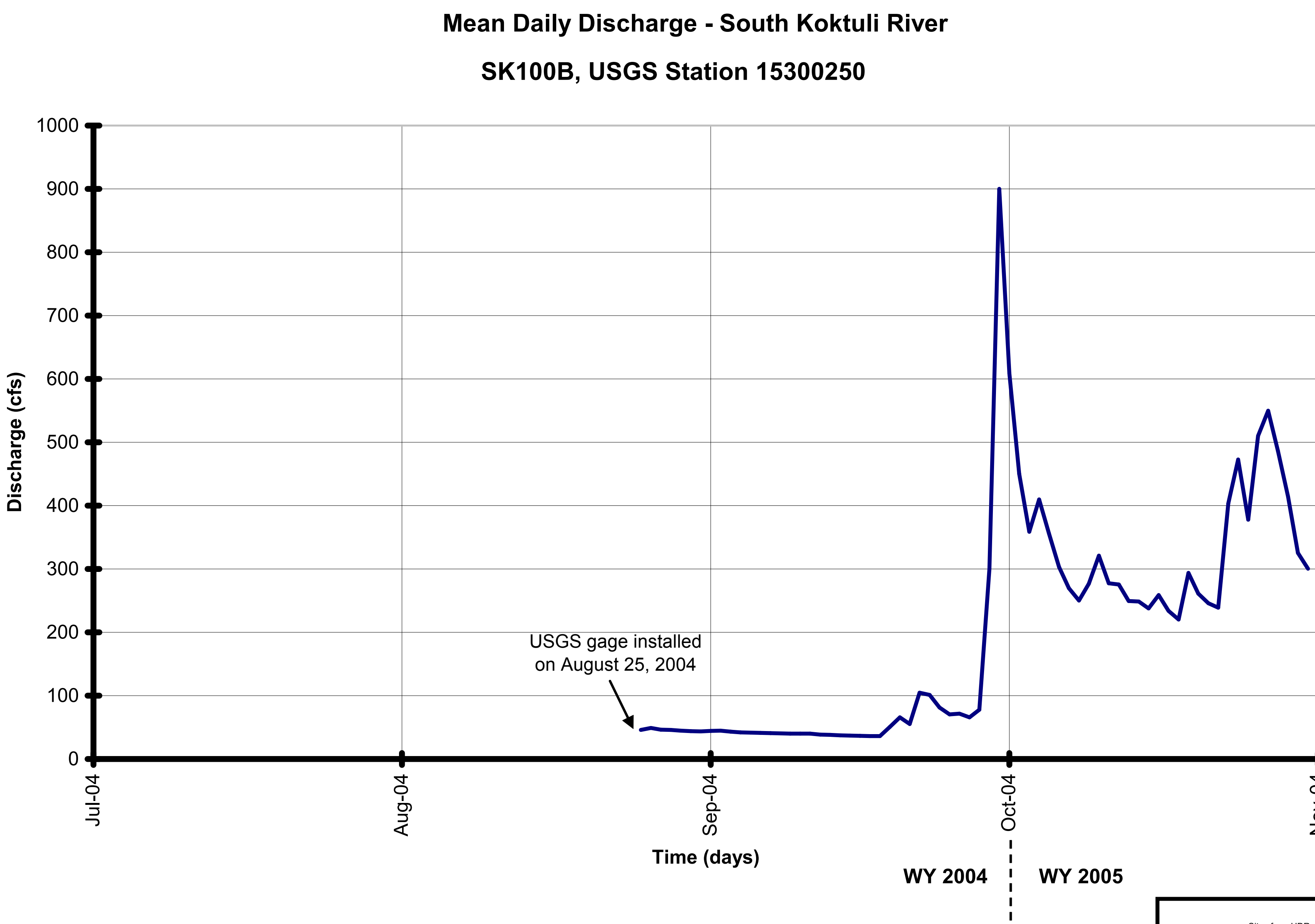

See Figure 4-4 for site location.
WY: Water Year (October 1 - September 30)

Sites from HDR, file date 02/07/2005
Privileged and Confidential
Northern Dynasty Mines Inc.

Pebble Project
Mean Daily Discharge
South Fork Koktuli River
Figure: 4-9

File: Fig4-9.mxd	Date: October 10, 2005
Version: 1	Author: HDR-DS/JC

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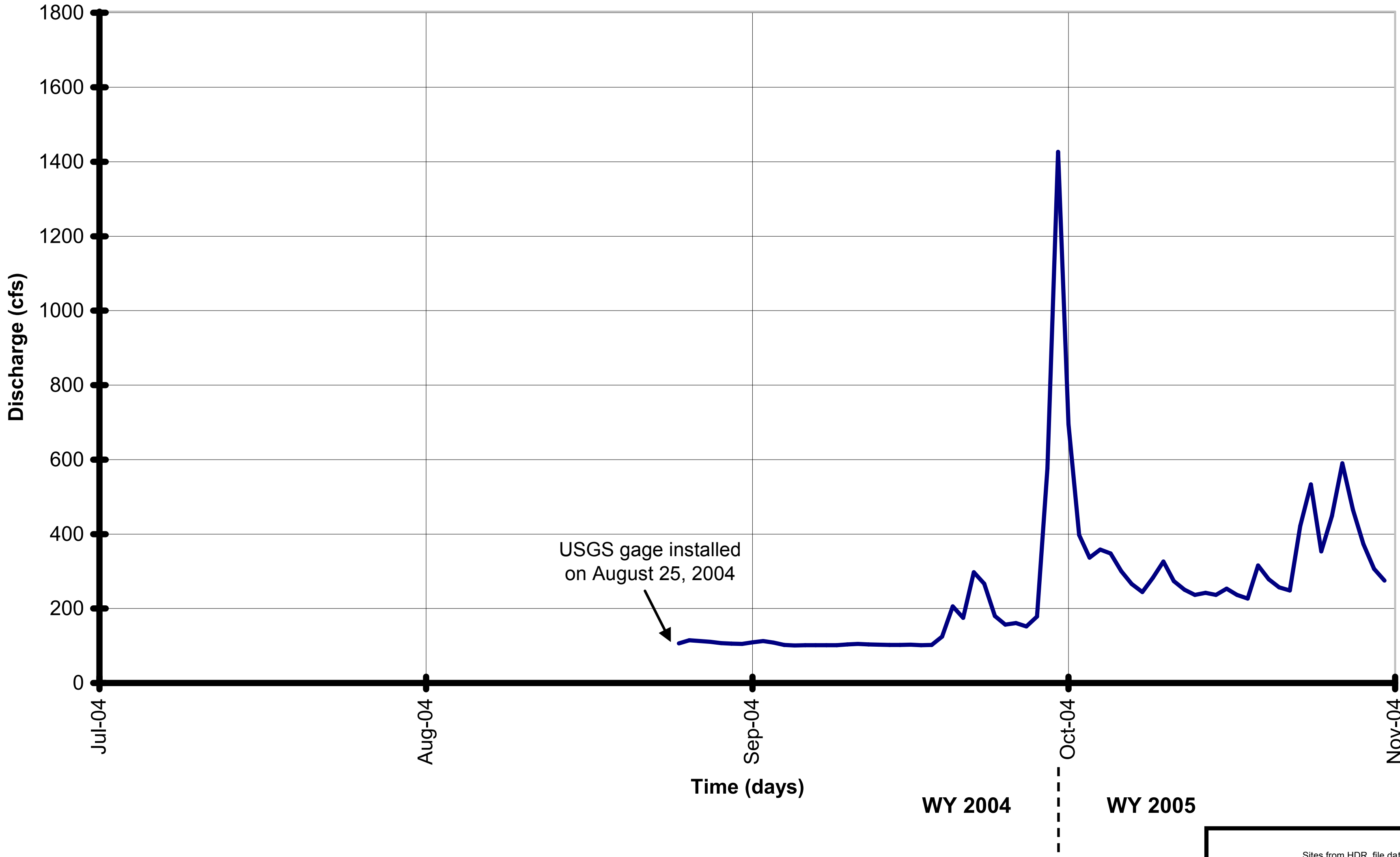
Mean Daily Discharge - Upper Talarik River

UT100B, USGS Station 15300250



Sites from HDR, file date 02/07/2005

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Northern Dynasty Mines Inc.

Pebble Project

Mean Daily Discharge
Upper Talarik Creek
Figure: 4-10

File: Fig4-10.mxd	Date: October 10, 2005
Version: 1	Author: HDR-DS/JC

See Figure 4-5 for site location.
WY: Water Year (October 1 - September 30)

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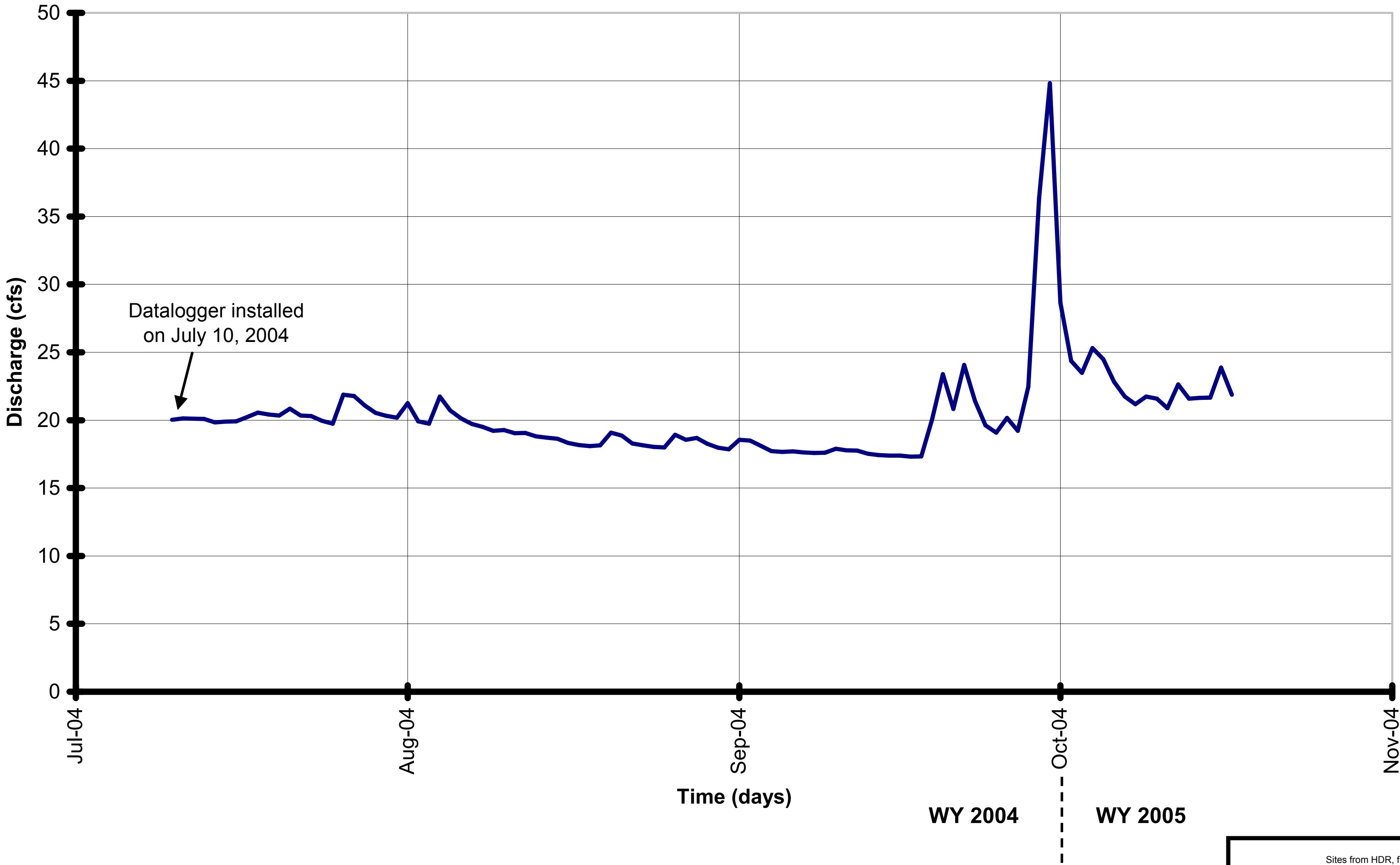
Mean Daily Discharge - Kaskanak River

KC100A



See Figure 4-6 for site location.
WY: Water Year (October 1 - September 30)

Sites from HDR, file date 02/07/2005

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Northern Dynasty Mines Inc.

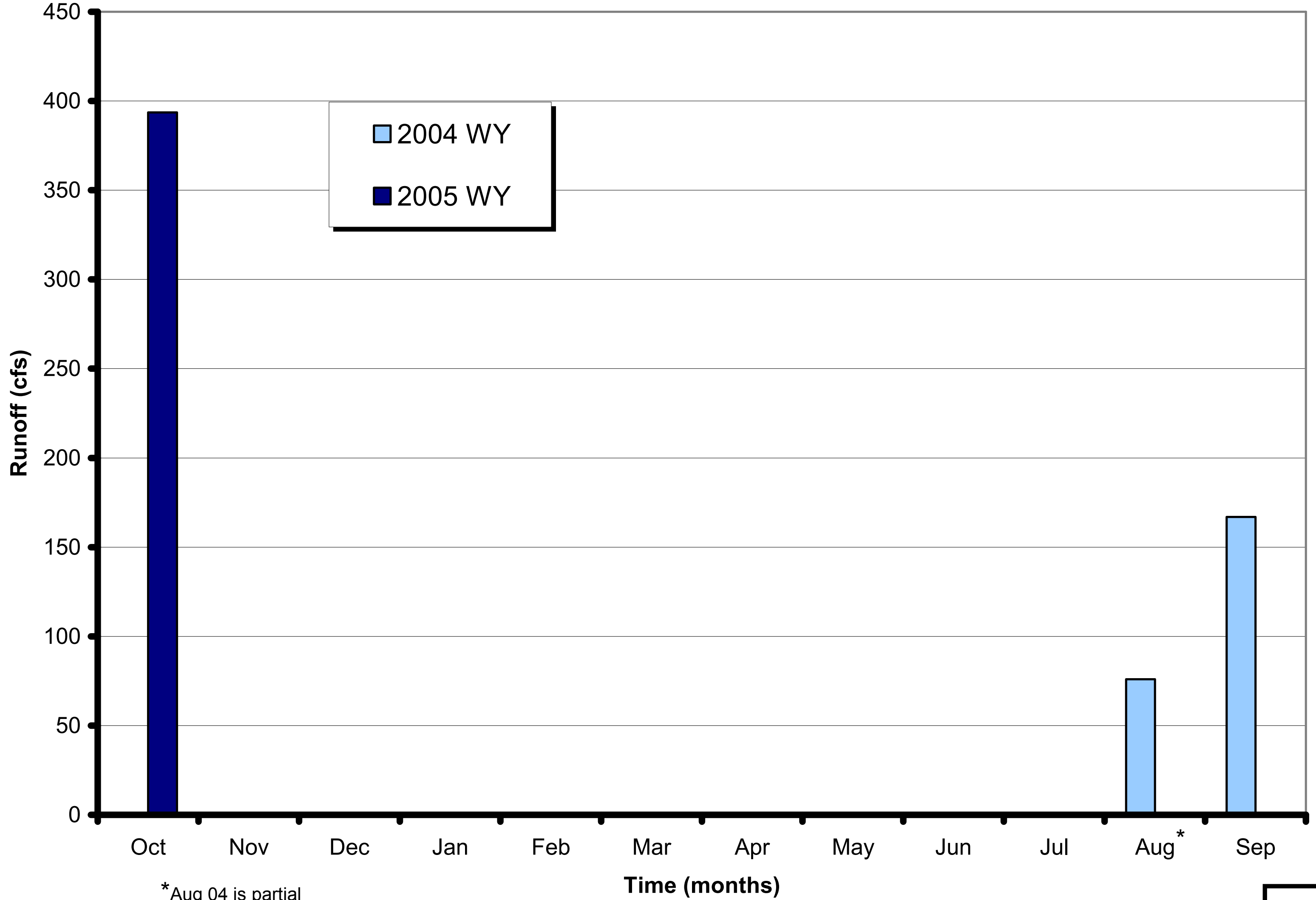
Pebble Project

Mean Daily Discharge
Kaskanak Creek
Figure: 4-11

File: Fig4-11.mxd	Date: October 10, 2005
Version: 1	Author: HDR-DS/JC

Mean Monthly Discharge - North Koktuli River

NK100A, USGS Station 15302250



*Aug 04 is partial

See Figure 4-3 for site location.
WY: Water Year (October 1 - September 30)

Sites from HDR, file date 02/07/2005

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Pebble Project

Mean Mounthly Discharge
North Fork Koktuli River
Figure: 4-12

File: Fig4-12.mxd	Date: October 10, 2005
Version: 1	Author: HDR-DS/JC

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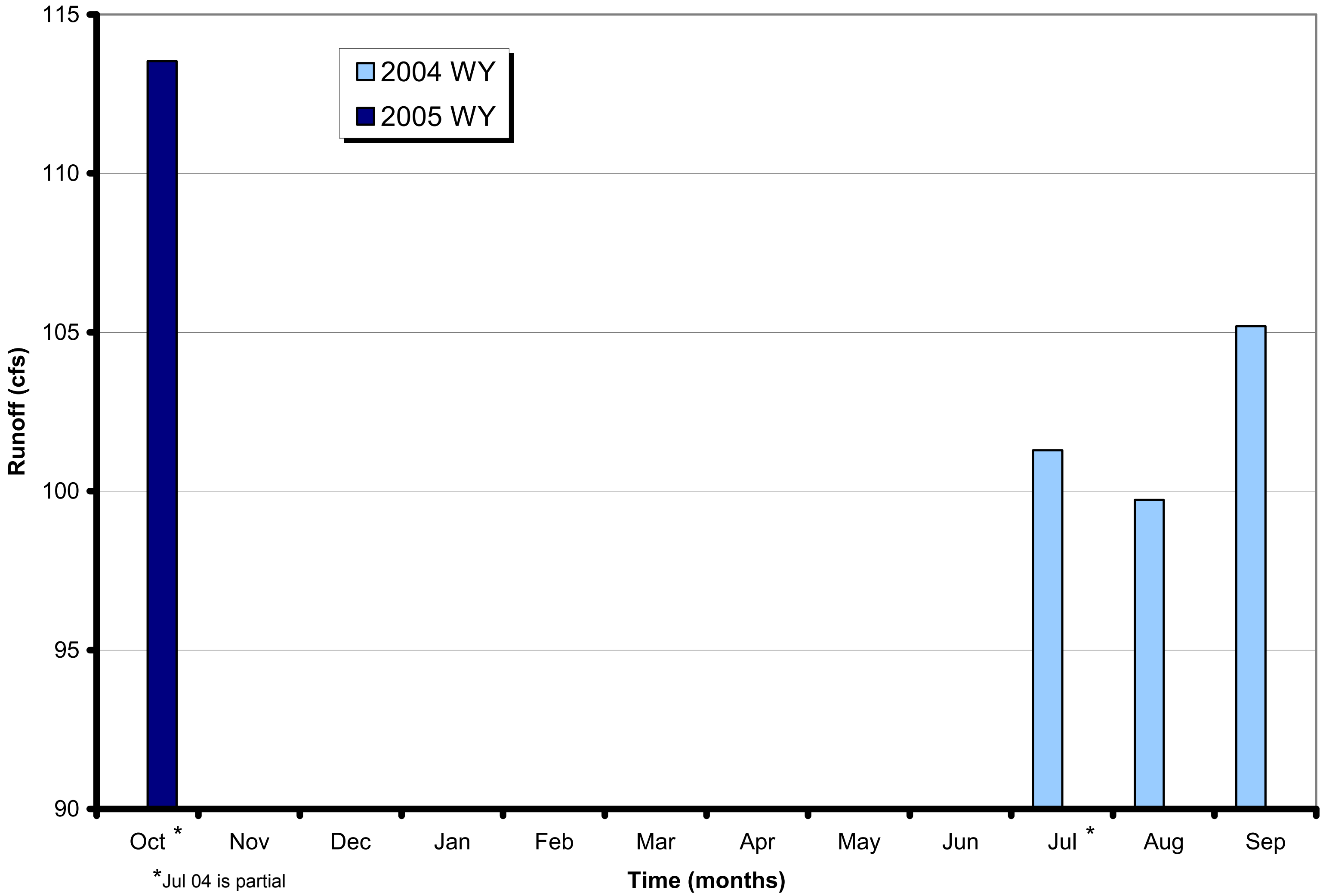
Mean Monthly Discharge - South Koktuli River

SK100A



*Jul 04 is partial

*Oct 04 is partial

See Figure 4-4 for site location.
WY: Water Year (October 1 - September 30)

Sites from HDR, file date 02/07/2005

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Pebble Project

Mean Monthly Discharge
South Fork Koktuli River
Figure: 4-13

File: Fig4-13.mxd	Date: October 10, 2005
Version: 1	Author: HDR-DS/JC

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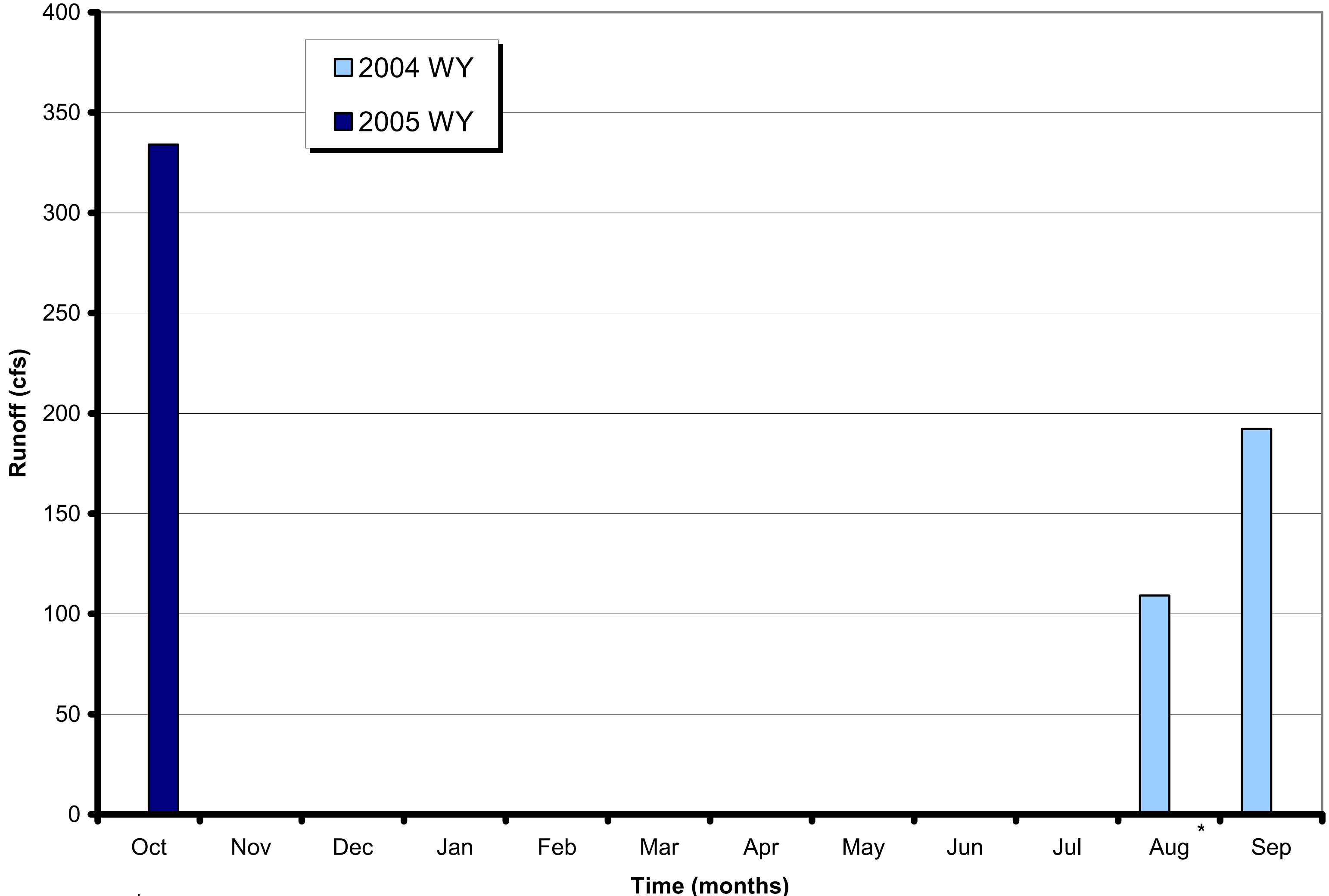
Mean Monthly Discharge - Upper Talarik River

UT100B, USGS Station 15300250



*Aug 04 is partial

See Figure 4-5 for site location.
WY: Water Year (October 1 - September 30)

Sites from HDR, file date 02/07/2005

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Pebble Project

Mean Monthly Discharge
Upper Talarik Creek
Figure: 4-14

File: Fig4-14.mxd	Date: October 10, 2005
Version: 1	Author: HDR-DS/JC

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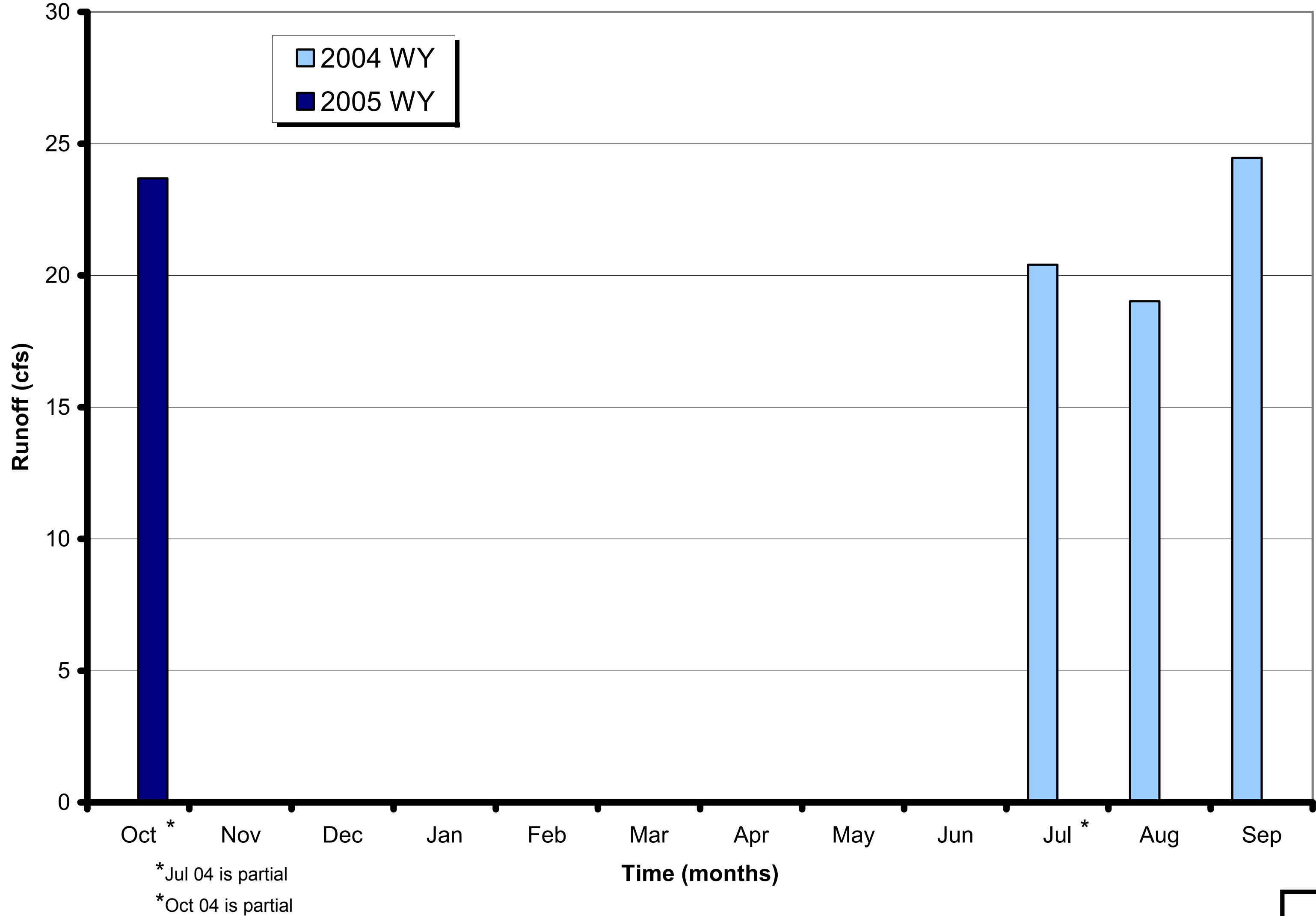
Mean Monthly Discharge - Kaskanak River

KC100A



See Figure 4-6 for site location.
WY: Water Year (October 1 - September 30)

Sites from HDR, file date 02/07/2005

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Northern Dynasty Mines Inc.

Pebble Project

Mean Monthly Discharge
Kaskanak Creek
Figure: 4-15

File: Fig4-15.mxd	Date: October 10, 2005
Version: 1	Author: HDR-DS/JC

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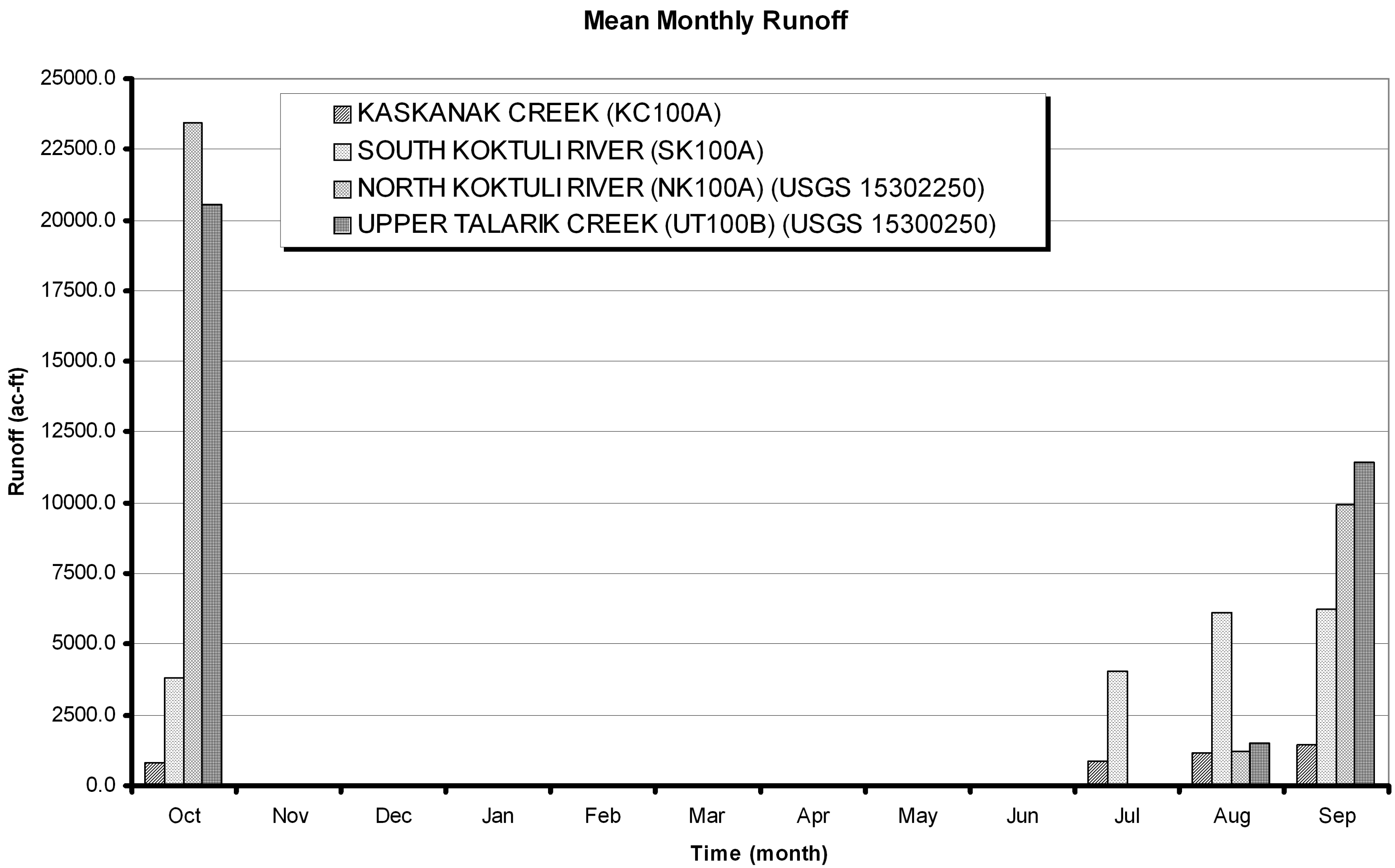

Sites from HDR, file date 02/07/2005

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Northern Dynasty Mines Inc.

Pebble Project

Mean Monthly Runoff
Figure: 4-16

File:Fig4.16.mxd	Date: February 7, 2005
Version: 1	Author: HDR-DS

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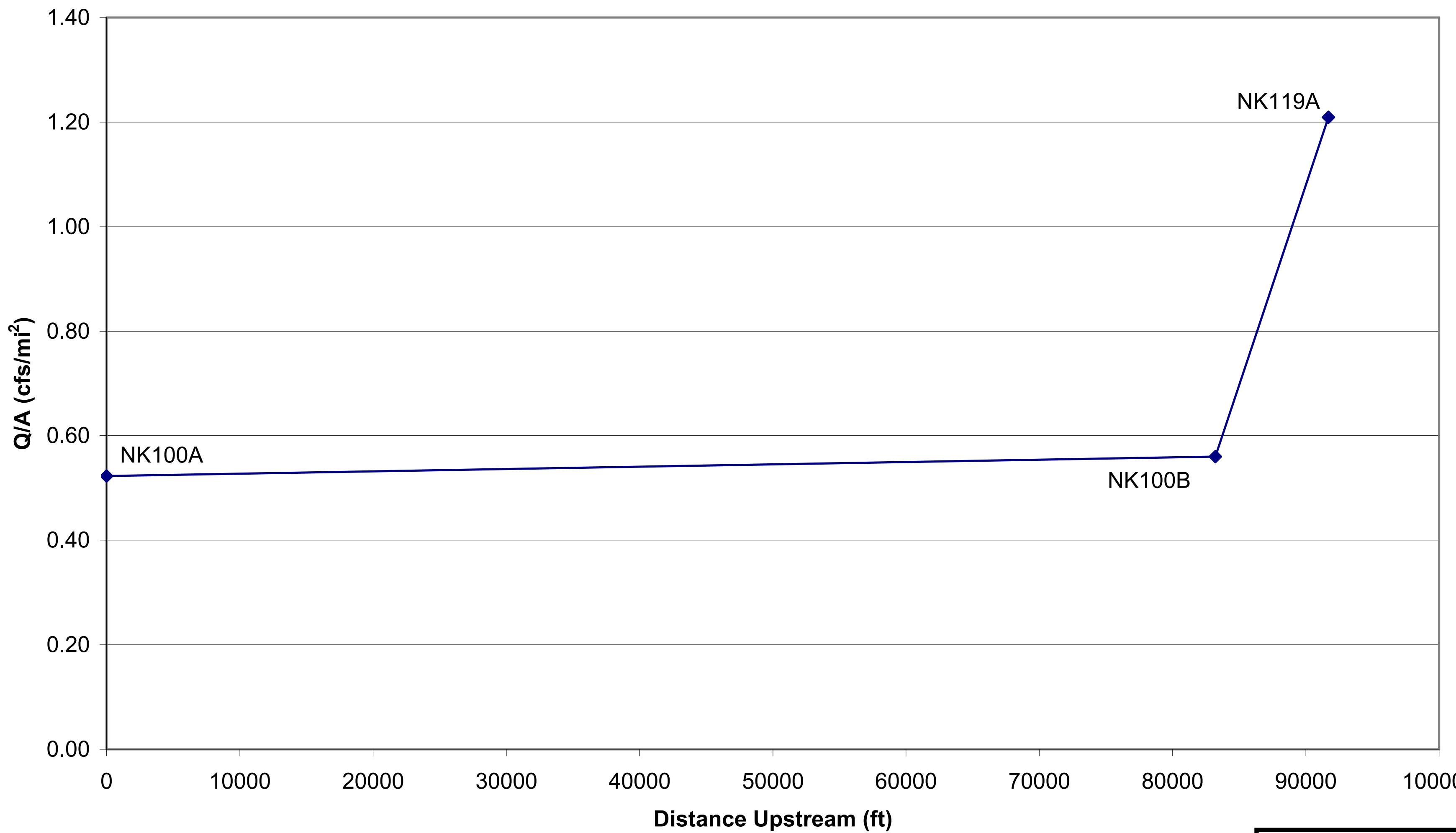
Minimum Mean Daily Discharge (cfs) per Unit Area, North Koktuli River
(Reference Period: September 15, 2004)



See Figure 4-3 for site location.

Sites from HDR, file date 02/07/2005

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Northern Dynasty Mines Inc.

Pebble Project

Minimum Mean Daily Discharge Per Unit Area
North Fork Koktuli River
Figure: 4-17

File: Fig4-17.mxd	Date: October 20, 2005
Version: 1	Author: HDR-DS

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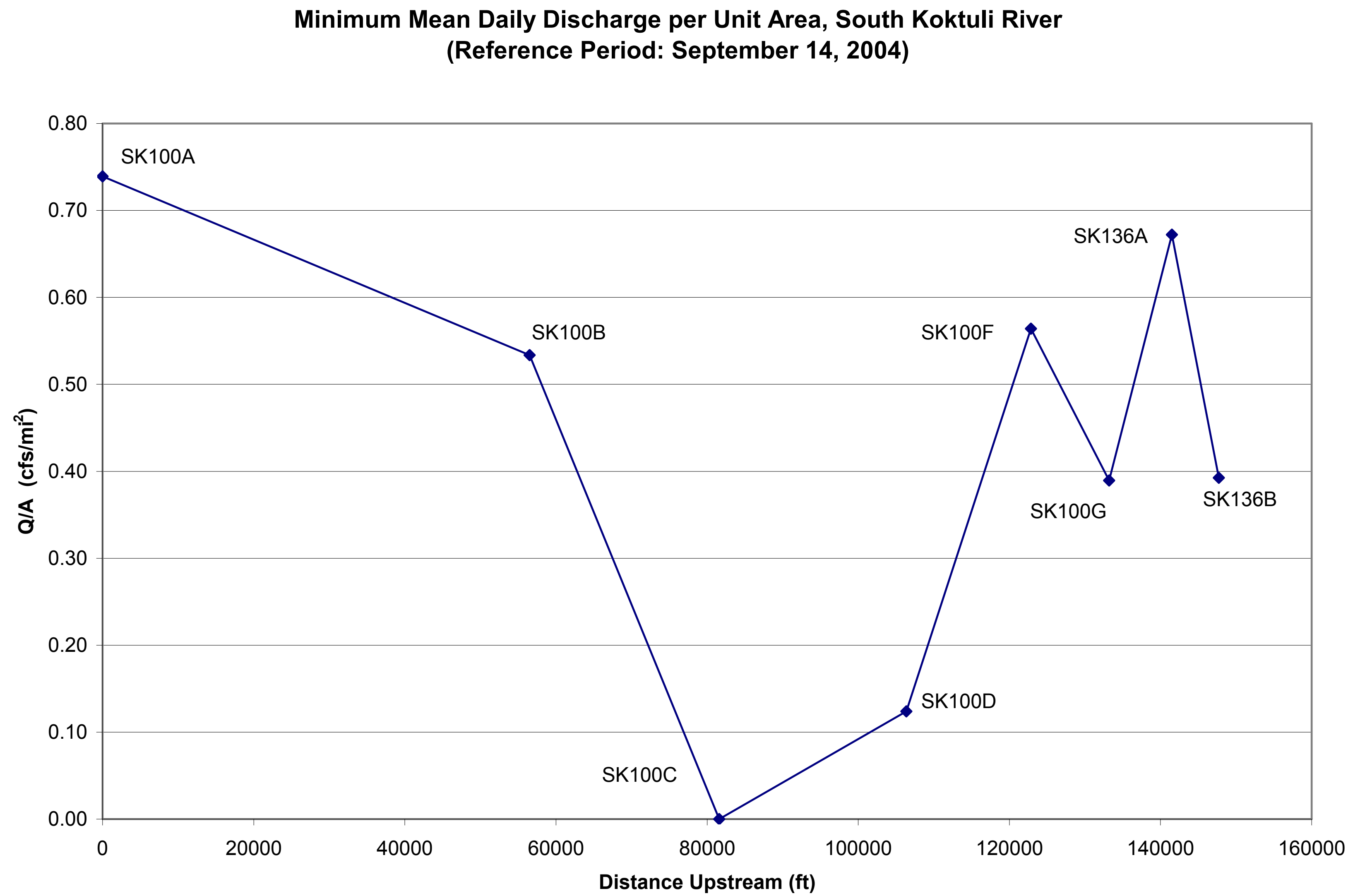

See Figure 4-4 for site location.

Sites from HDR, file date 02/07/2005

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Northern Dynasty Mines Inc.

Pebble Project

Minimum Mean Daily Discharge Per Unit Area
South Fork Koktuli River
Figure: 4-18

File: Fig4-18.mxd	Date: October 20, 2005
Version: 1	Author: HDR-DS

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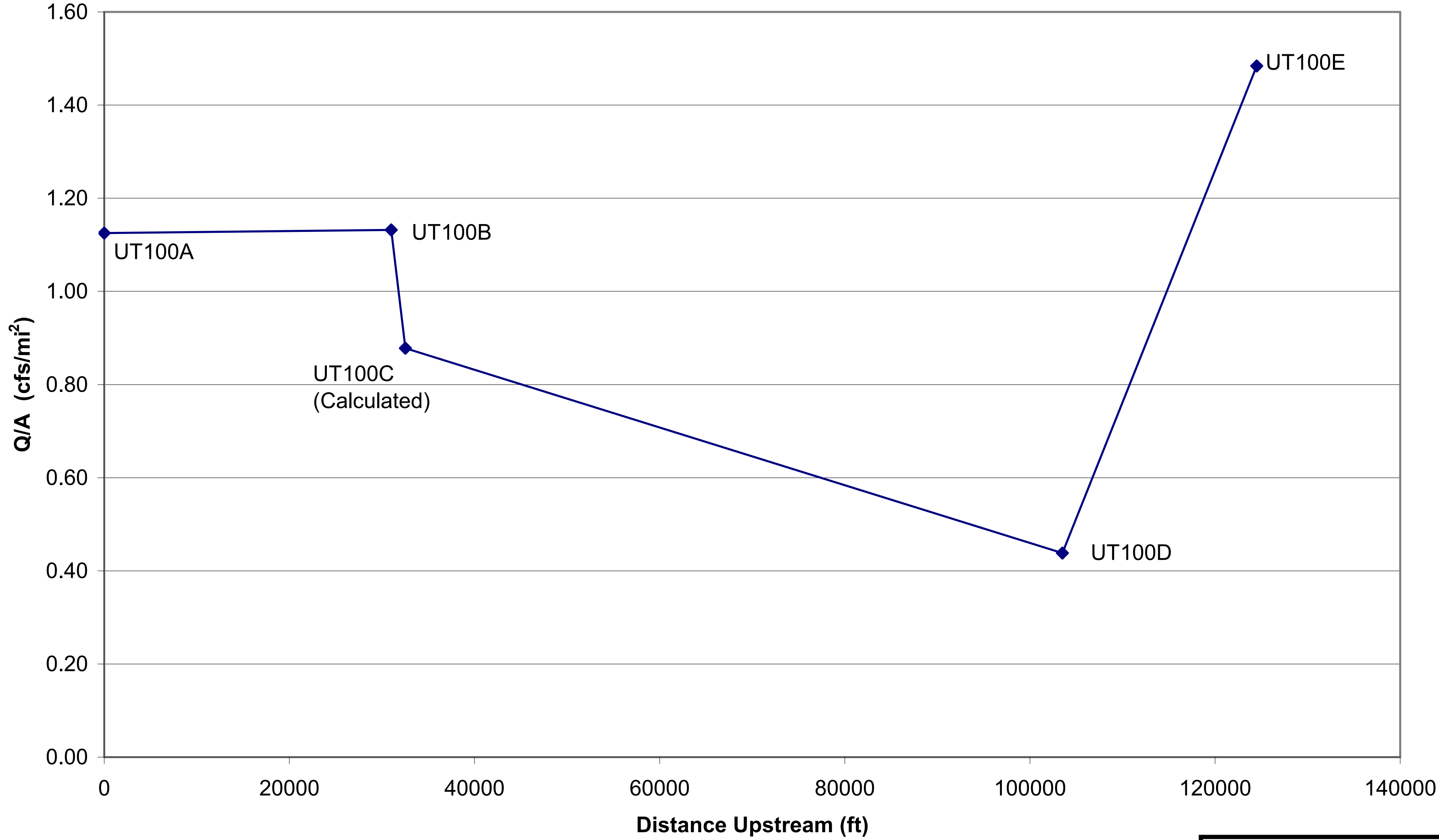
Minimum Mean Daily Discharge per Unit Area, Upper Talarik River
(Reference Period: September 16, 2004)



See Figure 4-5 for site location.

Sites from HDR, file date 02/07/2005

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Northern Dynasty Mines Inc.

Pebble Project

Minimum Mean Daily Discharge Per Unit Area
Upper Talarik Creek
Figure: 4-19

File: Fig4-19.mxd	Date: October 20, 2005
Version: 1	Author: HDR-DS

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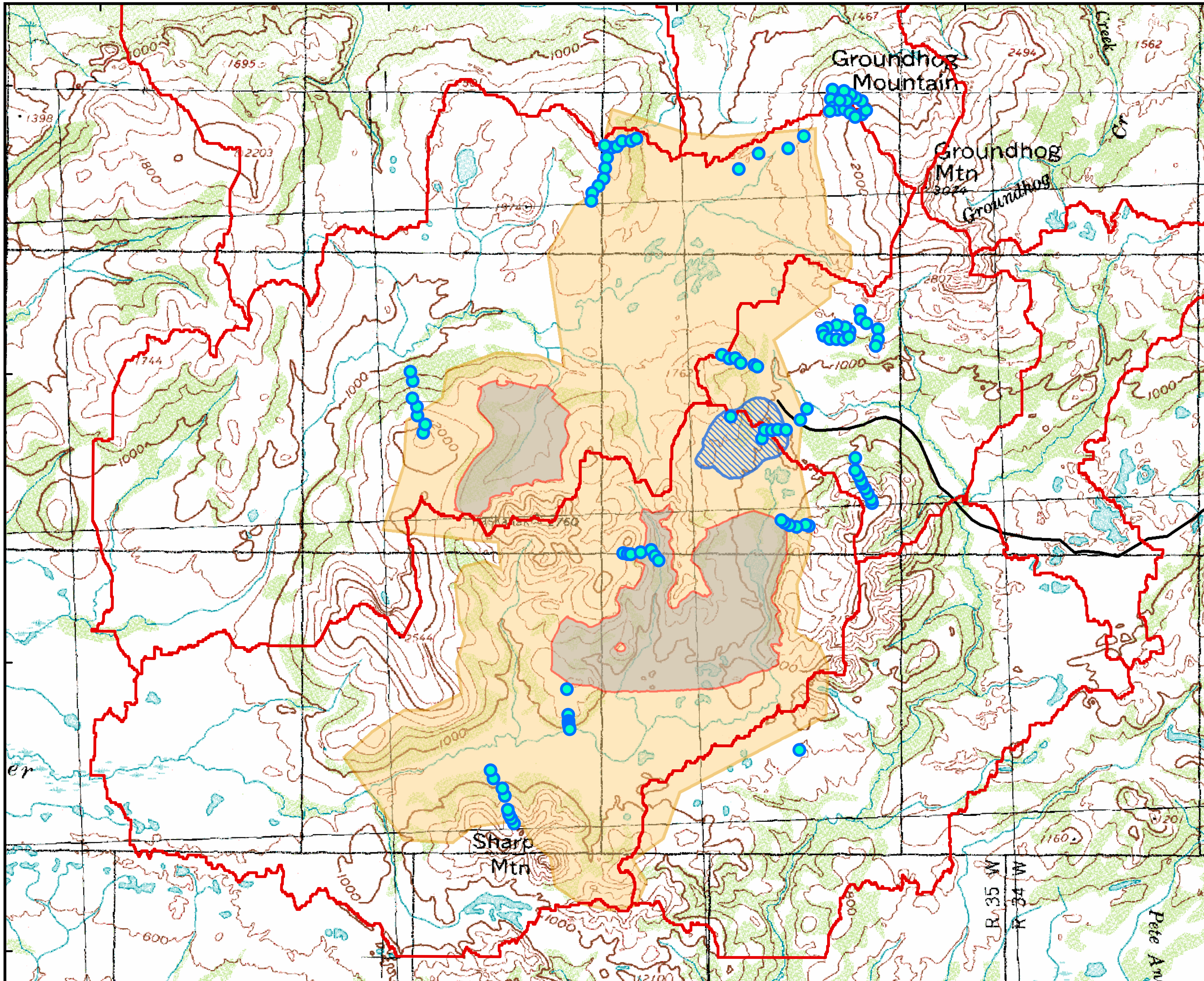

Northern Dynasty Mines Inc.

Pebble Project

Study area and snow survey station locations relative to major catchments in the Pebble Mine survey area, 2004.
Figure 4 – 20

Legend

- Snow Survey Locations 2004
- Local Drainage Basins
- 2004 Study Area
- Mine Pit
- Mine Development Concept
- ADOT/PF Road Alignment, August 2004

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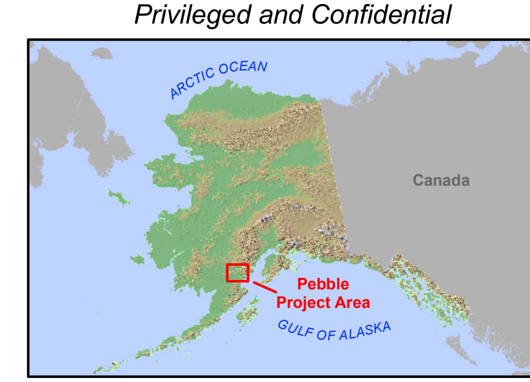


Miles 0 1 2 3 4
Kilometers 0 1 2 3 4 5 6
Scale 1:125,000

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

File: Snow_Survey_2004_05-170-7.mxd	Date: Jan 28, 2005
Version: 1	Author: ABR-DD

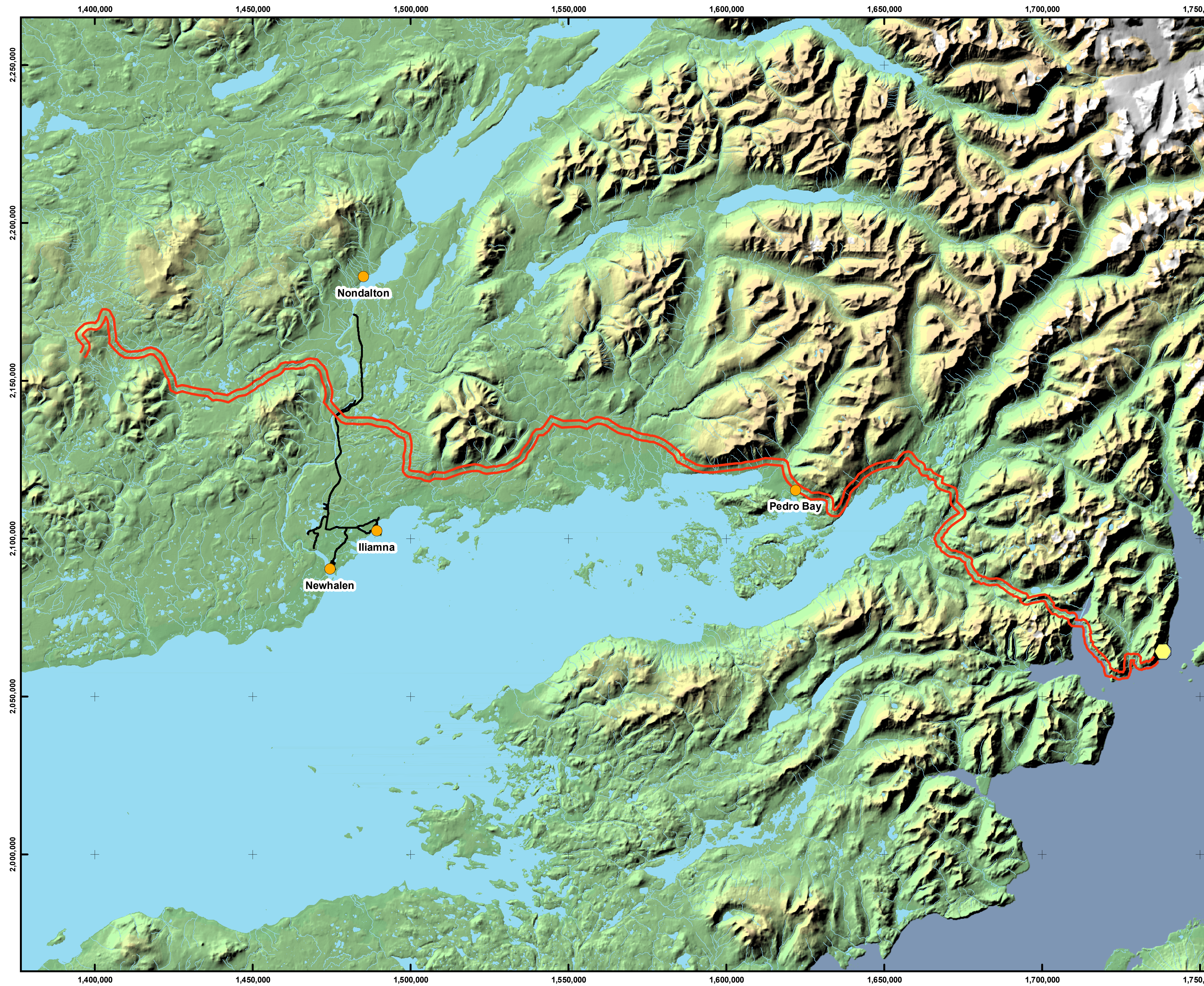
FIGURE 4-21. Photographs of the snowpack at a snow-course station on April 17 and May 15 showing the rate of loss of snowpack that occurred in spring 2004.

Northern Dynasty Mines Inc.

Pebble Project

Surface Water Study Area
Road - Port

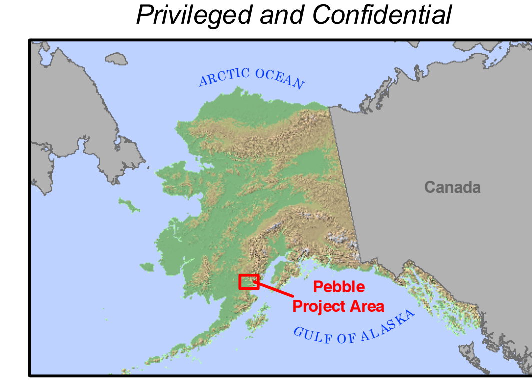
Figure 4-22.



Legend

- Port Site 1
- Towns
- Preferred ADOT&PF Road Corridor

Privileged and Confidential



N

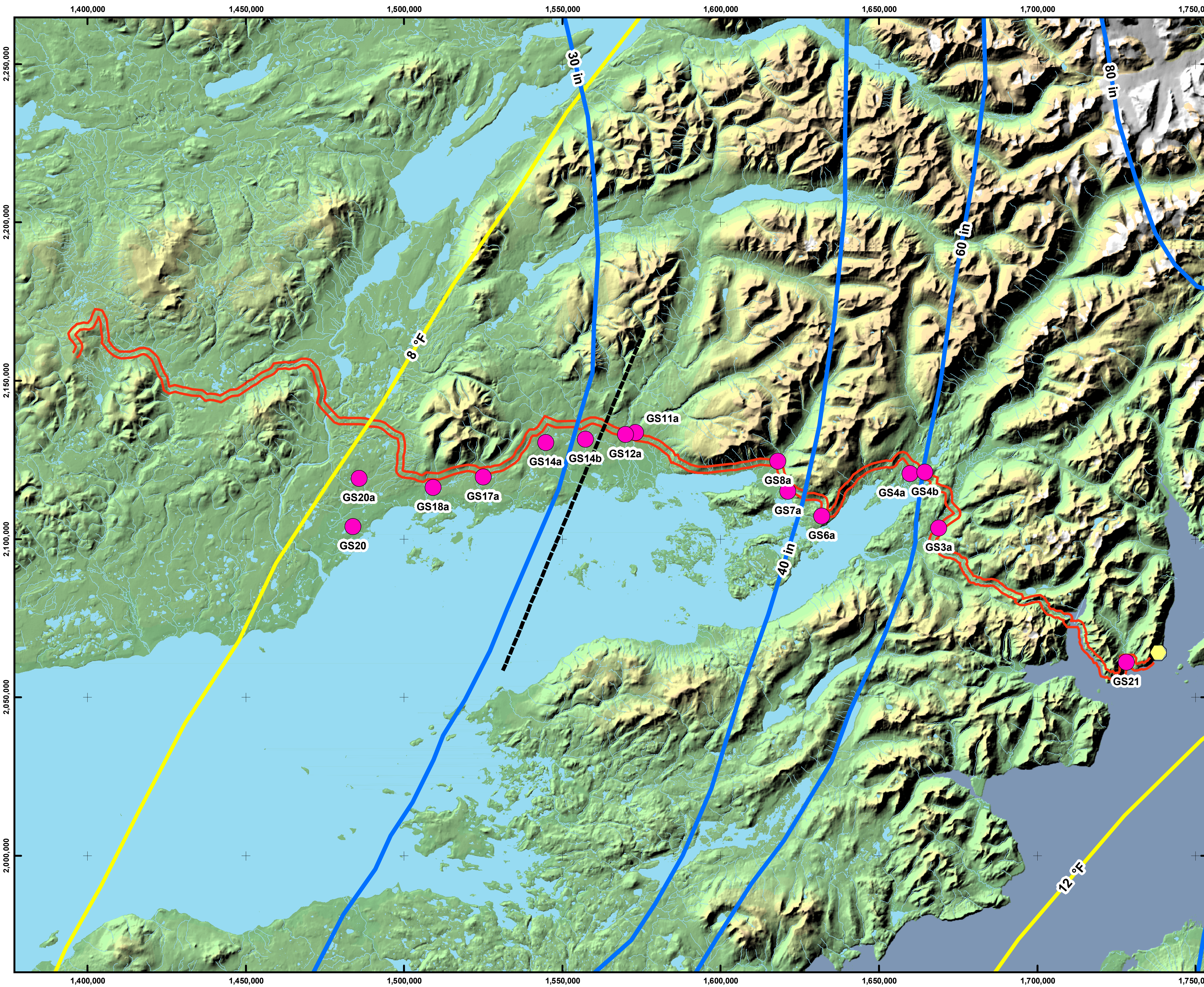
Feet: 0 | 16,000 | 32,000 | 48,000 | 64,000

Meters: 0 | 4,900 | 9,800 | 14,700 | 19,600

Scale 1:361,929

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

File: Hydro_Sty_V02.mxd	**Date: Sept. 8, 2005**
Version: 2	**Author: BEESC-ME**



Northern Dynasty Mines Inc.

Pebble Project

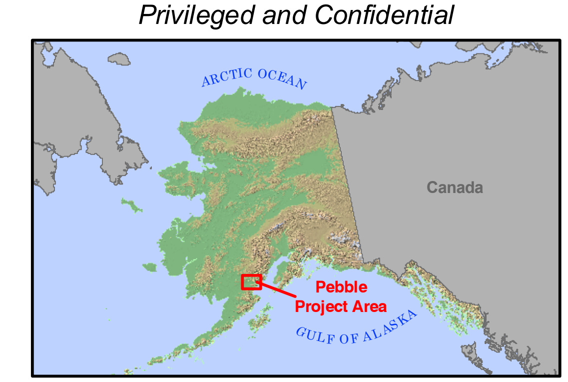
Stream Gage Station Locations
Road - Port

Figure 4-23.

Legend

- Surface Water Gauge
- Port Site 1
- Subregion Boundary
- Mean Annual Precipitation
- Mean Minimum January Temperature
- Preferred ADOT&PF Road Corridor

Privileged and Confidential



Feet: 0 16,000 32,000 48,000 64,000

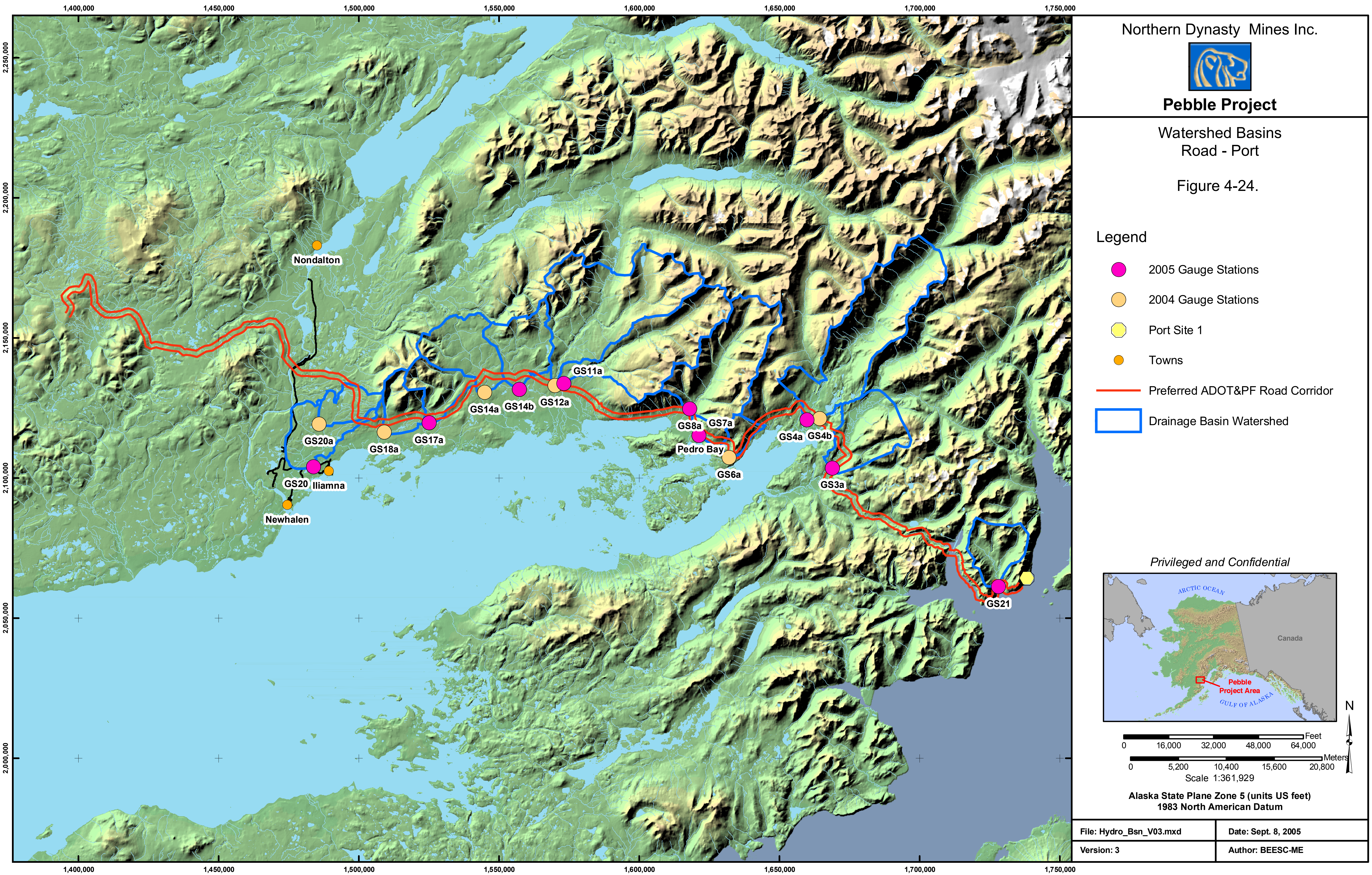
Meters: 0 5,100 10,200 15,300 20,400

Scale 1:361,929

N

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

File: Hydro_Stn_V02.mxd	Date: Sept. 8, 2005
Version: 2	Author: BEESC-ME



Northern Dynasty Mines Inc.
Pebble Project
Watershed Basins
Road - Port
Figure 4-24.
Legend
2005 Gauge Stations
2004 Gauge Stations
Port Site 1
Towns
Preferred ADOT&PF Road Corridor
Drainage Basin Watershed
Privileged and Confidential
ARCTIC OCEAN
Canada
Pebble Project Area
GULF OF ALASKA
N
Feet
0 16,000 32,000 48,000 64,000
Meters
0 5,200 10,400 15,600 20,800
Scale 1:361,929
Alaska State Plane Zone 5 (units US feet)
1983 North American Datum
File: Hydro_Bsn_V03.mxd
Date: Sept. 8, 2005
Version: 3
Author: BEESC-ME
Nondalton
Iliamna
Newhalen
Pedro Bay
GS20
GS20a
GS18a
GS17a
GS14a
GS14b
GS12a
GS11a
GS8a
GS7a
GS6a
GS4a
GS4b
GS3a
GS21
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2,050,000
2,000,000

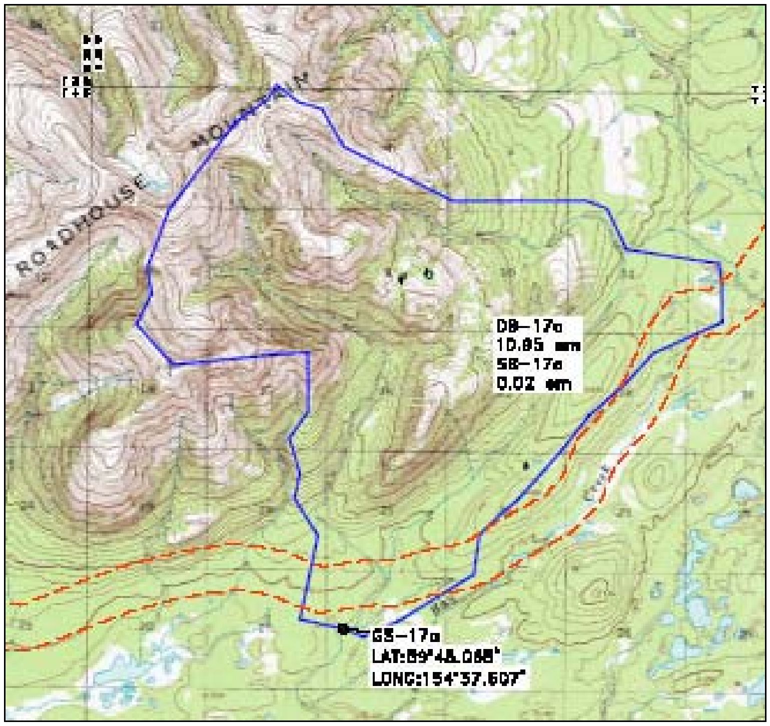

FIGURE 4-25. Example of watershed basin map

FIGURE 4-26. Example of newly installed crest gauge

FIGURE 4-27. Field crew taking a discharge measurement on Knutson Creek

FIGURE 4-28. Field crew taking a discharge measurement using a small boat on the Pile River

HMST v2.0 One-Point Velocity Discharge Measurement Checker

By: W. F. (Skip) Barber, Senior Hydrologist

Station Name:	Canyon Creek East Channel				
Station Number:	11a	WIDTH	48.000	# of Sections	24
Date:	10/16/2004	AREA	34.600	Sections > 5%	9
Measurement #:		VELOCITY	2.796	Sections > 10%	2
Pygmy or AA (p/a)	a				
Rating # (1 or 2)	2	**TOTAL DISCHARGE**	**96.740**		

Print Header | Print Full Sheet | Clear Sheet

Correction Coefficient	Distance	Width	Depth	Revolutions	Seconds	Velocity At Point	Mean Velocity	Adjusted Velocity	Area	Discharge
	0	1.00	0			0.000	0.000	0.000	0.000	0.000
	2	2.00	0.2			0.140	0.140	0.140	0.400	0.056
	4	2.00	0.4			1.140	1.140	1.140	0.800	0.912
	6	2.00	0.5			1.620	1.620	1.620	1.000	1.620
	8	2.00	0.6			2.050	2.050	2.050	1.200	2.460
	10	2.00	0.7			1.900	1.900	1.900	1.400	2.660
	12	2.00	0.6			2.440	2.440	2.440	1.200	2.928
	14	2.00	0.4			2.020	2.020	2.020	0.800	1.616
	16	2.00	0.4			1.490	1.490	1.490	0.800	1.192
	18	2.00	0.4			1.910	1.910	1.910	0.800	1.528
	20	2.00	0.7			2.060	2.060	2.060	1.400	2.884
	22	2.00	0.8			3.030	3.030	3.030	1.600	4.848
	24	2.00	0.9			3.040	3.040	3.040	1.800	5.472
	26	3.00	1.2			4.300	4.300	4.300	3.600	15.480
	30	3.00	1.2			3.990	3.990	3.990	3.600	14.364
	32	2.00	1.3			3.270	3.270	3.270	2.600	8.502
	34	2.00	1			3.150	3.150	3.150	2.000	6.300
	36	2.00	0.9			3.980	3.980	3.980	1.800	7.164
	38	2.00	1			3.040	3.040	3.040	2.000	6.080
	40	2.00	0.9			2.870	2.870	2.870	1.800	5.166
	42	2.00	1			2.400	2.400	2.400	2.000	4.800
	44	2.00	0.6			0.470	0.470	0.470	1.200	0.564
	46	2.00	0.4			0.180	0.180	0.180	0.800	0.144
	48	1.00	0			0.000	0.000	0.000	0.000	0.000
		0.00				0.000	0.000	0.000	0.000	0.000
		0.00				0.000	0.000	0.000	0.000	0.000
		0.00				0.000	0.000	0.000	0.000	0.000
		0.00				0.000	0.000	0.000	0.000	0.000
		0.00				0.000	0.000	0.000	0.000	0.000

FIGURE 4-29. Example of discharge computation sheet

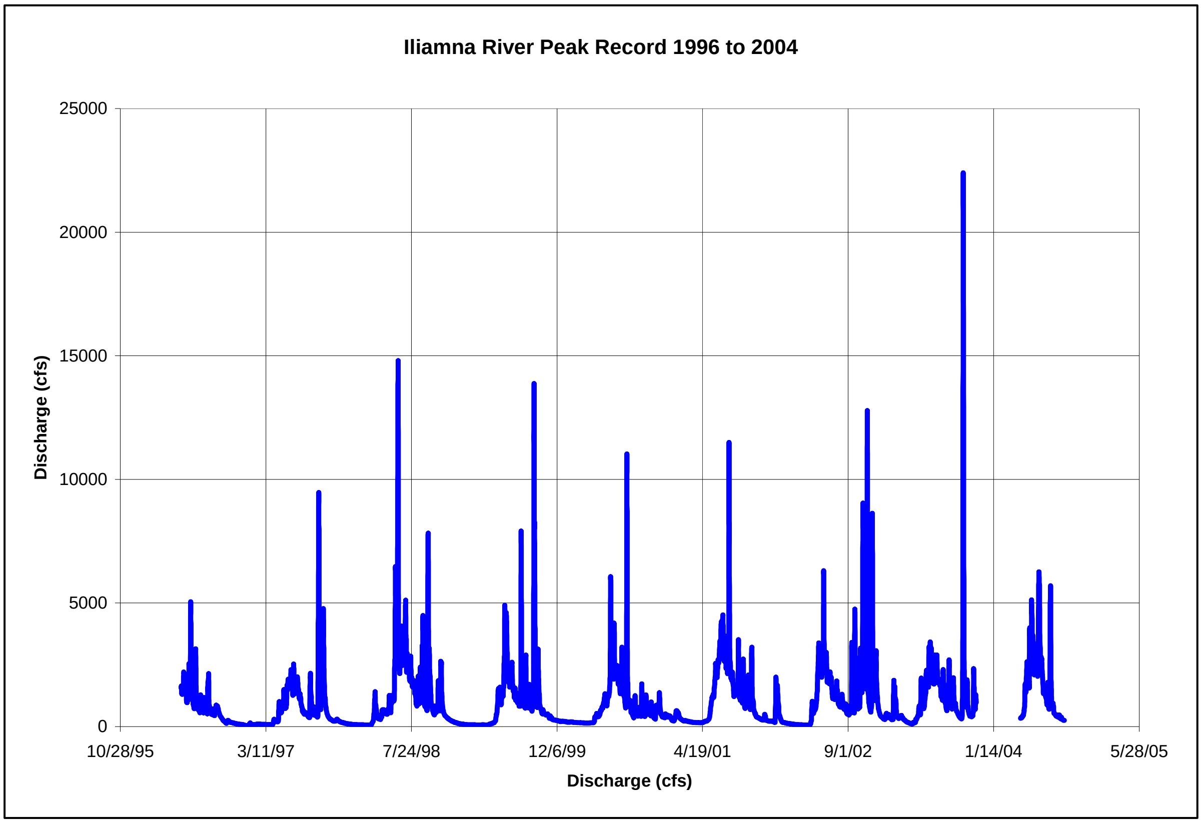

FIGURE 4-30. USGS peak daily discharge records for Iliamna River

FIGURE 4-31. Flood in Iliamna River on October 1, 2003 (GS 3a).

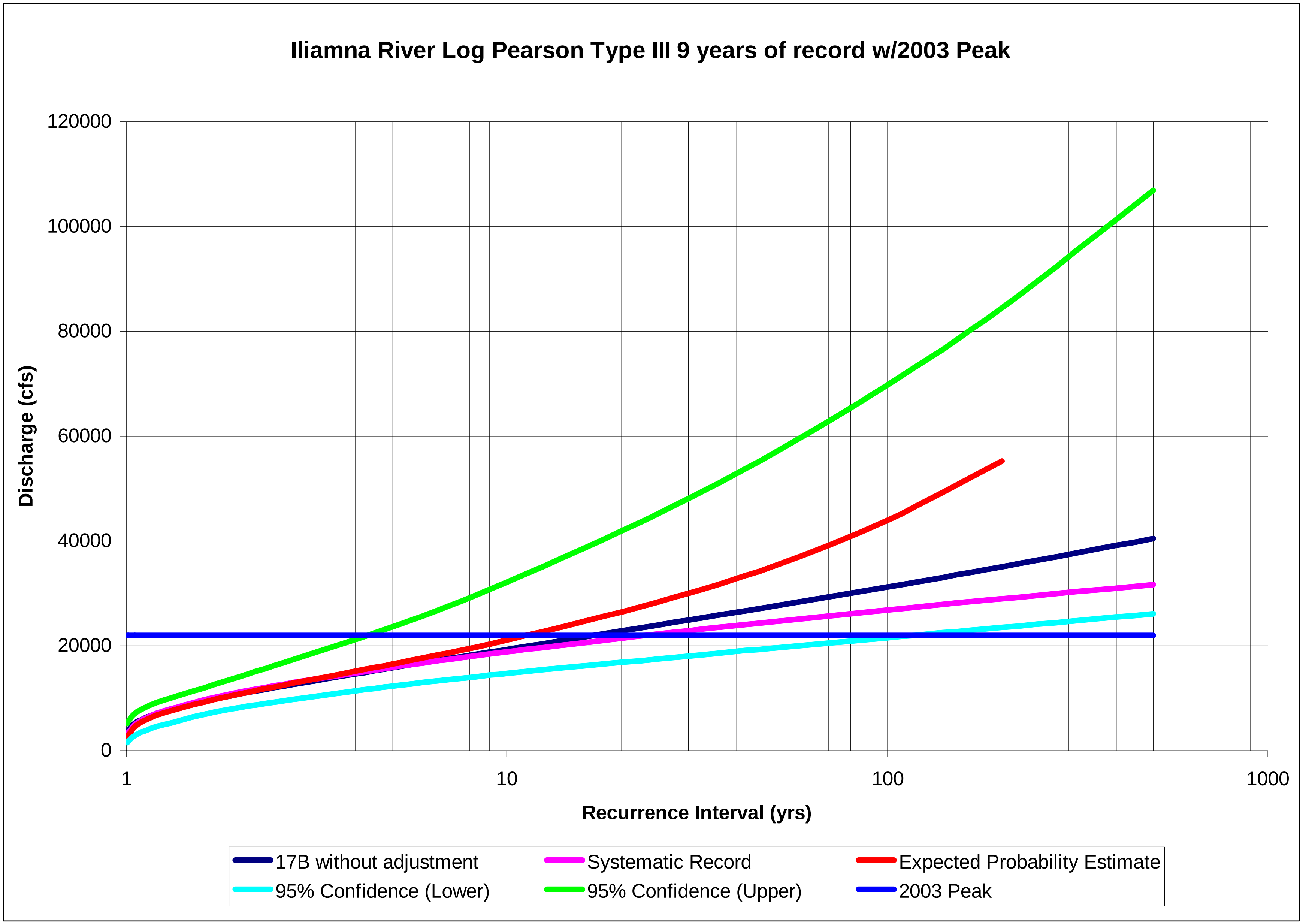

FIGURE 4-32. Comparison of the Log Pearson Type III analysis and the 2003 Flood

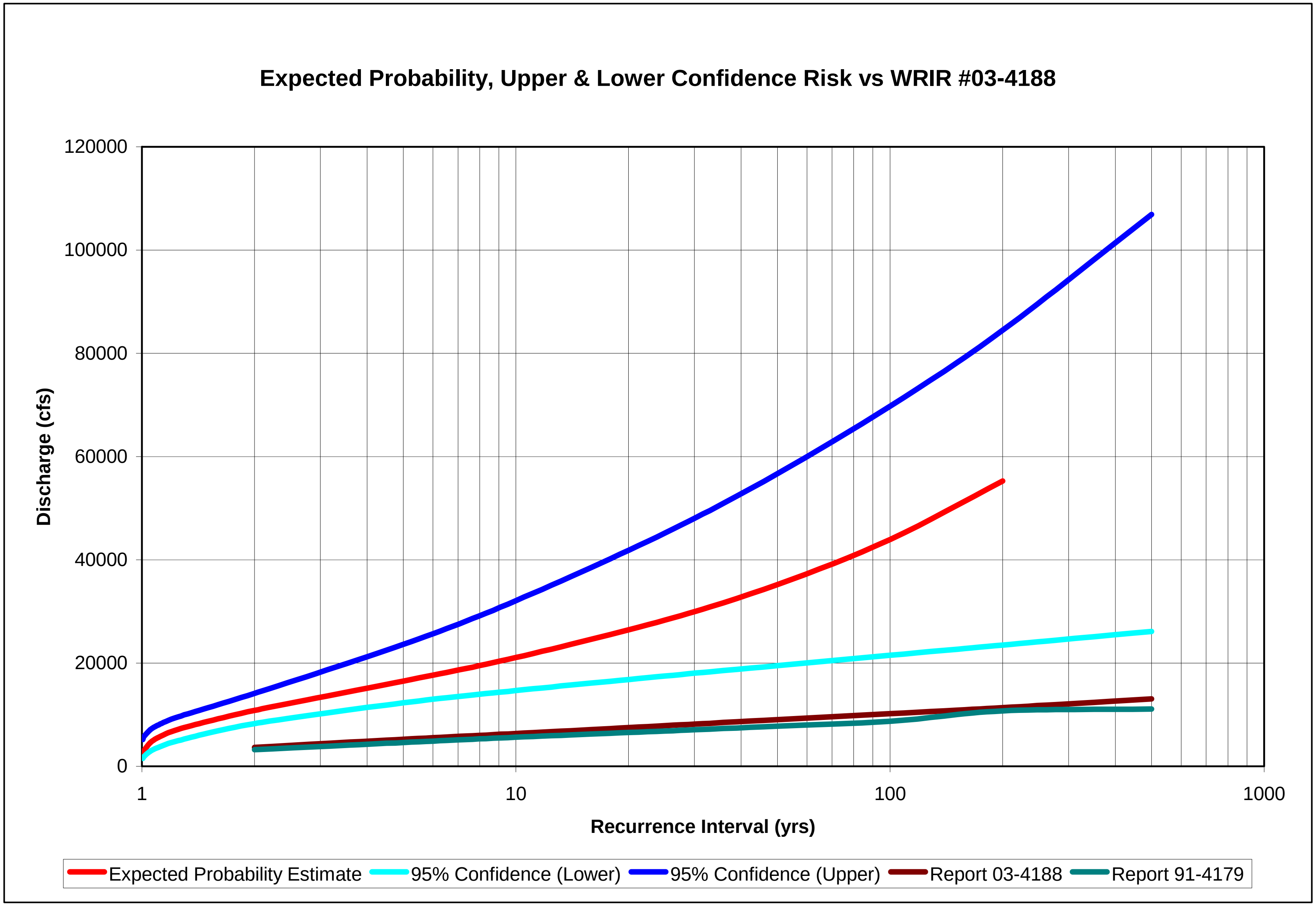

FIGURE 4-33. Comparison of Log Pearson Type III and WRIR 03-4188 analyses

$$Q_2 := 11190\left[\frac{.2535\,Da^{.9462}\cdot\left[\left[\left(\frac{St}{Da}\right)\cdot 100+1\right]^{-.1981}\cdot Pr^{1.201}\right]}{3655.86}\right]$$

$$Q_5 := 15910\left[\frac{.5171\cdot Da^{.9084}\cdot\left[\left[\left(\frac{St}{Da}\right)\cdot 100+1\right]^{-.2128}\cdot Pr^{1.162}\right]}{5214}\right]$$

$$Q_{10} := 18810\left[\frac{.7445\,Da^{.8887}\cdot\left[\left[\left(\frac{St}{Da}\right)\cdot 100+1\right]^{-.2204}\cdot Pr^{1.147}\right]}{6373.216}\right]$$

$$Q_{25} := 22230\left[\frac{1.091\cdot Da^{.8686}\cdot\left[\left[\left(\frac{St}{Da}\right)\cdot 100+1\right]^{-.2273}\cdot Pr^{1.131}\right]}{7882.664}\right]$$

$$Q_{50} := 24600\left[\frac{1.395\cdot Da^{.8563}\cdot\left[\left[\left(\frac{St}{Da}\right)\cdot 100+1\right]^{-.2313}\cdot Pr^{1.120}\right]}{9040.285}\right]$$

$$Q_{100} := 26840\left[\frac{1.738\,Da^{.8457}\cdot\left[\left[\left(\frac{St}{Da}\right)\cdot 100+1\right]^{-.2347}\cdot Pr^{1.109}\right]}{10189.513}\right]$$

$$Q_{200} := 28970\left[\frac{2.124\,Da^{.8363}\cdot\left[\left[\left(\frac{St}{Da}\right)\cdot 100+1\right]^{-.2377}\cdot Pr^{1.099}\right]}{11382.304}\right]$$

$$Q_{500} := 31641\cdot\left[\frac{2.704\,Da^{.8253}\cdot\left[\left[\left(\frac{St}{Da}\right)\cdot 100+1\right]^{-.2413}\cdot Pr^{1.088}\right]}{13082}\right]$$

FIGURE 4-34: Preliminary calibrated regression equations for streams between Iniskin Bay and Canyon Creek

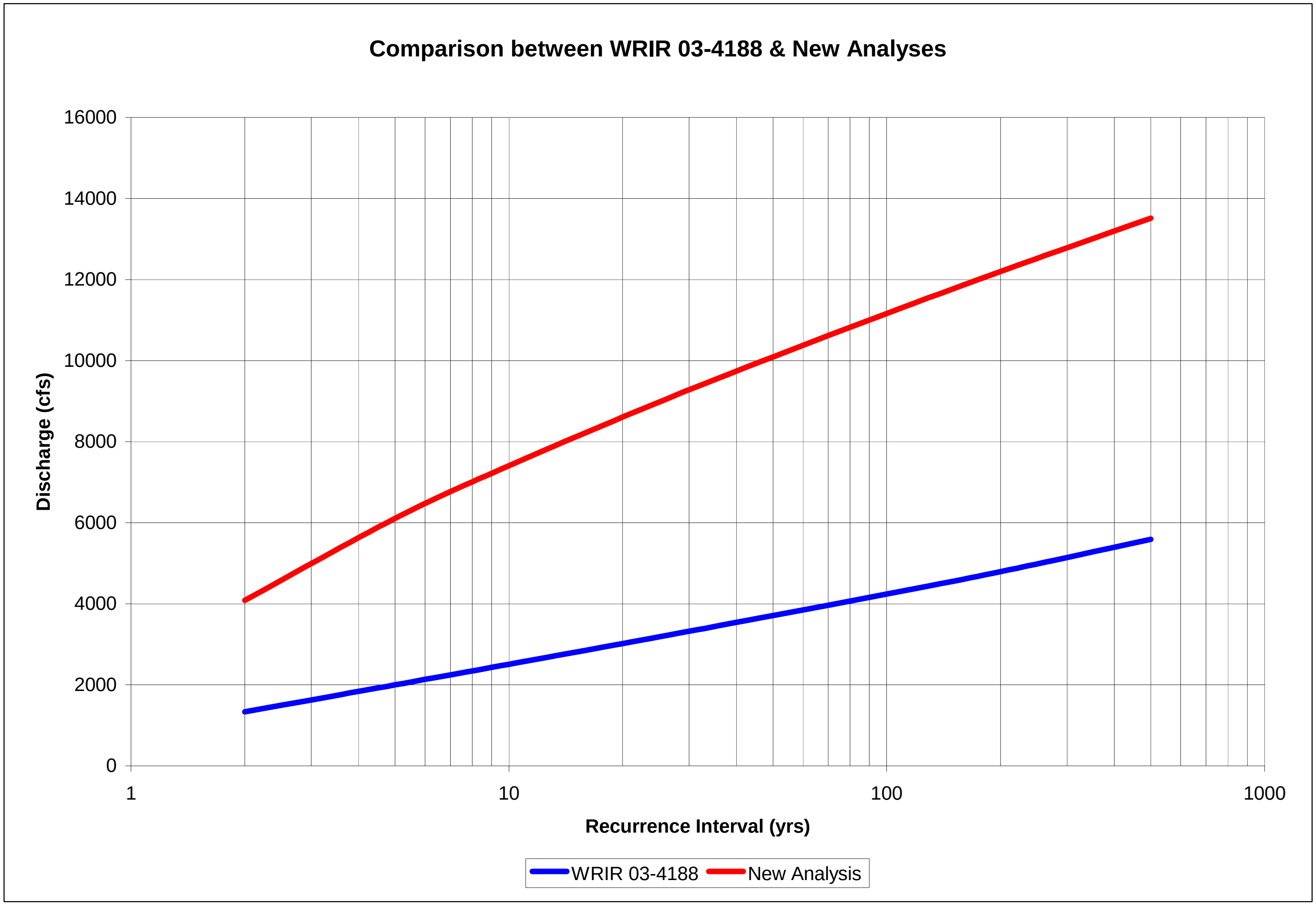

FIGURE 4-35. Comparison of flood predictions by WRIR 03-4188 and by the calibrated regression equations for the Pile River

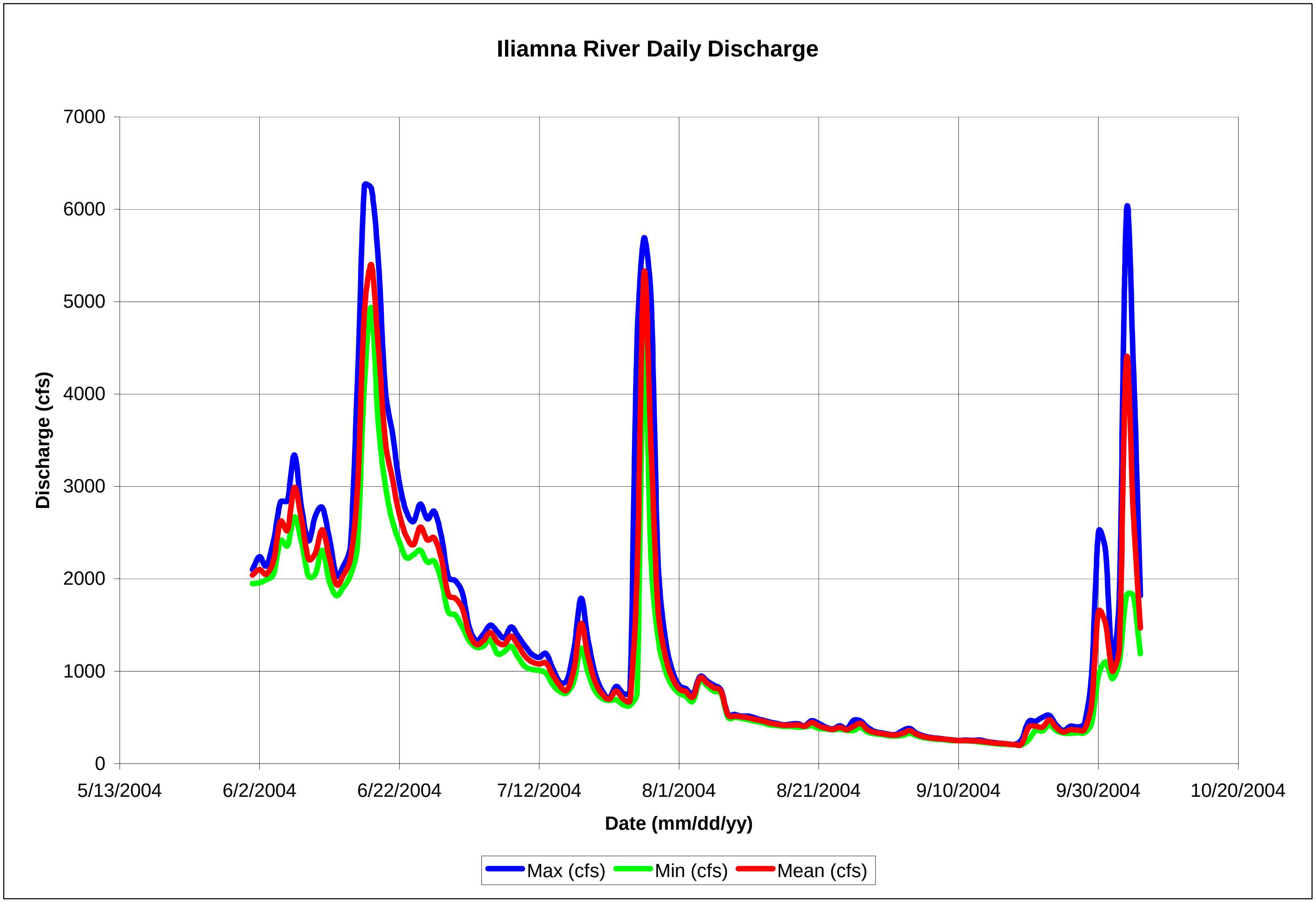

FIGURE 4-36. Discharge records for Iliamna River from June 1 through September 2004.

APPENDICES

APPENDIX 4-A
Daily Mean Discharges for
Continuous Surface-Water Stations, Mine Area

NK100A

date	Q (cfs)
08/24/04 Average	68.47619
08/25/04 Average	70.04167
08/26/04 Average	77.76042
08/27/04 Average	80.64583
08/28/04 Average	79.60417
08/29/04 Average	77.54167
08/30/04 Average	74.9375
08/31/04 Average	72.5625
Aug 04 Average	75.92352

NK100A

date	Q (cfs)
09/01/04 Average	72.271
09/02/04 Average	74.969
09/03/04 Average	74.479
09/04/04 Average	70.688
09/05/04 Average	69.000
09/06/04 Average	67.031
09/07/04 Average	64.854
09/08/04 Average	63.792
09/09/04 Average	63.729
09/10/04 Average	64.000
09/11/04 Average	64.000
09/12/04 Average	64.000
09/13/04 Average	63.958
09/14/04 Average	63.521
09/15/04 Average	62.854
09/16/04 Average	63.688
09/17/04 Average	62.167
09/18/04 Average	61.979
09/19/04 Average	77.625
09/20/04 Average	164.417
09/21/04 Average	159.625
09/22/04 Average	261.229
09/23/04 Average	249.479
09/24/04 Average	155.771
09/25/04 Average	128.563
09/26/04 Average	132.719
09/27/04 Average	122.313
09/28/04 Average	143.417
09/29/04 Average	569.198
09/30/04 Average	1652.500
Sep 04 Average	166.928

NK100A

date	Q (cfs)
10/01/04 Average	774.458
10/02/04 Average	450.484
10/03/04 Average	395.385
10/04/04 Average	488.458
10/05/04 Average	450.438
10/06/04 Average	357.344
10/07/04 Average	300.750
10/08/04 Average	268.646
10/09/04 Average	286.146
10/10/04 Average	349.667
10/11/04 Average	291.625
10/12/04 Average	299.448
10/13/04 Average	268.802
10/14/04 Average	263.781
10/15/04 Average	251.167
10/16/04 Average	316.427
10/17/04 Average	274.146
10/18/04 Average	245.354
10/19/04 Average	315.031
10/20/04 Average	298.208
10/21/04 Average	286.427
10/22/04 Average	271.198
10/23/04 Average	596.156
10/24/04 Average	724.250
10/25/04 Average	432.073
10/26/04 Average	517.490
10/27/04 Average	695.979
10/28/04 Average	520.865
10/29/04 Average	428.443
10/30/04 Average	307.000
Oct 04 Average	393.554

NK100C

date	Q (cfs)
7/11/2004 Average	34.2876
7/12/2004 Average	33.9683
7/13/2004 Average	32.92202
7/14/2004 Average	32.1476
7/15/2004 Average	31.76993
7/16/2004 Average	31.57875
7/17/2004 Average	31.41543
7/18/2004 Average	33.26384
7/19/2004 Average	34.08715
7/20/2004 Average	33.4768
7/21/2004 Average	34.65956
7/22/2004 Average	32.32871
7/23/2004 Average	30.97966
7/24/2004 Average	29.74896
7/25/2004 Average	28.71326
7/26/2004 Average	30.16673
7/27/2004 Average	32.78741
7/28/2004 Average	31.60139
7/29/2004 Average	30.3336
7/30/2004 Average	31.60161
7/31/2004 Average	31.25489
Grand Average	31.93748

NK100C

date	Q (cfs)
8/1/2004 Average	31.49764
8/2/2004 Average	29.27139
8/3/2004 Average	25.71681
8/4/2004 Average	34.10982
8/5/2004 Average	32.43149
8/6/2004 Average	29.588
8/7/2004 Average	27.84875
8/8/2004 Average	26.72797
8/9/2004 Average	25.73379
8/10/2004 Average	25.56718
8/11/2004 Average	24.83963
8/12/2004 Average	24.07597
8/13/2004 Average	23.32113
8/14/2004 Average	22.70769
8/15/2004 Average	22.42995
8/16/2004 Average	22.25537
8/17/2004 Average	21.75976
8/18/2004 Average	20.45476
8/19/2004 Average	20.6636
8/20/2004 Average	21.80947
8/21/2004 Average	21.91934
8/22/2004 Average	21.11562
8/23/2004 Average	20.37183
8/24/2004 Average	19.93572
8/25/2004 Average	19.88023
8/26/2004 Average	22.7081
8/27/2004 Average	22.48714
8/28/2004 Average	21.06479
8/29/2004 Average	20.18799
8/30/2004 Average	18.8413
8/31/2004 Average	18.48454
Grand Average	23.89369

NK100C

date	Q (cfs)
9/1/2004 Average	18.75603
9/2/2004 Average	19.4132
9/3/2004 Average	18.61905
9/4/2004 Average	17.20909
9/5/2004 Average	16.9974
9/6/2004 Average	16.85754
9/7/2004 Average	16.62863
9/8/2004 Average	16.34564
9/9/2004 Average	16.34637
9/10/2004 Average	16.48178
9/11/2004 Average	15.77211
9/12/2004 Average	15.55809
9/13/2004 Average	15.3592
9/14/2004 Average	15.01404
9/15/2004 Average	14.83266
9/16/2004 Average	14.55941
9/17/2004 Average	14.14046
9/18/2004 Average	14.42939
9/19/2004 Average	19.62873
9/20/2004 Average	32.77375
9/21/2004 Average	29.7174
9/22/2004 Average	35.97118
9/23/2004 Average	36.48905
9/24/2004 Average	28.40693
9/25/2004 Average	25.69038
9/26/2004 Average	26.18643
9/27/2004 Average	24.65434
9/28/2004 Average	26.62522
9/29/2004 Average	49.15963
9/30/2004 Average	81.46695
Grand Average	30.56515

NK100C

date	Q (cfs)
10/1/2004 Average	67.51516
10/2/2004 Average	52.58096
10/3/2004 Average	49.92384
10/4/2004 Average	51.68125
10/5/2004 Average	51.29721
10/6/2004 Average	47.07966
10/7/2004 Average	43.91442
10/8/2004 Average	41.92833
10/9/2004 Average	44.61055
10/10/2004 Average	49.89717
10/11/2004 Average	44.72077
10/12/2004 Average	43.31932
10/13/2004 Average	41.47791
10/14/2004 Average	40.88811
10/15/2004 Average	39.84413
10/16/2004 Average	41.42187
10/17/2004 Average	39.80852
10/18/2004 Average	38.63024
Grand Average	48.43109

NK119A

date	Q (cfs)
7/11/2004 Average	15.877
7/12/2004 Average	15.489
7/13/2004 Average	15.147
7/14/2004 Average	14.688
7/15/2004 Average	14.421
7/16/2004 Average	14.313
7/17/2004 Average	14.668
7/18/2004 Average	15.904
7/19/2004 Average	15.744
7/20/2004 Average	14.496
7/21/2004 Average	16.998
7/22/2004 Average	14.239
7/23/2004 Average	13.267
7/24/2004 Average	12.576
7/25/2004 Average	12.168
7/26/2004 Average	16.020
7/27/2004 Average	17.479
7/28/2004 Average	15.554
7/29/2004 Average	14.124
7/30/2004 Average	15.349
7/31/2004 Average	14.369
Grand Average	14.915

NK119A

date	Q (cfs)
8/1/2004 Average	14.316
8/2/2004 Average	12.617
8/3/2004 Average	12.694
8/4/2004 Average	20.256
8/5/2004 Average	16.674
8/6/2004 Average	14.037
8/7/2004 Average	12.476
8/8/2004 Average	11.694
8/9/2004 Average	11.229
8/10/2004 Average	11.196
8/11/2004 Average	10.591
8/12/2004 Average	10.079
8/13/2004 Average	9.651
8/14/2004 Average	9.337
8/15/2004 Average	9.076
8/16/2004 Average	8.727
8/17/2004 Average	8.068
8/18/2004 Average	7.754
8/19/2004 Average	7.914
8/20/2004 Average	8.955
8/21/2004 Average	8.561
8/22/2004 Average	7.807
8/23/2004 Average	7.448
8/24/2004 Average	7.449
8/25/2004 Average	7.222
8/26/2004 Average	11.641
8/27/2004 Average	8.877
8/28/2004 Average	8.231
8/29/2004 Average	7.616
8/30/2004 Average	7.081
8/31/2004 Average	6.856
Grand Average	10.320

NK119A

date	Q (cfs)
9/1/2004 Average	7.583
9/2/2004 Average	8.420
9/3/2004 Average	7.221
9/4/2004 Average	6.353
9/5/2004 Average	5.874
9/6/2004 Average	5.418
9/7/2004 Average	5.089
9/8/2004 Average	4.932
9/9/2004 Average	5.028
9/10/2004 Average	4.805
9/11/2004 Average	4.763
9/12/2004 Average	4.576
9/13/2004 Average	4.414
9/14/2004 Average	4.299
9/15/2004 Average	5.471
9/16/2004 Average	5.847
9/17/2004 Average	5.829
9/18/2004 Average	5.893
9/19/2004 Average	13.883
9/20/2004 Average	30.764
9/21/2004 Average	21.197
9/22/2004 Average	57.436
9/23/2004 Average	34.674
9/24/2004 Average	24.044
9/25/2004 Average	20.443
9/26/2004 Average	19.342
9/27/2004 Average	17.782
9/28/2004 Average	23.515
9/29/2004 Average	107.830
9/30/2004 Average	133.304
Grand Average	24.269

NK119A

date	Q (cfs)
10/1/2004 Average	63.310
10/2/2004 Average	41.818
10/3/2004 Average	41.748
10/4/2004 Average	57.984
10/5/2004 Average	44.573
10/6/2004 Average	33.893
10/7/2004 Average	26.034
10/8/2004 Average	21.866
10/9/2004 Average	35.240
10/10/2004 Average	40.745
10/11/2004 Average	28.712
10/12/2004 Average	25.091
10/13/2004 Average	21.753
10/14/2004 Average	24.944
10/15/2004 Average	22.725
10/16/2004 Average	30.814
10/17/2004 Average	28.263
10/18/2004 Average	31.535
Grand Average	34.663

SK100A

date	Q (cfs)
7/12/2004 Average	101.1698
7/13/2004 Average	101.0561
7/14/2004 Average	100.7962
7/15/2004 Average	100.7484
7/16/2004 Average	100.697
7/17/2004 Average	100.8598
7/18/2004 Average	101.3726
7/19/2004 Average	101.6451
7/20/2004 Average	101.7519
7/21/2004 Average	101.9438
7/22/2004 Average	101.3968
7/23/2004 Average	101.3238
7/24/2004 Average	100.6687
7/25/2004 Average	100.4824
7/26/2004 Average	101.3903
7/27/2004 Average	102.3496
7/28/2004 Average	101.8068
7/29/2004 Average	101.4008
7/30/2004 Average	101.2755
7/31/2004 Average	101.4538
Jul 04 Average	101.2916

SK100A

date	Q (cfs)
8/1/2004 Average	101.6753
8/2/2004 Average	100.6895
8/3/2004 Average	100.5739
8/4/2004 Average	102.2222
8/5/2004 Average	101.9933
8/6/2004 Average	101.1913
8/7/2004 Average	100.5877
8/8/2004 Average	100.384
8/9/2004 Average	100.1712
8/10/2004 Average	100.1271
8/11/2004 Average	99.85234
8/12/2004 Average	99.52827
8/13/2004 Average	99.23039
8/14/2004 Average	99.12176
8/15/2004 Average	98.98895
8/16/2004 Average	98.87584
8/17/2004 Average	98.61087
8/18/2004 Average	98.40599
8/19/2004 Average	98.40586
8/20/2004 Average	99.24862
8/21/2004 Average	99.10113
8/22/2004 Average	98.61009
8/23/2004 Average	98.375
8/24/2004 Average	98.30096
8/25/2004 Average	98.24124
8/26/2004 Average	98.91072
8/27/2004 Average	98.73212
8/28/2004 Average	99.0089
8/29/2004 Average	98.62875
8/30/2004 Average	98.37557
8/31/2004 Average	98.23536
Aug 04 Average	99.72145

SK100A

date	Q (cfs)
9/1/2004 Average	98.55938
9/2/2004 Average	98.50207
9/3/2004 Average	98.12014
9/4/2004 Average	97.93987
9/5/2004 Average	98.0143
9/6/2004 Average	97.9303
9/7/2004 Average	97.78837
9/8/2004 Average	97.63177
9/9/2004 Average	97.62322
9/10/2004 Average	97.69273
9/11/2004 Average	97.68014
9/12/2004 Average	97.69418
9/13/2004 Average	97.84836
9/14/2004 Average	97.8214
9/15/2004 Average	97.73323
9/16/2004 Average	97.6398
9/17/2004 Average	97.62433
9/18/2004 Average	97.67662
9/19/2004 Average	99.01235
9/20/2004 Average	102.7238
9/21/2004 Average	102.0492
9/22/2004 Average	103.7686
9/23/2004 Average	105.1675
9/24/2004 Average	103.5025
9/25/2004 Average	102.4568
9/26/2004 Average	102.6336
9/27/2004 Average	102.2518
9/28/2004 Average	103.3323
9/29/2004 Average	111.4072
9/30/2004 Average	123.4262
Sep 04 Average	105.1895

SK100A

date	Q (cfs)
10/1/2004 Average	121.3595
10/2/2004 Average	117.2051
10/3/2004 Average	115.1541
10/4/2004 Average	115.2552
10/5/2004 Average	115.1579
10/6/2004 Average	113.4656
10/7/2004 Average	112.226
10/8/2004 Average	111.4308
10/9/2004 Average	111.3499
10/10/2004 Average	112.6456
10/11/2004 Average	111.7648
10/12/2004 Average	111.9265
10/13/2004 Average	111.0664
10/14/2004 Average	110.817
10/15/2004 Average	110.6004
10/16/2004 Average	111.6308
10/17/2004 Average	110.7517
Oct 04 Average	113.5322

SK100B

date	Q (cfs)
8/25/2004 Average	45.796
8/26/2004 Average	49.073
8/27/2004 Average	46.490
8/28/2004 Average	45.781
8/29/2004 Average	44.688
8/30/2004 Average	43.938
8/31/2004 Average	43.583
Grand Average	45.610

SK100B

date	Q (cfs)
9/1/2004 Average	44.500
9/2/2004 Average	44.656
9/3/2004 Average	43.198
9/4/2004 Average	42.083
9/5/2004 Average	41.760
9/6/2004 Average	41.385
9/7/2004 Average	40.760
9/8/2004 Average	40.313
9/9/2004 Average	40.094
9/10/2004 Average	40.063
9/11/2004 Average	39.938
9/12/2004 Average	38.604
9/13/2004 Average	37.958
9/14/2004 Average	37.469
9/15/2004 Average	37.031
9/16/2004 Average	36.542
9/17/2004 Average	36.073
9/18/2004 Average	36.094
9/19/2004 Average	50.573
9/20/2004 Average	65.938
9/21/2004 Average	55.156
9/22/2004 Average	104.531
9/23/2004 Average	101.281
9/24/2004 Average	81.219
9/25/2004 Average	70.615
9/26/2004 Average	71.760
9/27/2004 Average	65.927
9/28/2004 Average	77.938
9/29/2004 Average	300.521
9/30/2004 Average	899.917
Grand Average	88.79653

SK100B

date	Q (cfs)
10/1/2004 Average	609.000
10/2/2004 Average	450.146
10/3/2004 Average	358.708
10/4/2004 Average	409.781
10/5/2004 Average	355.844
10/6/2004 Average	303.177
10/7/2004 Average	269.531
10/8/2004 Average	250.333
10/9/2004 Average	276.750
10/10/2004 Average	321.010
10/11/2004 Average	277.563
10/12/2004 Average	275.323
10/13/2004 Average	249.427
10/14/2004 Average	248.688
10/15/2004 Average	237.615
10/16/2004 Average	258.708
10/17/2004 Average	233.938
10/18/2004 Average	220.094
10/19/2004 Average	293.667
10/20/2004 Average	261.271
10/21/2004 Average	245.781
10/22/2004 Average	239.063
10/23/2004 Average	403.333
10/24/2004 Average	472.573
10/25/2004 Average	377.958
10/26/2004 Average	510.073
10/27/2004 Average	549.729
10/28/2004 Average	486.031
10/29/2004 Average	413.885
10/30/2004 Average	325.135
10/31/2004 Average	300.330
Grand Average	338.158

SK100C

date	Q (cfs)	
7/10/2004 Average	16.535	
7/11/2004 Average	14.724	
7/12/2004 Average	11.895	
7/13/2004 Average	7.440	
7/14/2004 Average	4.620	
7/15/2004 Average	4.287	
7/16/2004 Average	5.522	
7/17/2004 Average	4.318	
7/18/2004 Average	12.334	
7/19/2004 Average	12.857	
7/20/2004 Average	17.292	
THROUGH 9/22/2004	0.000	Stream Went Dry
Grand Average	9.753	

SK100C

date	Q (cfs)	
SINCE 7/20/2004	0.000	Stream Was Dry
9/23/2004 Average	36.667	
9/24/2004 Average	20.544	
9/25/2004 Average	6.348	
9/26/2004 Average	6.222	
9/27/2004 Average	0.000	
9/28/2004 Average	0.000	
9/29/2004 Average	50.887	
9/30/2004 Average	127.751	
Grand Average	65.331	

SK100C

date	Q (cfs)
10/1/2004 Average	135.252
10/2/2004 Average	116.550
10/3/2004 Average	96.929
10/4/2004 Average	93.713
10/5/2004 Average	91.541
10/6/2004 Average	83.105
10/7/2004 Average	74.580
10/8/2004 Average	67.681
10/9/2004 Average	69.247
10/10/2004 Average	83.606
10/11/2004 Average	75.533
10/12/2004 Average	69.258
10/13/2004 Average	65.561
10/14/2004 Average	64.004
10/15/2004 Average	61.469
10/16/2004 Average	65.562
Grand Average	88.931

SK100F

date	Q (cfs)
7/14/2004 Average	16.123
7/15/2004 Average	20.554
7/16/2004 Average	20.067
7/17/2004 Average	20.988
7/18/2004 Average	24.443
7/19/2004 Average	24.374
7/20/2004 Average	24.150
7/21/2004 Average	24.734
7/22/2004 Average	24.767
7/23/2004 Average	22.094
7/24/2004 Average	21.631
7/25/2004 Average	19.296
7/26/2004 Average	21.267
7/27/2004 Average	23.158
7/28/2004 Average	24.278
7/29/2004 Average	23.896
7/30/2004 Average	23.995
7/31/2004 Average	24.291
Grand Average	22.606

SK100F

date	Q (cfs)
8/1/2004 Average	25.120
8/2/2004 Average	23.542
8/3/2004 Average	19.029
8/4/2004 Average	22.472
8/5/2004 Average	22.029
8/6/2004 Average	22.745
8/7/2004 Average	21.357
8/8/2004 Average	17.393
8/9/2004 Average	18.204
8/10/2004 Average	19.462
8/11/2004 Average	15.664
8/12/2004 Average	14.914
8/13/2004 Average	13.460
8/14/2004 Average	17.057
8/15/2004 Average	17.623
8/16/2004 Average	15.159
8/17/2004 Average	13.388
8/18/2004 Average	12.562
8/19/2004 Average	13.940
8/20/2004 Average	14.180
8/21/2004 Average	14.628
8/22/2004 Average	11.840
8/23/2004 Average	12.943
8/24/2004 Average	14.953
8/25/2004 Average	13.584
8/26/2004 Average	14.206
8/27/2004 Average	12.319
8/28/2004 Average	12.670
8/29/2004 Average	9.712
8/30/2004 Average	9.592
8/31/2004 Average	6.448
Grand Average	15.885

SK100F

date	Q (cfs)
9/1/2004 Average	6.919
9/2/2004 Average	11.984
9/3/2004 Average	16.733
9/4/2004 Average	3.506
9/5/2004 Average	1.427
9/6/2004 Average	3.966
9/7/2004 Average	2.796
9/8/2004 Average	4.422
9/9/2004 Average	3.894
9/10/2004 Average	3.676
9/11/2004 Average	4.816
9/12/2004 Average	5.411
9/13/2004 Average	2.709
9/14/2004 Average	-0.376
9/15/2004 Average	-1.100
9/16/2004 Average	2.143
9/17/2004 Average	-4.167
9/18/2004 Average	-11.155
9/19/2004 Average	-6.990
9/20/2004 Average	10.438
9/21/2004 Average	10.151
9/22/2004 Average	16.060
9/23/2004 Average	23.986
9/24/2004 Average	13.713
9/25/2004 Average	11.264
9/26/2004 Average	11.608
9/27/2004 Average	6.250
9/28/2004 Average	8.238
9/29/2004 Average	22.399
9/30/2004 Average	51.825
Grand Average	12.493

SK100F

date	Q (cfs)
10/1/2004 Average	45.393
10/2/2004 Average	35.203
10/3/2004 Average	31.767
10/4/2004 Average	33.291
10/5/2004 Average	34.340
10/6/2004 Average	30.179
10/7/2004 Average	26.971
10/8/2004 Average	24.529
10/9/2004 Average	25.011
10/10/2004 Average	30.428
10/11/2004 Average	26.676
10/12/2004 Average	25.164
10/13/2004 Average	23.709
10/14/2004 Average	24.081
10/15/2004 Average	22.297
10/16/2004 Average	25.677
Grand Average	30.385

SK100G

date	Q (cfs)
7/11/2004 Average	6.901
7/12/2004 Average	6.900
7/13/2004 Average	6.643
7/14/2004 Average	6.682
7/15/2004 Average	6.671
7/16/2004 Average	6.962
7/17/2004 Average	7.856
7/18/2004 Average	9.395
7/19/2004 Average	10.646
7/20/2004 Average	10.869
7/21/2004 Average	11.671
7/22/2004 Average	10.140
7/23/2004 Average	9.308
7/24/2004 Average	8.590
7/25/2004 Average	8.293
7/26/2004 Average	9.655
7/27/2004 Average	11.828
7/28/2004 Average	10.960
7/29/2004 Average	10.067
7/30/2004 Average	11.882
7/31/2004 Average	11.366
Grand Average	9.310

SK100G

date	Q (cfs)
8/1/2004 Average	10.580
8/2/2004 Average	9.301
8/3/2004 Average	8.411
8/4/2004 Average	13.583
8/5/2004 Average	12.491
8/6/2004 Average	10.341
8/7/2004 Average	9.546
8/8/2004 Average	8.346
8/9/2004 Average	7.419
8/10/2004 Average	7.407
8/11/2004 Average	6.981
8/12/2004 Average	6.331
8/13/2004 Average	5.867
8/14/2004 Average	5.760
8/15/2004 Average	5.733
8/16/2004 Average	5.520
8/17/2004 Average	5.012
8/18/2004 Average	4.759
8/19/2004 Average	4.458
8/20/2004 Average	6.362
8/21/2004 Average	6.430
8/22/2004 Average	5.259
8/23/2004 Average	4.812
8/24/2004 Average	4.780
8/25/2004 Average	4.695
8/26/2004 Average	6.606
8/27/2004 Average	6.222
8/28/2004 Average	5.516
8/29/2004 Average	4.364
8/30/2004 Average	4.144
8/31/2004 Average	3.761
Grand Average	6.840

SK100G

date	Q (cfs)
9/1/2004 Average	4.310
9/2/2004 Average	5.604
9/3/2004 Average	5.074
9/4/2004 Average	2.549
9/5/2004 Average	2.031
9/6/2004 Average	2.344
9/7/2004 Average	2.348
9/8/2004 Average	2.200
9/9/2004 Average	2.276
9/10/2004 Average	2.590
9/11/2004 Average	2.703
9/12/2004 Average	1.900
9/13/2004 Average	1.452
9/14/2004 Average	0.871
9/15/2004 Average	0.710
9/16/2004 Average	0.663
9/17/2004 Average	-0.237
9/18/2004 Average	-0.365
9/19/2004 Average	5.854
9/20/2004 Average	15.459
9/21/2004 Average	10.872
9/22/2004 Average	19.487
9/23/2004 Average	16.870
9/24/2004 Average	9.444
9/25/2004 Average	6.924
9/26/2004 Average	8.270
9/27/2004 Average	5.796
9/28/2004 Average	9.973
9/29/2004 Average	29.646
9/30/2004 Average	50.347
Grand Average	11.561

SK100G

date	Q (cfs)
10/1/2004 Average	34.051
10/2/2004 Average	21.412
10/3/2004 Average	19.483
10/4/2004 Average	24.190
10/5/2004 Average	23.521
10/6/2004 Average	18.798
10/7/2004 Average	16.076
10/8/2004 Average	14.503
10/9/2004 Average	18.416
10/10/2004 Average	23.143
10/11/2004 Average	17.743
10/12/2004 Average	15.480
10/13/2004 Average	13.641
10/14/2004 Average	13.983
10/15/2004 Average	13.322
10/16/2004 Average	15.485
Grand Average	20.414

SK119A

date	Q (cfs)
7/11/2004 Average	10.520
7/12/2004 Average	10.688
7/13/2004 Average	10.552
7/14/2004 Average	10.403
7/15/2004 Average	10.321
7/16/2004 Average	10.296
7/17/2004 Average	10.509
7/18/2004 Average	10.840
7/19/2004 Average	11.190
7/20/2004 Average	11.414
7/21/2004 Average	11.746
7/22/2004 Average	10.546
7/23/2004 Average	10.210
7/24/2004 Average	9.767
7/25/2004 Average	9.521
7/26/2004 Average	11.498
7/27/2004 Average	12.738
7/28/2004 Average	11.583
7/29/2004 Average	11.084
7/30/2004 Average	11.578
7/31/2004 Average	10.821
Grand Average	10.879

SK119A

date	Q (cfs)
8/1/2004 Average	10.373
8/2/2004 Average	9.615
8/3/2004 Average	9.479
8/4/2004 Average	11.928
8/5/2004 Average	11.325
8/6/2004 Average	10.187
8/7/2004 Average	9.438
8/8/2004 Average	9.046
8/9/2004 Average	8.876
8/10/2004 Average	8.893
8/11/2004 Average	8.601
8/12/2004 Average	8.373
8/13/2004 Average	8.226
8/14/2004 Average	8.079
8/15/2004 Average	7.885
8/16/2004 Average	7.658
8/17/2004 Average	7.475
8/18/2004 Average	7.361
8/19/2004 Average	7.400
8/20/2004 Average	8.046
8/21/2004 Average	7.800
8/22/2004 Average	7.320
8/23/2004 Average	7.116
8/24/2004 Average	7.034
8/25/2004 Average	6.858
8/26/2004 Average	8.097
8/27/2004 Average	7.453
8/28/2004 Average	7.219
8/29/2004 Average	6.914
8/30/2004 Average	6.678
8/31/2004 Average	6.605
Grand Average	8.316

SK119A

date	Q (cfs)
9/1/2004 Average	7.272
9/2/2004 Average	7.677
9/3/2004 Average	7.012
9/4/2004 Average	6.544
9/5/2004 Average	6.151
9/6/2004 Average	6.107
9/7/2004 Average	5.974
9/8/2004 Average	5.886
9/9/2004 Average	5.898
9/10/2004 Average	5.793
9/11/2004 Average	5.537
9/12/2004 Average	5.321
9/13/2004 Average	5.220
9/14/2004 Average	5.171
9/15/2004 Average	5.143
9/16/2004 Average	5.004
9/17/2004 Average	5.091
9/18/2004 Average	5.267
9/19/2004 Average	9.507
9/20/2004 Average	15.196
9/21/2004 Average	11.132
9/22/2004 Average	19.685
9/23/2004 Average	14.067
9/24/2004 Average	11.593
9/25/2004 Average	10.776
9/26/2004 Average	11.343
9/27/2004 Average	10.524
9/28/2004 Average	12.823
9/29/2004 Average	31.769
9/30/2004 Average	39.808
Grand Average	15.241

SK119A

date	Q (cfs)
10/1/2004 Average	28.260
10/2/2004 Average	25.049
10/3/2004 Average	23.599
10/4/2004 Average	26.568
10/5/2004 Average	23.437
10/6/2004 Average	21.375
10/7/2004 Average	20.015
10/8/2004 Average	19.229
10/9/2004 Average	21.206
10/10/2004 Average	22.689
10/11/2004 Average	19.682
10/12/2004 Average	19.389
10/13/2004 Average	18.631
10/14/2004 Average	19.745
10/15/2004 Average	18.647
10/16/2004 Average	20.101
10/17/2004 Average	18.295
10/18/2004 Average	17.438
Grand Average	21.913

UT100B

date	Q (cfs)
8/25/2004 Average	106.235
8/26/2004 Average	114.448
8/27/2004 Average	112.958
8/28/2004 Average	110.604
8/29/2004 Average	107.313
8/30/2004 Average	105.521
8/31/2004 Average	104.688
Aug 04 Average	109.087

UT100B

date	Q (cfs)
9/1/2004 Average	109.063
9/2/2004 Average	112.708
9/3/2004 Average	108.458
9/4/2004 Average	102.167
9/5/2004 Average	101.104
9/6/2004 Average	101.688
9/7/2004 Average	101.354
9/8/2004 Average	101.167
9/9/2004 Average	101.500
9/10/2004 Average	103.688
9/11/2004 Average	104.750
9/12/2004 Average	103.458
9/13/2004 Average	102.750
9/14/2004 Average	101.896
9/15/2004 Average	102.250
9/16/2004 Average	102.896
9/17/2004 Average	101.583
9/18/2004 Average	102.354
9/19/2004 Average	124.865
9/20/2004 Average	205.917
9/21/2004 Average	174.865
9/22/2004 Average	297.500
9/23/2004 Average	266.719
9/24/2004 Average	179.896
9/25/2004 Average	156.531
9/26/2004 Average	161.042
9/27/2004 Average	151.833
9/28/2004 Average	178.552
9/29/2004 Average	576.021
9/30/2004 Average	1426.146
Sep 04 Average	192.157

UT100B

date	Q (cfs)
10/1/2004 Average	694.875
10/2/2004 Average	397.646
10/3/2004 Average	336.427
10/4/2004 Average	358.490
10/5/2004 Average	347.729
10/6/2004 Average	300.396
10/7/2004 Average	265.667
10/8/2004 Average	244.302
10/9/2004 Average	281.927
10/10/2004 Average	326.344
10/11/2004 Average	273.750
10/12/2004 Average	250.781
10/13/2004 Average	236.469
10/14/2004 Average	242.427
10/15/2004 Average	236.344
10/16/2004 Average	253.646
10/17/2004 Average	236.615
10/18/2004 Average	226.542
10/19/2004 Average	315.823
10/20/2004 Average	278.750
10/21/2004 Average	257.135
10/22/2004 Average	248.188
10/23/2004 Average	421.385
10/24/2004 Average	533.115
10/25/2004 Average	353.240
10/26/2004 Average	448.302
10/27/2004 Average	589.792
10/28/2004 Average	464.402
10/29/2004 Average	372.969
10/30/2004 Average	306.417
10/31/2004 Average	275.400
Oct 04 Average	333.995

UT100D

date	Q (cfs)
7/12/2004 Average	15.19
7/13/2004 Average	15.01
7/14/2004 Average	14.75
7/15/2004 Average	15.56
7/16/2004 Average	16.12
7/17/2004 Average	16.69
7/18/2004 Average	19.49
7/19/2004 Average	21.39
7/20/2004 Average	19.49
7/21/2004 Average	21.17
7/22/2004 Average	16.46
7/23/2004 Average	15.02
7/24/2004 Average	13.58
7/25/2004 Average	13.05
7/26/2004 Average	14.94
7/27/2004 Average	17.33
7/28/2004 Average	16.06
7/29/2004 Average	14.81
7/30/2004 Average	18.02
7/31/2004 Average	15.72
Grand Average	16.59

UT100D

date	Q (cfs)
8/1/2004 Average	14.70
8/2/2004 Average	12.13
8/3/2004 Average	11.62
8/4/2004 Average	20.50
8/5/2004 Average	16.92
8/6/2004 Average	12.93
8/7/2004 Average	11.16
8/8/2004 Average	10.64
8/9/2004 Average	10.31
8/10/2004 Average	10.35
8/11/2004 Average	9.77
8/12/2004 Average	9.25
8/13/2004 Average	8.65
8/14/2004 Average	8.39
8/15/2004 Average	8.68
8/16/2004 Average	7.92
8/17/2004 Average	7.47
8/18/2004 Average	7.17
8/19/2004 Average	6.86
8/20/2004 Average	9.72
8/21/2004 Average	8.61
8/22/2004 Average	7.38
8/23/2004 Average	6.61
8/24/2004 Average	6.70
8/25/2004 Average	6.58
8/26/2004 Average	10.58
8/27/2004 Average	8.48
8/28/2004 Average	7.70
8/29/2004 Average	7.03
8/30/2004 Average	7.28
8/31/2004 Average	7.07
Grand Average	9.72

UT100D

date	Q (cfs)
9/1/2004 Average	8.08
9/2/2004 Average	9.04
9/3/2004 Average	7.84
9/4/2004 Average	6.83
9/5/2004 Average	5.98
9/6/2004 Average	5.81
9/7/2004 Average	6.23
9/8/2004 Average	5.99
9/9/2004 Average	6.17
9/10/2004 Average	6.64
9/11/2004 Average	6.73
9/12/2004 Average	7.16
9/13/2004 Average	7.45
9/14/2004 Average	8.12
9/15/2004 Average	7.95
9/16/2004 Average	7.52
9/17/2004 Average	7.40
9/18/2004 Average	7.69
9/19/2004 Average	16.88
9/20/2004 Average	29.67
9/21/2004 Average	21.51
9/22/2004 Average	44.87
9/23/2004 Average	31.49
9/24/2004 Average	20.09
9/25/2004 Average	16.68
9/26/2004 Average	18.89
9/27/2004 Average	16.16
9/28/2004 Average	21.27
9/29/2004 Average	65.51
9/30/2004 Average	76.10
Grand Average	28.91

UT100D

date	Q (cfs)
10/1/2004 Average	50.75
10/2/2004 Average	38.60
10/3/2004 Average	35.58
10/4/2004 Average	39.80
10/5/2004 Average	37.85
10/6/2004 Average	32.29
10/7/2004 Average	28.35
10/8/2004 Average	26.32
10/9/2004 Average	33.89
10/10/2004 Average	42.35
10/11/2004 Average	31.36
10/12/2004 Average	28.12
10/13/2004 Average	26.21
10/14/2004 Average	26.69
10/15/2004 Average	26.10
10/16/2004 Average	29.59
10/17/2004 Average	25.98
10/18/2004 Average	24.46
Grand Average	34.30

UT100E

date	Q (cfs)
7/12/2004 Average	6.88
7/13/2004 Average	6.85
7/14/2004 Average	6.91
7/15/2004 Average	6.87
7/16/2004 Average	6.85
7/17/2004 Average	7.01
7/18/2004 Average	7.49
7/19/2004 Average	7.47
7/20/2004 Average	7.13
7/21/2004 Average	7.56
7/22/2004 Average	6.96
7/23/2004 Average	6.84
7/24/2004 Average	6.69
7/25/2004 Average	6.56
7/26/2004 Average	6.96
7/27/2004 Average	7.18
7/28/2004 Average	6.99
7/29/2004 Average	6.73
7/30/2004 Average	7.28
7/31/2004 Average	6.86
Grand Average	7.01

UT100E

date	Q (cfs)
8/1/2004 Average	6.76
8/2/2004 Average	6.36
8/3/2004 Average	6.31
8/4/2004 Average	7.55
8/5/2004 Average	6.63
8/6/2004 Average	6.04
8/7/2004 Average	5.76
8/8/2004 Average	5.58
8/9/2004 Average	5.40
8/10/2004 Average	5.47
8/11/2004 Average	5.32
8/12/2004 Average	5.11
8/13/2004 Average	5.06
8/14/2004 Average	5.04
8/15/2004 Average	5.06
8/16/2004 Average	4.96
8/17/2004 Average	4.85
8/18/2004 Average	4.82
8/19/2004 Average	4.86
8/20/2004 Average	5.14
8/21/2004 Average	4.99
8/22/2004 Average	4.79
8/23/2004 Average	4.70
8/24/2004 Average	4.81
8/25/2004 Average	4.71
8/26/2004 Average	5.11
8/27/2004 Average	4.72
8/28/2004 Average	4.65
8/29/2004 Average	4.53
8/30/2004 Average	4.48
8/31/2004 Average	4.42
Grand Average	5.29

UT100E

date	Q (cfs)
9/1/2004 Average	4.45
9/2/2004 Average	4.61
9/3/2004 Average	4.41
9/4/2004 Average	4.25
9/5/2004 Average	4.24
9/6/2004 Average	4.19
9/7/2004 Average	4.17
9/8/2004 Average	4.14
9/9/2004 Average	4.18
9/10/2004 Average	4.21
9/11/2004 Average	4.23
9/12/2004 Average	4.15
9/13/2004 Average	4.07
9/14/2004 Average	4.04
9/15/2004 Average	4.04
9/16/2004 Average	4.02
9/17/2004 Average	4.02
9/18/2004 Average	4.07
9/19/2004 Average	6.00
9/20/2004 Average	7.92
9/21/2004 Average	5.84
9/22/2004 Average	9.67
9/23/2004 Average	6.68
9/24/2004 Average	5.26
9/25/2004 Average	4.93
9/26/2004 Average	5.58
9/27/2004 Average	5.07
9/28/2004 Average	5.98
9/29/2004 Average	14.83
9/30/2004 Average	18.81
Grand Average	6.29

UT100E

date	Q (cfs)
10/1/2004 Average	10.34
10/2/2004 Average	8.53
10/3/2004 Average	8.45
10/4/2004 Average	10.23
10/5/2004 Average	9.59
10/6/2004 Average	8.59
10/7/2004 Average	8.16
10/8/2004 Average	7.96
10/9/2004 Average	9.72
10/10/2004 Average	10.98
10/11/2004 Average	9.08
10/12/2004 Average	8.76
10/13/2004 Average	8.57
10/14/2004 Average	8.74
10/15/2004 Average	8.67
10/16/2004 Average	9.20
10/17/2004 Average	8.78
10/18/2004 Average	8.62
Grand Average	9.09

UT119A

date	Q (cfs)
7/12/2004 Average	27.124
7/13/2004 Average	27.111
7/14/2004 Average	27.104
7/15/2004 Average	26.979
7/16/2004 Average	26.865
7/17/2004 Average	26.872
7/18/2004 Average	26.893
7/19/2004 Average	26.985
7/20/2004 Average	26.648
7/21/2004 Average	26.538
7/22/2004 Average	26.145
7/23/2004 Average	26.712
7/24/2004 Average	26.729
7/25/2004 Average	26.759
7/26/2004 Average	26.987
7/27/2004 Average	26.752
7/28/2004 Average	26.719
7/29/2004 Average	26.603
7/30/2004 Average	26.726
7/31/2004 Average	26.528
Grand Average	26.765

UT119A

date	Q (cfs)
8/1/2004 Average	26.405
8/2/2004 Average	26.377
8/3/2004 Average	26.461
8/4/2004 Average	26.370
8/5/2004 Average	26.234
8/6/2004 Average	26.342
8/7/2004 Average	26.294
8/8/2004 Average	26.276
8/9/2004 Average	26.173
8/10/2004 Average	26.148
8/11/2004 Average	26.121
8/12/2004 Average	26.189
8/13/2004 Average	26.102
8/14/2004 Average	26.027
8/15/2004 Average	25.963
8/16/2004 Average	25.884
8/17/2004 Average	25.925
8/18/2004 Average	25.978
8/19/2004 Average	26.079
8/20/2004 Average	26.188
8/21/2004 Average	26.067
8/22/2004 Average	26.090
8/23/2004 Average	26.132
8/24/2004 Average	26.083
8/25/2004 Average	26.046
8/26/2004 Average	25.929
8/27/2004 Average	25.636
8/28/2004 Average	25.530
8/29/2004 Average	25.517
8/30/2004 Average	25.514
8/31/2004 Average	25.551
Grand Average	26.086

UT119A

date	Q (cfs)
9/1/2004 Average	25.447
9/2/2004 Average	25.398
9/3/2004 Average	25.238
9/4/2004 Average	25.231
9/5/2004 Average	25.180
9/6/2004 Average	25.178
9/7/2004 Average	25.167
9/8/2004 Average	25.183
9/9/2004 Average	25.177
9/10/2004 Average	25.170
9/11/2004 Average	25.130
9/12/2004 Average	24.865
9/13/2004 Average	24.872
9/14/2004 Average	24.894
9/15/2004 Average	24.869
9/16/2004 Average	24.976
9/17/2004 Average	25.296
9/18/2004 Average	25.371
9/19/2004 Average	25.794
9/20/2004 Average	26.048
9/21/2004 Average	25.503
9/22/2004 Average	26.135
9/23/2004 Average	25.414
9/24/2004 Average	25.285
9/25/2004 Average	25.350
9/26/2004 Average	25.418
9/27/2004 Average	25.390
9/28/2004 Average	25.678
9/29/2004 Average	27.467
9/30/2004 Average	27.757
Grand Average	25.660

UT119A

date	Q (cfs)
10/1/2004 Average	24.934
10/2/2004 Average	24.371
10/3/2004 Average	24.149
10/4/2004 Average	24.391
10/5/2004 Average	24.208
10/6/2004 Average	24.031
10/7/2004 Average	23.871
10/8/2004 Average	23.810
10/9/2004 Average	24.171
10/10/2004 Average	24.081
10/11/2004 Average	23.835
10/12/2004 Average	23.775
10/13/2004 Average	23.528
10/14/2004 Average	23.523
10/15/2004 Average	23.583
10/16/2004 Average	23.624
10/17/2004 Average	23.558
Grand Average	23.999

KC100A

date	Q (cfs)
7/10/2004 Average	20.0261
7/11/2004 Average	20.12203
7/12/2004 Average	20.10585
7/13/2004 Average	20.08027
7/14/2004 Average	19.83211
7/15/2004 Average	19.89783
7/16/2004 Average	19.90743
7/17/2004 Average	20.21614
7/18/2004 Average	20.54794
7/19/2004 Average	20.42773
7/20/2004 Average	20.3501
7/21/2004 Average	20.84122
7/22/2004 Average	20.33635
7/23/2004 Average	20.31247
7/24/2004 Average	19.95848
7/25/2004 Average	19.74528
7/26/2004 Average	21.87387
7/27/2004 Average	21.776
7/28/2004 Average	21.08748
7/29/2004 Average	20.54275
7/30/2004 Average	20.3168
7/31/2004 Average	20.18612
Jul 04 Average	20.40585

KC100A

date	Q (cfs)
8/1/2004 Average	21.25224
8/2/2004 Average	19.90804
8/3/2004 Average	19.74471
8/4/2004 Average	21.74118
8/5/2004 Average	20.71702
8/6/2004 Average	20.12872
8/7/2004 Average	19.72751
8/8/2004 Average	19.51165
8/9/2004 Average	19.20985
8/10/2004 Average	19.27537
8/11/2004 Average	19.04223
8/12/2004 Average	19.06748
8/13/2004 Average	18.81479
8/14/2004 Average	18.71018
8/15/2004 Average	18.63244
8/16/2004 Average	18.31523
8/17/2004 Average	18.16392
8/18/2004 Average	18.0863
8/19/2004 Average	18.15662
8/20/2004 Average	19.0761
8/21/2004 Average	18.86691
8/22/2004 Average	18.27699
8/23/2004 Average	18.15756
8/24/2004 Average	18.03121
8/25/2004 Average	17.99337
8/26/2004 Average	18.91638
8/27/2004 Average	18.54682
8/28/2004 Average	18.69073
8/29/2004 Average	18.25957
8/30/2004 Average	17.98125
8/31/2004 Average	17.85398
Aug 04 Average	19.01523

KC100A

date	Q (cfs)
9/1/2004 Average	18.55715
9/2/2004 Average	18.50273
9/3/2004 Average	18.11311
9/4/2004 Average	17.72279
9/5/2004 Average	17.66814
9/6/2004 Average	17.69736
9/7/2004 Average	17.62075
9/8/2004 Average	17.58856
9/9/2004 Average	17.61147
9/10/2004 Average	17.89973
9/11/2004 Average	17.78609
9/12/2004 Average	17.75121
9/13/2004 Average	17.5243
9/14/2004 Average	17.42099
9/15/2004 Average	17.39369
9/16/2004 Average	17.39593
9/17/2004 Average	17.30482
9/18/2004 Average	17.33157
9/19/2004 Average	20.05672
9/20/2004 Average	23.39803
9/21/2004 Average	20.82996
9/22/2004 Average	24.07241
9/23/2004 Average	21.4208
9/24/2004 Average	19.61838
9/25/2004 Average	19.07857
9/26/2004 Average	20.16319
9/27/2004 Average	19.2121
9/28/2004 Average	22.45347
9/29/2004 Average	36.36213
9/30/2004 Average	44.8264
Sep 04 Average	24.46758

KC100A

date	Q (cfs)
10/1/2004 Average	28.64424
10/2/2004 Average	24.3509
10/3/2004 Average	23.47921
10/4/2004 Average	25.30385
10/5/2004 Average	24.50366
10/6/2004 Average	22.8209
10/7/2004 Average	21.74575
10/8/2004 Average	21.18506
10/9/2004 Average	21.74701
10/10/2004 Average	21.58589
10/11/2004 Average	20.89421
10/12/2004 Average	22.62807
10/13/2004 Average	21.59242
10/14/2004 Average	21.63244
10/15/2004 Average	21.6552
10/16/2004 Average	23.8683
10/17/2004 Average	21.88249
Oct 04 Average	23.67864

APPENDIX 4-B
2004 Basin Characteristics File, Road/Port

TABLE 4B-1
Hydrologic Drainage Basin Characteristics
Pebble Mine - Road and Port Baseline Hydrology Study

Gage Number	Stream Name and USGS Gage Number (If existing)	Latidude (DDMMmmm)	Longitude (DDMMmmm)	Drainage Area (sq. mi.)	Pond, Lake Area (sq. mi.)	Forested Area (sq. mi.)	Mean Basin Elevation (ft)	Main Channel Slope (ft/mi)	Main Channel Length (mi)	Mean Annual Precipitation (in)	Mean Min January Temp (oF)
DB-21	No-name Creek	59°38.500	153°31.800	12.39	0.00						
DB-20a	Upper Roadhouse Creek	59°47.917	154°50.388	8.07	0.28						
DB-20	Roadhouse Creek	59°45.407	154°50.966	20.75	1.13		321			30	8
DB-18a	No-name Creek	59°47.491	154°42.772	9.29	0.10		977.759			25	9
DB-17a	W. Fork Eagle Bay Creek	59°48.065	154°37.607	10.95	0.02		1190.491			25	9
DB-14b	No-name Creek	59°50.057	154°27.122	15.91	0.29		973.232			28	9
DB-14a	No-name Creek	59°49.864	154°31.184	18.34	0.08		859.739			28	9
DB-12a	Chekok Creek	59°50.313	154°22.980	50.48	0.34		1764.003			30	9
DB-11a	Canyon Creek	59°50.418	154°21.952	36.20	0.14		2257.48			30	9
DB-8a	Knutson Creek	59°48.959	154°07.324	35.70	0.02		2254.944			38	10
DB-7a	No-name Creek	59°47.407	154°06.240	3.36	0.00					40	10
DB-6a	No-name Creek	59°46.111	154°02.759	4.41	0.13		1072.083			50	10
DB-4b	Long Lake Creek	59°48.389	153°52.183	*	*	*	*	*	*	*	*
DB-4a	Pile River	59°48.314	153°53.700	48.39	1.49		1462.644			60	10
DB-3a	Iliamna River (15300300)	59°45.467	153°51.127	19.63	0.09		2236.288			50	10

* Included in DB-4a

TABLE 4B-2
2004 Discharge Measurement Summary
Pebble Mine - Road and Port Baseline Hydrology Study

Sample Location (West to East)		July 2004 avg depth (ft)	July 2004 avg width (ft)	July 2004 discharge (cfs)	July 2004 area (sf)	July 2004 velocity (ft/sec)	August 2004 avg depth (ft)	August 2004 avg width (ft)	August 2004 discharge (cfs)	August 2004 area (sf)	August 2004 velocity (ft/sec)
GS-20	Lower Roadhouse Creek	0.83	18.00	14.99	14.86	1.01	0.49	27.50	11.39	13.50	0.84
GS-20a	Upper Roadhouse Creek	0.68	7.10	0.68	4.82	0.14	0.47	6.00	0.61	2.80	0.22
GS-18a	No-Name Creek (trib to Eagle Bay)	0.72	2.59	1.49	1.87	0.80	0.50	2.40	NR	NR	NR
GS-17a	No-Name Creek (West Fork of Eagle Bay Creek)	0.58	14.00	6.62	8.05	0.82	0.92	14.00	5.07	12.90	0.39
GS-14a	No-Name Creek (East Fork Chekok Bay Trib.)	0.43	22.80	20.02	9.75	2.05	0.52	20.00	12.62	10.47	1.21
GS-14b	No-Name Creek (West Fork Chekok Bay Trib.)	0.43	16.10	7.48	6.88	1.09	0.45	11.00	3.61	5.00	0.72
GS-12a	Chekok Creek	0.75	39.00	75.66	29.09	2.60	1.06	34.30	43.08	36.43	1.18
GS-11a	Canyon Creek	0.64	142.90	218.29	91.79	2.38	0.27	136.00	53.47	36.95	1.45
GS-8a	Knutson Creek	1.37	49.30	128.81	67.58	1.91	1.31	79.2	135.11	104.03	1.30
GS-7a	No-Name Creek	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
GS-6a	No-Named Creek (Dumbell Creek)	0.32	12.00	4.19	3.86	1.09	0.23	14.00	2.25	3.20	0.70
GS-4a	Pile River	1.99	235.00	1533.09	468.00	3.28	2.16	141.00	1277.15	304.23	4.20
GS-4b	Long Lake Creek	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
GS-3a	Iliamna River (USGS Gage 15300300)	NI	NI	888.71	NI	NI	3.59	148.00	433.25	531.17	0.77
GS-21	No-Name Creek (Near Port Site)	NI	NI	NI	NI	NI	1.65	32.90	26.55	54.31	0.49

NI = Not Installed
NR = Not Recorded

Sample Location (West to East)		September 2004 avg depth (ft)	September 2004 avg width (ft)	September 2004 discharge (cfs)	September 2004 area (sf)	September 2004 velocity (ft/sec)	October 2004 avg depth (ft)	October 2004 avg width (ft)	October 2004 discharge (cfs)	October 2004 area (sf)	October 2004 velocity (ft/sec)
GS-20	Lower Roadhouse Creek	NR	NR	NR	NR	NR	1.23	27.13	56.85	33.47	1.67
GS-20a	Upper Roadhouse Creek	0.76	10.00	2.40	7.55	0.32	1.51	8.70	5.27	13.10	0.40
GS-18a	No-Name Creek (trib to Eagle Bay)	0.14	13.00	0.52	1.85	0.28	0.45	2.00	0.52	0.90	0.58
GS-17a	No-Name Creek (West Fork of Eagle Bay Creek)	0.31	33.00	4.06	10.20	0.40	0.93	17.00	28.91	15.88	1.82
GS-14a	No-Name Creek (East Fork Chekok Bay Trib.)	1.2	24.00	86.13	28.85	2.99	0.90	28.00	66.34	25.10	2.64
GS-14b	No-Name Creek (West Fork Chekok Bay Trib.)	0.79	17.00	20.42	13.40	1.52	0.67	17.00	27.91	11.45	2.44
GS-12a	Chekok Creek	1.73	38.00	35.78	65.70	0.54	1.33	54.00	209.66	71.95	2.91
GS-11a	Canyon Creek	0.46	75.00	18.71	34.46	0.54	0.97	79.00	261.09	76.70	3.40
GS-8a	Knutson Creek	1.27	59.00	21.25	75.20	0.28	1.92	50.00	410.16	96.20	4.26
GS-7a	No-Name Creek	Dry	Dry	Dry	Dry	Dry	0.29	10.00	4.67	2.93	1.60
GS-6a	No-Named Creek (Dumbell Creek)	0.29	12.00	0.40	3.50	0.11	0.42	14.00	6.21	5.85	1.06
GS-4a	Pile River	1.23	148.00	64.52	181.65	0.36	1.72	163.00	748.44	280.00	2.67
GS-4b	Long Lake Creek	0.46	15.00	0.06	6.90	0.01	1.24	19.00	20.55	23.94	0.86
GS-3a	Iliamna River (USGS Gage 15300300)	2.51	130.00	451.60	326.50	1.10	NI	NI	1077.88	NI	NI
GS-21	No-Name Creek (Near Port Site)	1.81	32.00	6.13	58.00	0.11	2.26	51.00	100.86	115.50	0.87

NI = Not Installed
NR = Not Recorded