Pebble Project Environmental Baseline Studies
2004-2008

TECHNICAL SUMMARY

TABLE OF CONTENTS

TABLE OF CONTENTS 1-i

LIST OF TABLES 1-ii

LIST OF FIGURES 1-ii

ACRONYMS AND ABBREVIATIONS 1-iii

1. INTRODUCTION 1-1
   - 1.1 Project Location 1-1
   - 1.2 Place Names 1-2
   - 1.3 Project History 1-2
   - 1.4 Pebble Deposit 1-2
   - 1.5 Project Overview (Basis for Study Design) 1-3
   - 1.6 Baseline Study Program 1-3
   - 1.7 EBD Package Structure 1-8
   - 1.8 Document Structure 1-9
   - 1.9 EBD Formats 1-12
   - 1.10 References 1-12
2. CLIMATE AND METEOROLOGY 2-1
   - 2.1 Introduction 2-1
   - 2.2 Results and Discussion 2-1
3. GEOLOGY 3-1
   - 3.1 Introduction 3-1
   - 3.2 Results and Discussion 3-1
     - 3.2.1 Regional Geology 3-1
     - 3.2.2 Surficial Geology—Mine Study Area 3-1
     - 3.2.3 Bedrock Geology—Mine Study Area 3-1
     - 3.2.4 Structural Geology—Mine Study Area 3-2
     - 3.2.5 Deposit Geology 3-2
     - 3.2.6 Surficial Geology—Transportation-corridor Study Area 3-3
   - 3.3 References 3-3
4. PHYSIOGRAPHY 4-1
   - 4.1 Introduction 4-1
   - 4.2 Results and Discussion 4-1
     - 4.2.1 Mine Study Area 4-2

4.2.2 Transportation-corridor Study Area 4-2
4.2.3 Permafrost Conditions 4-3
4.3 References 4-3
5. SOILS 5-1
5.1 Introduction 5-1
5.2 Results and Discussion 5-1
5.3 References 5-2
6. GEOTECHNICAL AND SEISMIC 6-1
6.1 Introduction 6-1
6.2 Results and Discussion 6-1
7. SURFACE WATER HYDROLOGY 7-1
7.1 Regional Study Area 7-1
7.1.1 Introduction 7-1
7.1.2 Results and Discussion 7-1
7.2 Mine Study Area 7-2
7.2.1 Introduction 7-2
7.2.2 Results and Discussion 7-3
7.3 Transportation-corridor Study Area 7-6
7.3.1 Introduction 7-6
7.3.2 Results and Discussion 7-7
7.4 References 7-8
8. GROUNGWATER HYDROLOGY 8-1
8.1 Introduction 8-1
8.2 Results and Discussion 8-1
8.2.1 Geologic Controls 8-2
8.2.2 Groundwater Flow 8-3
9. WATER QUALITY 9-1
9.1 Introduction 9-1
9.2 Results and Discussion 9-1
9.2.1 Mine Study Area—Surface Water 9-1
9.2.2 Mine Study Area—Groundwater 9-4
9.2.3 Transportation-corridor Study Area—Surface Water 9-6
9.2.4 Transportation-corridor Study Area—Drinking Water Wells 9-6
9.2.5 Iliamna Lake 9-7
10. TRACE ELEMENTS 10-1
10.1 Introduction 10-1

10.2 Results and Discussion 10-2

11. GEOCHEMICAL CHARACTERIZATION 11-1

11.1 Introduction 11-1

11.2 Results and Discussion 11-1

11.2.1 Rock 11-1

11.2.2 Metallurgical Wastes 11-2

12. NOISE 12-1

12.1 Introduction 12-1

12.2 Results 12-1

13. VEGETATION 13-1

13.1 Introduction 13-1

13.2 Results and Discussion 13-2

13.2.1 Mine Study Area 13-2

13.2.2 Transportation-corridor Study Area 13-2

13.3 References 13-3

13.4 Glossary 13-3

14. WETLANDS AND WATERBODIES 14-1

14.1 Introduction 14-1

14.2 Results and Discussion 14-2

14.3 References 14-3

14.4 Glossary 14-3

15. FISH AND AQUATIC INVERTEBRATES 15.1-1

15.1 Fish—Mine Study Area 15.1-1

15.1.1 Introduction 15.1-1

15.1.2 Results and Discussion 15.1-3

15.1.3 References 15.1-18

15.2 Aquatic Invertebrates—Mine Study Area 15.2-1

15.2.1 Introduction 15.2-1

15.2.2 Results and Discussion 15.2-2

15.3 Fish—Transportation-corridor Study Area 15.3-1

15.3.1 Introduction 15.3-1

15.3.2 Results and Discussion 15.3-1

15.3.3 References 15.3-2

15.4 Aquatic Invertebrates—Transportation-corridor Study Area 15.4-1

15.4.1 Introduction 15.4-1

15.4.2 Results and Discussion 15.4-1

16. WILDLIFE AND HABITAT 16.1-1

16.1 Habitat Mapping and Habitat-value Assessments—Mine Study Area 16.1-1
  16.1.1 Introduction 16.1-1
  16.1.2 Results and Discussion 16.1-3
16.2 Terrestrial Mammals—Mine Study Area 16.2-1
  16.2.1 Introduction 16.2-1
  16.2.2 Results and Discussion 16.2-1
16.3 Raptors—Mine Study Area 16.3-1
  16.3.1 Introduction 16.3-1
  16.3.2 Results and Discussion 16.3-1
16.4 Waterbirds—Mine Study Area 16.4-1
  16.4.1 Introduction 16.4-1
  16.4.2 Results and Discussion 16.4-1
16.5 Breeding Landbirds and Shorebirds—Mine Study Area 16.5-1
  16.5.1 Introduction 16.5-1
  16.5.2 Results and Discussion 16.5-1
16.6 Habitat Mapping and Habitat-value Assessments—Transportation-corridor Study Area 16.6-1
  16.6.1 Introduction 16.6-1
  16.6.2 Results and Discussion 16.6-1
16.7 Terrestrial Mammals—Transportation-corridor Study Area 16.7-1
  16.7.1 Introduction 16.7-1
  16.7.2 Results and Discussion 16.7-1
16.8 Iliamna Lake Harbor Seals 16.8-1
  16.8.1 Introduction 16.8-1
  16.8.2 Results and Discussion 16.8-1
16.9 Raptors—Transportation-corridor Study Area 16.9-1
  16.9.1 Introduction 16.9-1
  16.9.2 Results and Discussion 16.9-1
16.10 Waterbirds—Transportation-corridor Study Area 16.10-1
  16.10.1 Introduction 16.10-1
  16.10.2 Results and Discussion 16.10-1
16.11 Breeding Landbirds and Shorebirds—Transportation-corridor Study Area 16.11-1
  16.11.1 Introduction 16.11-1
  16.11.2 Results and Discussion 16.11-1
16.12 Wood Frogs—Mine Study Area 16.12-1
  16.12.1 Introduction 16.12-1
  16.12.2 Results and Discussion 16.12-1

17. THREATENED AND ENDANGERED SPECIES AND SPECIES OF CONSERVATION CONCERN 17-1
17.1 Introduction 17-1
17.2 Results and Discussion 17-1
17.3 References 17-3
18. LAND AND WATER USE 18-1
18.1 Introduction 18-1
18.2 Results and Discussion 18-1
19. TRANSPORTATION 19-1
19.1 Introduction 19-1
19.2 Results and Discussion 19-1
19.3 References 19-2
20. POWER 20-1
20.1 Introduction 20-1
20.2 Results and Discussion 20-1
21. SOCIOECONOMICS 21-1
21.1 Introduction 21-1
21.2 Results and Discussion 21-1
21.2.1 Commercial Fishing/Seafood Processing 21-1
21.2.2 Visitor Industry 21-2
21.2.3 Government 21-4
21.2.4 Mining Industry 21-4
21.3 References 21-4
22. CULTURAL RESOURCES 22-1
22.1 Introduction 22-1
22.2 Results and Discussion 22-1
23. SUBSISTENCE USES AND TRADITIONAL KNOWLEDGE 23-1
23.1 Introduction 23-1
23.2 Results and Discussion 23-3
23.3 References 23-5
24. VISUAL RESOURCES 24-1
24.1 Introduction 24-1
24.2 Results and Discussion 24-1
24.3 References 24-2
25. RECREATION 25-1
25.1 Introduction 25-1

25.2 Results and Discussion 25-2
25.3 References 25-5
26. CLIMATE AND METEOROLOGY 26-1
26.1 Introduction 26-1
26.2 Results and Discussion 26-1
27. GEOLOGY 27-1
27.1 Introduction 25-1
27.2 Results and Discussion 27-1
27.2.1 Surficial Geology 27-1
27.2.2 Bedrock Geology 27-2
27.3 References 27-2
28. PHYSIOGRAPHY 28-1
28.1 Introduction 28-1
28.2 Results and Discussion 28-1
28.3 References 28-2
29. SOILS 29-1
29.1 Introduction 29-1
29.2 Results and Discussion 29-1
29.3 References 29-1
30. GEOTECHNICAL STUDIES, SEISMICITY, AND VOLCANISM 30-1
30.1 Introduction 30-1
30.2 Results and Discussion 30-1
30.2.1 Local Geotechnical Conditions 30-1
30.2.2 Regional Seismicity and Faulting 30-2
30.2.3 Regional Volcanism 30-2
30.3 References 30-3
31. SURFACE WATER HYDROLOGY 25-1
31.1 Introduction 31-1
31.2 Results and Discussion 31-1
31.3 References 31-2
32. GROUNDWATER HYDROLOGY 32-1
33. SURFACE FRESHWATER QUALITY AND SEDIMENT 33-1
33.1 Introduction 33-1
33.2 Results and Discussion 33-1
33.3 References 33-2
34 PHYSICAL OCEANOGRAPHY AND MARINE WATER QUALITY 34-1

- 34.1 Introduction 34-1
- 34.2 Results and Discussion 34-1
  - 34.2.1 Physical Oceanography 34-1
  - 34.2.2 Marine Water Quality 34-2

35. TRACE ELEMENTS....35-1

- 35.1 Introduction 35-1
- 35.2 Results and Discussion 35-1

36. MARINE HABITATS....36-1

- 36.1 Introduction 36-1
- 36.2 Results and Discussion 36-1
  - 36.2.1 Iniskin Bay 36-1
  - 36.2.2 Knoll Head to North Head 36-2
  - 36.2.3 Iliamna Bay 36-3

37. NOISE 37-1

- 37.1 Introduction 37-1
- 37.2 Results....37-1

38. VEGETATION 38-1

- 38.1 Introduction 38-1
- 38.2 Results and Discussion 38-2
- 38.3 References 38-3
- 38.4 Glossary....38-3

39. WETLANDS 39-1

- 39.1 Introduction 39-1
- 39.2 Results and Discussion 39-2
- 39.3 References 39-3
- 39.4 Glossary....39-3

40. FISH AND AQUATIC INVERTEBRATES 40-1

- 40.1 Fish 40.1-1
  - 40.1.1 Introduction 40.1-1
  - 40.1.2 Results & Discussion 40.1-1
  - 40.1.3 References 40.1-2
- 40.2 Aquatic Invertebrates....40.2-1
  - 40.2.1 Introduction 40.2-1
  - 40.2.2 Results & Discussion 40.2-1

41. TERRESTRIAL WILDLIFE AND HABITAT 41.1-1

- 41.1 Habitat Mapping and Habitat-value Assessments 41.1-1

41.1.1 Introduction 41.1-1
41.1.2 Results & Discussion 41.1-1
41.2 Terrestrial Mammals 41.2-1
41.2.1 Introduction 41.2-1
41.2.2 Results & Discussion 41.2-1
41.3 Raptors 41.3-1
41.3.1 Introduction 41.3-1
41.3.2 Results & Discussion 41.3-1
41.4 Waterbirds 41.4-1
41.4.1 Introduction 41.4-1
41.4.2 Results & Discussion 41.4-1
41.5 Breeding Landbirds and Shorebirds 41.5-1
41.5.1 Introduction 41.5-1
41.5.2 Results & Discussion 41.5-1
42. MARINE BENTHOS 42-1
42.1 Introduction 42-1
42.2 Results and Discussion 42-2
42.2.1 Intertidal Epibiota 42-2
42.2.2 Subtidal Habitats 42-4
42.2.3 Infauna 42-4
42.3 References 42-6
43. NEARSHORE FISH AND INVERTEBRATES 43-1
43.1 Introduction 43-1
43.2 Results and Discussion 43-1
43.3 References 43-4
44. MARINE WILDLIFE 44-1
44.1 Introduction 44-1
44.2 Results and Discussion 44-1
44.3 References 44-3
45. THREATENED AND ENDANGERED SPECIES AND SPECIES OF CONSERVATION CONCERN 45-1
45.1 Introduction 45-1
45.2 Results and Discussion 45-1
45.3 References 45-4
46. LAND AND WATER USE 46-1
46.1 Introduction 46-1
46.2 Results and Discussion 46-1

47. REGIONAL TRANSPORTATION 47-1
  47.1 Introduction 47-1
  47.2 Results and Discussion...47-1
  47.3 References..47-2
48. POWER..48-1
  48.1 Introduction 48-1
  48.2 Results and Discussion...48-1
49. SOCIOECONOMICS 49-1
  49.1 Introduction 49-1
  49.2 Results and Discussion...49-1
50. CULTURAL RESOURCES 50-1
  50.1 Introduction 50-1
  50.2 Results and Discussion...50-1
51. SUBSISTENCE USES AND TRADITIONAL KNOWLEDGE 51-1
52. VISUAL RESOURCES..52-1
  52.1 Introduction 52-1
  52.2 Results and Discussion...52-1
  52.3 References..52-2
53. RECREATION..53-1
  53.1 Introduction 53-1
  53.2 Results and Discussion...53-2
  53.3 References..53-3

LIST OF TABLES

Table 1-1, Baseline Study Disciplines and Associated Consultants

Table 2-1, Meteorological Parameters Measured at each Monitoring Station

Table 7-1, Streamflow Gaging Stations, Mine Study Area

Table 7-2, Snow Model Results, Mine Study Area

Table 7-3, Gaging Station Basin Characteristics, Transportation-corridor Study Area

Table 12-1, Sound Survey Locations, Number of Sites, and Survey Dates

Table 12-2, Typical Noise Sources and Equivalent dBA

Table 13-1, Grouped Vegetation Types and their Acreages within the Mine Mapping Area, Bristol Bay Drainages

Table 13-2, Grouped Vegetation Types and their Acreages within the Transportation-corridor Mapping Area, Bristol Bay Drainages

Table 14-1, Comparison of Wetland and Waterbody Acreages and Percentages Identified in the Mine Mapping Area by the Pebble Project Study and by the National Wetlands Inventory

Table 14-2, Comparison of Wetland and Waterbody Acreages Identified in the Transportation-corridor Mapping Area by the Pebble Project Study and by the National Wetlands Inventory

Table 14-3, Hydrogeomorphic Classifications in the Bristol Bay Drainages Mapping Areas

Table 15.1-1, Fish Resource Studies, by Major Study Category, Conducted in the Mine Study Area, 2004 through 2008

Table 15.1-2, Fish Taxa Found in the North Fork Koktuli Watershed, by Study Reach, 2004 through 2008

Table 15.1-3, Fish Taxa Found in the South Fork Koktuli Watershed, by Study Reach, 2004 through 2008

Table 15.1-4, Fish Taxa Found in the Upper Talarik Watershed, by Study Reach, 2004 through 2008

Table 15.1-5, Fish Species Found in the Upper Koktuli River Mainstem, 2004 through 2008

Table 21-1, Selected Demographic and Economic Overview of the Iliamna Lake/Lake Clark Communities, Lake and Peninsula Borough, Bristol Bay Borough, and Dillingham Census Area, Various Years

Table 31-1, Drainage Basin Characteristics, Cook Inlet Drainages Study Area

Table 31-2, Estimated Monthly Low-duration Flows at Gage Stations in the Cook Inlet Drainages Study Area

Table 31-3, Estimated Peak Flows at Gage Stations in the Cook Inlet Drainages Study Area

Table 37-1, Typical Noise Sources and Equivalent dBA

Table 38-1, Grouped Vegetation Types and their Acreages within the Cook Inlet Drainages Mapping Area

Table 39-1, Comparison of Wetland and Waterbody Acreages Identified in the Cook Inlet Drainages Mapping Area in the Pebble Project Study and by the National Wetlands Inventory

Table 39-2, Hydrogeomorphic Classifications in the Cook Inlet Drainages Mapping Area

LIST OF FIGURES

Figure 1-1, Pebble Project Environmental Baseline Studies, Regional Map

Figure 1-2a, Drainages in the Mine Study Area

Figure 1-2b, Hydrologic Units within the Bristol Bay Watershed

Figures 1-3a through 1-3c, Place Names

Figure 1-4, Pebble Project Environmental Baseline Studies, Generalized Study Areas

Figure 2-1, Locations of Meteorological Monitoring Stations in the Mine Study Area

Figure 5-1, Bristol Bay and Cook Inlet Drainages Exploratory Soil Survey

Figure 7-1, Surface Hydrology Stations, Mine Study Area

Figure 7-2, Annual Hydrograph of the South Fork Koktuli River at SK100B.

Figure 7-3, SK100B Hyrdrograph, 2004-2008

Figure 7-4, Surface Hydrology, 2006 Open Water Survey Results, Mine Study Area

Figure 7-5, Surface Hydrology, Snow Model Output, April, 2006-2008, Mine Study Area

Figure 7-6, Surface Water Gage Stations, Transportation Corridor, Bristol Bay Study Area, 2004-2005

Figure 8-1, Schematic Representation of Site-wide Groundwater System

Figure 8-2, Schematic Representation of Groundwater-Surface Water Interaction along South Fork Koktuli River

Figure 8-3, Schematic Representation of Groundwater-Surface Water Interaction along North Fork Koktuli River

Figure 8-4, Schematic Representation of Groundwater-Surface Water Interaction along Upper Talarik Creek

Figure 8-5, Stream Gaging Stations and Watershed Boundaries

Figure 11-1, Acid-base Accounting Results for pre-Tertiary Mineralized Samples (Pebble East Zone)

Figure 13-1, Vegetation Mapping in the Mine Study Area, 2004-2008

Figure 13-2, Overview Vegetation Mapping, Transportation-corridor Mapping Area, 2004-2008

Figure 14-1, Field Plot Locations Overview, Mine Study Area, 2004-2008

Figure 14-2, Overview Field Plot Locations, Transportation-corridor Study Area, 2004-2008

Figure 15.1-1, Bristol Bay Regional Drainages

Figure 15.1-2, Fish—Mine Study Area Reaches

Figure 20-1, Power Study Area, Bristol Bay Drainages

Figure 25-1, Recreation Study Area, Bristol Bay Drainages

Figure 26-1, Locations of Meteorological Monitoring Stations with Dates of Operation, Cook Inlet Drainage Study Area

Figure 29-1, Bristol Bay and Cook Inlet Drainages Exploratory Soil Survey

Figure 31-1, Surface Water Gage Stations Transportation Corridor, Cook Inlet Study Area 2004-2005

Figure 38-1, Overview Vegetation Mapping, Cook Inlet Drainages Study Area, 2004 and 2005

Figure 39-1, Overview Field Plot Locations, Cook Inlet Drainages Study Area, 2004 and 2005

Figure 40-1, Primary and Support Survey Sites for the Representative Road Alignment by Cook Inlet Watershed

Figure 53-1, Recreation Regional Study Area Cook Inlet Drainages Study Boundaries for Land Use, Big Game Hunting, and Sportfishing

ACRONYMS AND ABBREVIATIONS

ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
ANCSA	Alaska Native Claims Settlement Act
ARD	acid rock drainage
CAE	Cominco Alaska Exploration
cfs	cubic feet per second
ºC	degrees Celsius
DO	dissolved oxygen
DWS	drinking water standards
EBD	environmental baseline document
EPT	Ephemeroptera, Plecoptera, and Trichoptera
ºF	degrees Fahrenheit
GIS	geographic information system
KC	Kaskanak Creek
km	kilometer(s)
KR	Koktuli River mainstem
MCH	Mulchatna Caribou Herd
mi^2	square mile(s)
NDML	Northern Dynasty Minerals Ltd.
NFK	North Fork Koktuli River
NK	North Fork Koktuli River (for hydrology studies)
NOCs	naturally occurring constituents
PAG	potentially acid-rock-drainage producing
PDF	portable document format
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
SFK	South Fork Koktuli River
SK	South Fork Koktuli River (for hydrology studies)
SRB&A	Stephen R. Braund & Associates
TDS	total dissolved solids
USGS	United States Geological Survey
UT	Upper Talarik Creek

PEBBLE PROJECT
ENVIRONMENTAL BASELINE DOCUMENT
2004 through 2008

CHAPTER 1.
INTRODUCTION

PREPARED BY:
PEBBLE LIMITED PARTNERSHIP

TABLE OF CONTENTS

TABLE OF CONTENTS 1-i

LIST OF TABLES 1-ii

LIST OF FIGURES 1-ii

ACRONYMS AND ABBREVIATIONS 1-iii

1. INTRODUCTION 1-1
   - 1.1 Project Location 1-1
   - 1.2 Place Names 1-2
   - 1.3 Project History 1-2
   - 1.4 Pebble Deposit 1-2
   - 1.5 Project Overview (Basis for Study Design) 1-3
   - 1.6 Baseline Study Program 1-3
     - 1.6.1 EBD Study Disciplines 1-4
     - 1.6.2 Quality Assurance/ Quality Control (QA/QC) 1-7
   - 1.7 EBD Package Structure 1-8
     - 1.7.1 Technical Summary 1-8
     - 1.7.2 Environmental Baseline Document 1-8
   - 1.8 EBD Document Structure 1-9
     - 1.8.1 Geographical Division 1-9
     - 1.8.2 Study Areas 1-9
     - 1.8.3 Discipline Grouping 1-10
     - 1.8.4 Chapter Structure 1-10
     - 1.8.5 EBD Appendices 1-11
   - 1.9 EBD Formats 1-12
     - 1.9.1 Electronic Versions 1-13
       - 1.9.1.1 Online EBD 1-13
       - 1.9.1.2 EBD on DVD 1-13
     - 1.9.2 Paper Version 1-13
   - 1.10 References 1-13

LIST OF TABLES (following Section 1.10)

Table 1-1, Baseline Study Disciplines and Associated Consultants

LIST OF FIGURES (following table)

Figure 1-1, Pebble Project Environmental Baseline Studies, Regional Map

Figure 1-2a, Drainages in the Mine Study Area

Figure 1-2b, Major Watersheds that Drain into Bristol Bay

Figures 1-3a through 1-3c, Place Names

Figure 1-4, Pebble Project Environmental Baseline Studies, Generalized Study Areas

ACRONYMS AND ABBREVIATIONS

ANCSA	Alaska Native Claims Settlement Act
CAE	Cominco Alaska Exploration
EBD	Environmental Baseline Document
FSO	Field Sampling Plan
GIS	geographical information system
NDML	Northern Dynasty Minerals Ltd.
PDF	portable document format
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
SOW	Statement of work
SP	Study Plan
USGS	United States Geological Survey

1. INTRODUCTION

This environmental baseline document (EBD) has been completed to characterize the existing physical, chemical, biological, and social environments in the areas of the Bristol Bay and Cook Inlet regions where development and reclamation of the Pebble Project may occur. The Pebble Partnership has published this EBD to provide the public and regulatory agencies with a description of the environmental baseline studies that were conducted for the Pebble Project in 2004 through 2008, as well as the results of those studies.

Although this EBD presents primarily the results of the baseline studies conducted from 2004 through 2008, in a few cases, results from other years may be included as well. For example, for a few disciplines (e.g., meteorology and geology), data from studies earlier than 2004 are included. For other studies (e.g., bear and moose surveys), results for years after 2008 are included. Additionally, a few chapters present fewer than 5 years of data because fewer years of study were sufficient to adequately describe baseline conditions for those particular disciplines (e.g., noise and wood frog surveys). Also, several studies are ongoing, and their results will be provided in separate reports to PLP as additional baseline documentation.

When the environmental baseline studies were initiated, Northern Dynasty Mines Inc. was the project proponent. In 2007, Northern Dynasty Mines Inc. joined with Anglo American to form the Pebble Partnership, which assumed responsibility for continuation of the environmental baseline studies in July 2007. Although Northern Dynasty Mines Inc. has been succeeded by the Pebble Partnership, the name Northern Dynasty Mines Inc. appears occasionally in the EBD as necessary for historical accuracy.

1.1 Project Location

The Pebble Deposit is located approximately 200 miles southwest of Anchorage, Alaska, and north of Iliamna Lake, approximately 17 miles northwest of the communities of Iliamna and Newhalen in southwestern Alaska (Figure 1-1).

The Pebble Deposit is located at the headwaters of the Upper Talarik Creek drainage and the South Fork Koktuli River drainage and adjacent to the headwaters of the North Fork Koktuli River drainage (Figure 1-2a). The Kaskanak Creek drainage lies south of the South Fork Koktuli River drainage. These drainages are located in two of the ten hydrologic units that comprise the Bristol Bay watershed (Figure 1-2b). The north and south forks of the Koktuli River are in the Nushagak River watershed and comprise 1.6 percent (by area) of that watershed. These forks of the Koktuli River are two of 24 tributaries of similar or larger size in the 315-mile-long Nushagak River system. The headwaters of the Nushagak River system are at the source of the Mulchatna River above Turquoise Lake, approximately 86 miles northeast of the Pebble Deposit. Upper Talarik Creek is in the Kvichak River watershed and comprises 1.4 percent of that watershed's area. Kaskanak Creek also lies in the Kvichak watershed and comprises 0.27 percent (by area) of the watershed. Both Kaskanak and Upper Talarik creeks are in the 225-mile-long Kvichak River system. The headwaters of the Kvichak River system are approximately 109 miles northeast of the Pebble Deposit at the source of the Tlikakila River at Lake Clark Pass.

The infrastructure necessary to support the Pebble Project would include a transportation corridor extending eastward from the Pebble Deposit area north of Iliamna Lake to the coast and a port on Cook Inlet in the vicinity of Iliamna and Iniskin bays.

1.2 Place Names

While most place names used in this document are found on standard U.S. Geological Survey (USGS) topographic maps, some names not found on the USGS maps are used. Figures 1-3a, 1-3b, and 1-3c show common place names that may be used in this document.

For certain study disciplines, rivers and tributaries are labeled with codes composed of numbers and/or letters. When this is the case, the naming convention is explained within the relevant chapter.

1.3 Project History

Cominco Alaska Exploration (CAE) began investigations in the Pebble Deposit area in 1986 and filed its claims for the Pebble Deposit with the State of Alaska in 1988. Early exploration focused on color anomalies visible from aircraft. The near-surface Pebble West deposit was discovered during the first drilling season in 1988. CAE continued annual drilling and other work through 1993, the results of which indicated a calculated resource of 3 million metric tons of copper metal and 11 million ounces of gold contained in 1,000 million metric tons of ore. After 1993, the only drilling for nearly a decade occurred in 1997.

Northern Dynasty Minerals Ltd. (NDML, the parent company of Northern Dynasty Mines Inc.) optioned the property from Teck Cominco (the successor company to CAE's parent company) in 2001 and, in 2002, began an extensive exploration program that is still in progress 9 years later. By 2004, NDML had expanded the estimate of the known resources at Pebble West to include 4,100 million metric tons of ore. In 2004, detailed engineering and physical, biological, and socioeconomic baseline studies commenced. In 2005, NDML discovered the deep-underground Pebble East deposit. Also that year, NDML acquired 100 percent ownership of the Pebble mining claims from Teck Cominco. Through 2008, the Pebble Partnership and its predecessors had drilled 1,053 holes on the Pebble Claim Block; the holes comprised 548 exploration and delineation core holes and 505 holes for groundwater monitoring, metallurgical testing, and geotechnical purposes.

1.4 Pebble Deposit

The Pebble Deposit is classified geologically as a porphyry copper deposit. Like many porphyry deposits, the Pebble Deposit contains, in addition to copper, other potentially economic minerals. The deposit is among the largest copper-gold porphyry systems in the world. As of 2008, the measured and indicated categories of the Pebble Deposit were estimated to contain 48 billion pounds of copper, 57 million ounces of gold, and 2.9 billion pounds of molybdenum. In addition, the deposit was estimated to contain inferred resources of 24 billion pounds of copper, 37 million ounces of gold, and 1.9 billion pounds of molybdenum, as well as economically significant quantities of silver, palladium, and rhenium. (As of February 2010 the measured and indicated categories were estimated to contain 55 billion pounds of copper, 67 million ounces of gold, and 3.3 billion pounds of molybdenum, while the inferred resource was estimated to contain 25 billion pounds of copper, 40 million ounces of gold, and 2.3 billion pounds of molybdenum.)

1.5 Project Overview (Basis for Study Design)

A mining project such as the Pebble Project is a combination of many possible individual components that together have the potential to be developed into a working mine. Examples of possible components, in addition to a mine pit or workings, include access infrastructure, power facilities, a mill, tailings storage, low-grade-ore stockpiles, warehousing, administrative facilities, and worker housing. As the Pebble Project evolves, the possible locations, sizes, and initial designs of many of these possible components continue to change to address increased reserve size, baseline study results, and changing technical and economic conditions. The study areas have changed, as follows, to provide baseline characterization for possible variations in the project:

- The Pebble Deposit itself has been further delineated from a single near-surface deposit (Pebble West) to include a second, much deeper deposit to the east (Pebble East). Study areas have been expanded to encompass new lands and drainages that are associated with Pebble East.
- Various road alignments are under consideration in efforts to define options that minimize effects on communities, the number of anadromous fish stream crossings, and the filling of wetlands. Studies have been conducted within a transportation-corridor study area that encompasses the area that would most likely accommodate a transportation route. In some chapters, a specific representative road alignment is used as the basis for the transportation-corridor study area. The chapters on transportation (Chapters 19 and 47) address the route described in the *Revised Southwest Alaska Transportation Plan* prepared for the State of Alaska Department of Transportation and Public Facilities (PB Consult, 2004). Marine studies have been conducted in Iliamna and Iniskin bays to characterize areas that could be associated with possible port facilities.
- Determining a power source for the Pebble Project involves ongoing investigations of numerous, varied options and is not directly addressed in this EBD, with the exception of existing power resources.

1.6 Baseline Study Program

The baseline study program commenced in 2004 and has consisted entirely of research conducted by independent, third-party consultants and, in some cases, cooperating government agencies. Forty-four separate consulting firms and testing laboratories were selected by the Pebble Partnership (or by Northern Dynasty Mines Inc.) to conduct studies based on their specific expertise, Alaskan experience, and reputation in the scientific and regulatory communities.

Consultants characterize biophysical and cultural conditions, collect data through detailed surveys and mapping, and analyze the collected information. The disciplines for which baseline conditions are being characterized for the Pebble Project and the associated consultants involved in the baseline studies are listed in Table 1-1. For several disciplines, the lead consultants listed used subcontractors to assist them with the studies.

Each EBD chapter, except this one, was written by an independent consultant (or consultants), not by the Pebble Partnership. Chapters were then reviewed for technical content by a discipline expert. The Pebble Partnership then reviewed all chapters for completeness and consistency across the entire EBD document. In all cases, the original independent consultants made the final determination to accept or reject the Pebble Partnership comments. Some appendices of the EBD were compiled, but not authored, by the Pebble Partnership. In all cases the final chapters reflect the independent judgment of the author(s) and were finalized in accordance with the professional standards of the author's field of expertise.

1.6.1 EBD Study Disciplines

The EBD addresses a wide scope of study disciplines to fully characterize the study areas. These disciplines are as follows:

- **Climate and Meteorology**—the range and seasonality of precipitation, evaporation, temperatures, and wind data collected in the mine and Cook Inlet study areas are discussed along with comparisons to other regional data.
- **Geology and Mineralization**—surficial and bedrock geology, geological structure, deposit types, alteration and mineralization based on previous studies, exploration drilling programs, test pits, and aerial photographs are discussed. This information is important to understanding the mining potential and structural stability of the area. Geology and mineralization may also affect water quality, hydrology, and soils.
- **Physiography**—these chapters present information on topography, landforms, permafrost, and stream drainage patterns from previous studies, geotechnical site investigations, maps, and aerial photos.
- **Soils**—these chapters provide a comprehensive overview of soil types in the study areas based on the *Exploratory Soil Survey of Alaska* completed by the U.S. Department of Agriculture, Soil Conservation Service (Rieger et al., 1979).
- **Geotechnical Studies, Seismicity and Volcanism**—based on-site geotechnical investigations and previous literature, these chapters discuss aspects of surficial geology, overburden and bedrock geology, hydrogeology, physiography, topography, and surficial materials in their relation to rock mass characterization, movement of water through these materials, and seismicity. Regional volcanism and active fault systems also are addressed.
- **Surface Water Hydrology**—an overview of regional hydrology is presented for the greater Bristol Bay drainages based on published government information. Localized hydrology for the mine study area is described in detail based on extensive streamflow gaging and snow survey programs. Data on localized hydrology for the transportation-corridor and Cook Inlet study areas are presented as estimates, with some site-specific input.
- **Groundwater Hydrology**—these chapters describe the groundwater flow regime, including interactions between surface water and groundwater as determined through extensive field studies and water balance modeling. Information is provided on groundwater storage, hydraulic conductivity, flow rates, water-level fluctuations, and pathways.
- **Water Quality**—data on physical and chemical parameters related to surface water quality and groundwater quality are presented. The data are based on extensive year-round field sampling.

Temporal and spatial trends are described, and data are compared to Alaska Department of Environmental Conservation water quality standards to provide a comparative context.

- **Trace Elements and Other Naturally Occurring Constituents**—trace elements and other analytes that occur naturally in the environment are assessed for baseline concentrations and spatial and temporal variability in soil, vegetation, sediments, and fish tissue.
- **Geochemical Characterization**— waste characterization is presented for various rock types found in the mine study area and for representative Pebble Deposit tailings (based on simulated tailings). Extensive testing was conducted to determine geochemical properties. Tests included a wide variety of field, static, and kinetic methods that address reaction rates over time under conditions that include exposure to air, alternating cycles of wetting and drying, and saturated conditions. Testing will be ongoing for some time before final waste characterization is complete. Additional results will be presented in separate reports to PLP as baseline documentation.
- **Noise**—noise-monitoring data collected to establish baseline noise levels are presented. Noise can be perceived as desired, beneficial, or detrimental.
- **Vegetation**—these chapters discuss dominant vegetation types as well as typical plant-species composition and distribution, as determined based on existing literature, extensive field work, and aerial photography. Maps present groupings of vegetation types across the study areas.
- **Wetlands**—the extent and types of wetlands in the study areas are discussed and mapped based on existing literature, aerial photography, and extensive field work.
- **Fish and Aquatic Invertebrates**—These chapters present the results from extensive field studies addressing fish and aquatic invertebrate distribution, density, and abundance; channel morphology; habitat; flow/habitat relationships; fluvial geomorphology; and water temperature modeling. The discussion addresses spatial and temporal trends.
- **Wildlife and Habitat**—this diverse discipline covers data from a wide variety of ground-based and aerial surveys and aerial photography. Baseline studies of habitat availability and habitat-value assessments for bird and mammal habitat were based on aerial photography, and the results are presented and mapped for the study areas. The chapters also present the study results for presence, distribution and abundance, and/or habitat use for terrestrial mammals, raptors, waterbirds, shorebirds, landbirds, wood frogs, and seals in Iliamna Lake.
- **Threatened and Endangered Species**—literature reviews and information from field surveys were used to determine the potential for rare plant species to be present in the study areas and to summarize the occurrence and conservation status of protected wildlife and plant species and species of conservation concern found or likely to occur in the study areas.
- **Land and Water Use**—existing land ownership, present use, and management status of private and public lands and surface waters are described and mapped based on existing data sources and publications. Federal, state, and local regulatory powers and plans also are discussed.
- **Regional Transportation**—land, water, and air transportation facilities and services, both existing and proposed, are described for the greater Bristol Bay area. The information presented is based on existing transportation studies, regional plans, and interviews with representatives of service providers from the area.

- **Power**—these chapters describe existing services and facilities for supplying electrical power and petroleum fuels to the Bristol Bay communities, as determined based on various publications and online information resources.
- **Socioeconomics**—information on demographics, economy, infrastructure, and history are provided for several communities in the Lake and Peninsula Borough, Bristol Bay Borough, and the Dillingham Census Area. A general discussion of socioeconomics for the Municipality of Anchorage, Kenai Peninsula Borough and the Matanuska Susitna Borough are also provided. The discussion is based on the most recent government data available at the time of preparation.
- **Cultural Resources**—existing data on prehistory, ethnography, and history are summarized. Additionally, information from interviews with tribes and other interested local parties and from field surveys are provided.
- **Subsistence**—the role of subsistence in local communities, information about current and historical subsistence harvests and use areas, traditional knowledge about changes in subsistence resources, and local concerns related to subsistence are presented based on household harvest surveys conducted by the Alaska Department of Fish and Game, and subsistence mapping and traditional knowledge interviews conducted by Pebble Project researchers with active and/or knowledgeable harvesters.
- **Visual Resources**—the scenic quality of the landscape is analyzed using U.S. Forest Service methods. The analysis provides information on viewed areas, constituent viewer groups and their sensitivities and expected exposure, and an analysis of the landscape's existing character and quality.
- **Recreation**—outdoor recreational resources and activities are described and mapped. An estimate of their economic contribution to the study areas' economy also is presented. The information presented is based on state and federal land use plans, Alaska Department of Fish and Game reports on sportfishing and big game hunting, and an inventory of recreational lodges.
- **Oceanography and Marine Water Quality**—the shape and depth of Iliamna and Iniskin bays, tidal range and currents, wave and ice-scour action in the vicinity, and a brief analysis of some of the inputs to and outputs from the bays are addressed through literature searches of previous study results and through field investigations. Marine water quality data for physical and chemical parameters sampled in the field are presented, and the results for the inorganic chemical parameters are compared to the Environmental Protection Agency's National Recommended Water Quality Criteria to give context.
- **Marine Nearshore Habitat**—the chapter describes the diverse range of habitats in the vicinity of Iliamna and Iniskin bays, based on information drawn from the marine investigators' long history of work in the area and from field observations during these studies.
- **Marine Benthos**—the benthic flora and fauna of the intertidal and subtidal habitats of Iliamna and Iniskin bays are presented. The information presented is based on the marine investigators' long history of work in the area and field investigations during these studies.
- **Nearshore (Marine) Fish and Invertebrates**—marine investigations included beach seine sampling, gill net and trammel net sampling, and trawl net sampling for fish and invertebrates. Herring-spawn surveys and fish-stomach content analyses also were conducted. The data from

these investigations, along with information from previous studies, are presented by species with discussions on seasonal trends and distinct habitat usage.

- **Marine Wildlife**—the seasonal distribution and abundance of marine-oriented wildlife (birds and mammals) is presented. The information presented is based on previous literature, boat surveys, fixed-wing aircraft surveys, and helicopter surveys. The chapter addresses seasonal and interannual patterns, taxonomic patterns, and spatial patterns

1.6.2 Quality Assurance/ Quality Control (QA/QC) Program

The Pebble Project QA/QC program is specific to the collection, review and management of field and laboratory data. The QA component of the program is a systematic process of verifying that activities are meeting specified requirements. It strengthens the confidence in the data generated from various activities that help form the interpretations and conclusions made for baseline conditions. This strength is accomplished by establishing consistency and building in efficiencies that provide benefits throughout the project. Study plans (SPs), field sampling plans (FSPs), quality assurance project plans (QAPPs) and statements of work (SOWs) document the QA program and processes. The QC component of the program is implemented through field and laboratory audits, peer review, data validation, and statistical analyses. Field and laboratory QA/QC protocols are presented in the consolidated SPs (EBD Appendix E), FSPs (EBD Appendix F) and QAPPs (EBD Appendix G) for each year of the study.

SPs were prepared for each discipline (e.g., fish, wetlands, geochemistry, etc.) by consultants to describe how the study would be conducted. The specific objectives of the SPs were to:

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

FSPs were developed for some disciplines to describe in detail the procedures and protocols researchers would use to collect physical samples in the field for laboratory analysis. The FSPs acted as instructions for use in the field to ensure proper field techniques, and to provide documentation for reviewers of the data. Not all disciplines have FSPs because many do not require collection of physical samples for laboratory analysis. FSPs were not necessarily developed each year for a given discipline, because once a refined plan existed there was no need to change it.

QAPPs were updated each year to define analytical QA/QC specification for water, soil, sediment, vegetation and tissue samples collected for laboratory analysis. These plans document all data quality objectives necessary to obtain data that is defensible and representative of the environment. Analytical laboratory QA/QC results are presented in EBD Appendix A.

The specification for QC review of field data is as follows.

Field data are considered final when quality control (QC) is completed as defined below.

> Level 1 QC – The individual collecting field data reviews the data for completeness, legibility and logic on all information recorded. The field team leader then conducts the same review on 100 percent of the data collected. This is typically completed in the field at the end of each day.

> Level 2 QC – For field data that are manually entered into either a spreadsheet or database at least 20 percent of the data entries are checked by a peer who did not enter the data. If errors are found then the check is conducted on 100 percent of the entries. Shorthand codes are often used in the field, to represent species, location names, crew, equipment, etc. These shorthand codes must be deciphered into standard or more meaningful values during QC level 2 data entry.
>
> Level 3 QC – This is senior level review of the data for possible data quality issues observed in trends and statistical analyses. It is understood QC level 3 continues during data analyses for report writing and or modeling applications. Statistical outliers and questionable data should be thoroughly reviewed for QA/QC to determine the cause. Should data be deemed not useable (i.e., invalid) during this process PLP must be notified so that the archived data can be qualified accordingly.

These QA/QC processes are based on a defined and documented set of criteria, which are accepted by industry and comply with relevant regulatory guidelines. The result of this program is a baseline data set of known quality for characterizing environmental conditions. The data are managed to ensure the data quality is maintained and secure. EBD consultants reported their study findings in draft EBD documents that were subject to rigorous scientific peer reviews, technical editing and consistency reviews. All of the reviews included quality checks on study findings. Discrepancies identified during this process were resolved by study authors for all disciplines.

1.7 EBD Package Structure

The EBD package being published by the Pebble Partnership is composed of two parts: a technical summary and the EBD itself.

1.7.1 Technical Summary

The technical summary consists of summaries for each chapter and appendix of the EBD. Each chapter of the technical summary briefly describes the given discipline’s study objectives and methods, but focuses on the results and discussion. The purpose of the technical summary is to provide one document of reasonable length that introduces the disciplines covered by the baseline studies and broadly describes the results of those studies. Based on the technical summary, readers can better determine what chapters of the EBD they might wish to delve into. The technical summary is being published as a stand-alone document for distribution in electronic and paper formats, although it will be distributed in conjunction with the EBD.

1.7.2 Environmental Baseline Document

This document contains the details of all the baseline studies. Each of the 53 chapters describes the study objectives, study area, scope of work, methods, and results and discussion for its particular discipline. As previously noted, the EBD was written by the Pebble Partnership’s consultants and is a product of their efforts and professional judgment. The printed version contains approximately 20,000 pages, including text, tables, figures, photographs, and some appendices (other appendices are available only electronically because of their length). Because of the inclusion of the additional appendices, the electronic version has approximately 27,000 pages. Because of its size, the EBD is being published primarily in electronic format, with a limited distribution of paper copies. The electronic version will be available on a website at pebbleresearch.com.

1.8 EBD Document Structure

1.8.1 Geographical Division

The chapters in the EBD are organized into two parts to reflect the geographical realities of the Pebble Project study areas. Chapters 1 through 25 comprise the first part, by far the larger part, which (except for this chapter) presents information for study areas in the Bristol Bay drainages (Figure 1-4). The second part, Chapters 26 through 53, presents information for the Cook Inlet drainages study area, which encompasses a much smaller area than the study areas in the Bristol Bay drainages. This division was made because the Cook Inlet study area is almost completely defined by the coastal and marine environments of Cook Inlet, which have substantially different characteristics than the interior environments of the study areas in the Bristol Bay drainages.

Each chapter of the EBD addresses one discipline (e.g., meteorology, water quality, land use, etc.). The chapters for the Bristol Bay drainages are often organized into two subsections—one for the mine study area that is centered around the Pebble Deposit and another for the transportation-corridor study area that extends from the mine study area to the boundary between the Bristol Bay and Cook Inlet drainages. The chapters for the Cook Inlet drainages address the terrestrial environment from the drainages boundary eastward to and surrounding Iliamna and Iniskin bays, and also include the marine environments of those bays on Cook Inlet. Additionally, a few chapters are specific to only the Bristol Bay drainages (e.g., geochemistry) or the Cook Inlet drainages (e.g., marine benthos).

1.8.2 Study Areas

The study areas for many of the environmental disciplines have evolved over time as data have been collected and various project design options have been considered. In 2004 and 2005, the studies centered on the area immediately surrounding the deposit as it was then delineated, later defined as the Pebble West Deposit. By 2006 and 2007, the mine study area had been expanded considerably around the newly discovered Pebble East Deposit. Additional changes in study areas occurred over the years to include new areas of interest as different possibilities for infrastructure were considered.

Figure 1-4 shows the location of the four generalized study areas:

- The mine study area (in the vicinity of the Pebble Deposit).
- The transportation-corridor study area (the linear area north of Iliamna Lake stretching from the mine study area approximately 50 miles eastward to the boundary between the Bristol Bay and Cook Inlet drainages).
- Iliamna Lake study area.
- The Cook Inlet drainages study area, including marine areas in and near Iliamna and Iniskin bays (for certain disciplines, the entire Iniskin Peninsula and Chinitna Bay were included in the study area).

The study areas for a few disciplines extend beyond these generalized study areas. These extended study areas are described in the section on study area in the chapters for those disciplines.

The term “project area” has been intentionally avoided in this EBD because a project design has not yet been defined. Additionally, because of the potential size of a project associated with the Pebble Deposit, defining a general project study area for all disciplines is difficult. The areas of interest for different disciplines vary tremendously. Each chapter, therefore, describes a study area (or areas) specific to the baseline studies for the given discipline.

1.8.3 Discipline Grouping

The many study disciplines have been organized in the EBD into three categories: physical and chemical environment (e.g., climate, water quality, trace elements, etc.), biological environment (wetlands, fish and aquatic invertebrates, wildlife and habitat, etc.), and human environment (land and water use, socioeconomics, subsistence, etc.). These categories and the disciplines within them are presented in the same order for both the Bristol Bay drainages and the Cook Inlet drainages (with the few exceptions of disciplines, such as marine studies, that are discussed for only one of the drainage areas).

1.8.4 Chapter Structure

Each chapter of this EBD is self-contained, with its own table of contents and, as applicable, definitions of acronyms and abbreviations used in the chapter, a list of references cited in the chapter, and a glossary of terms used in the chapter. All tables, figures, photographs, and/or appendices associated with each chapter are included with that chapter.

Most chapters have the following elements, generally presented in the order shown below (elements enclosed in brackets are not always present):

- Acronyms and Abbreviations
- Introduction
- Study Objectives
- Study Area
- [Previous Studies]
- Scope of Work
- Methods
- Results and Discussion
- Summary
- [References]
- [Glossary]
- [Tables]
- [Figures]

- [Photographs]
- [Appendices]
    - [Attachments (to Appendices)]
        - [Supplements (to Attachments)]

Many of the chapters for the Bristol Bay drainages are separated into primary subsections based on study area (i.e., mine study area and transportation-corridor study area). Because for most disciplines the objectives, scope of work, and methods were the same for both study areas, to minimize duplication the subsections for the transportation-corridor study area often refer readers to the descriptions of these elements for the mine study area.

For most chapters, the tables, figures, and/or photographs are located at the end of the chapter. In some cases, these elements are placed at the end of primary subsections within the chapter. In a few chapters that contain many tables and figures, these elements are interspersed throughout the text of the chapter to allow for smoother reading.

Many chapters include appendices that contain supporting information or other data, for example, tables of laboratory analytical data. In some chapters, for example Chapter 15 (fish and aquatic invertebrates for the Bristol Bay drainages), appendices contain reports on specialized research that supports but may not be directly addressed in the body of the chapter. Readers are referred to all appendices as appropriate.

In Chapter 23 (subsistence and traditional knowledge for the Bristol Bay drainages), the nature of the information being presented does not fit well into the standard format of EBD. The main body of the chapter is essentially an introduction to and overview of the methodology for collecting detailed information about each community. The detailed community information is provided in a series of appendices formatted to more effectively present the information.

Chapters 32 (groundwater hydrology for the Cook Inlet drainages) and Chapter 51 (subsistence and traditional knowledge for the Cook Inlet drainages) exist as placeholders only with no content. These studies have not yet been conducted. Results will be provided in reports to PLP as additional baseline documentation.

Note there may be some minor inconsistencies in certain dynamic data presented in more than one place in the EBD. For example, values for average annual precipitation in the Pebble Deposit area may be slightly different in different chapters of the EBD depending on the most current information available at the time a given chapter was written.

1.8.5 EBD Appendices

Many chapters have appendices that provide additional information relevant only to that chapter; however, the overall EBD itself has seven appendices containing information that is relevant to multiple chapters. These appendices appear at the end of the entire EBD and are described briefly below.

- **Appendix A, Analytical Quality Assurance/Quality Control Review.** This appendix presents an overview of the analytical quality assurance/quality control program for the Pebble Project. This program is specific to the collection and handling of, laboratory analyses of, and data deliverables for samples collected in the field during the environmental baseline studies. The findings of the data-quality assessment of analytical data are reported for surface water, groundwater, sediment, vegetation, soil, freshwater fish and mussel tissues, marine fish and bivalve tissue, marine sediment, and marine water.

- **Appendix B, Iliamna Lake Studies.** This appendix describes and reports the findings of studies of surface water, sediment, mussel tissue, and zooplankton from Iliamna Lake during 2005, 2006, and 2007.
- **Appendix C, Data Management and Geographic Information System.** This appendix describes the Pebble Project geographic information system (GIS), as well as the data management program, which includes meteorological, wetlands, laboratory analytical, and other types of data for the Pebble Project.
- **Appendix D, Chemical Abbreviation.** This appendix defines chemical abbreviations that may be used throughout the EBD.
- **Appendix E, Consolidated Study Program.** This appendix presents the environmental baseline study program for individual disciplines. The consolidated study program was compiled by the Pebble Partnership based on individual study plans developed by consultants each year. The consolidated study program for each discipline describes the study areas, approach and methods, and major activities for each year of the study period.
- **Appendix F, Field Sampling Plans**. This appendix contains the detailed annual field sampling plans for the following studies:
  - Surface water quality and hydrology.
  - Groundwater quality and hydrology.
  - Trace elements and other naturally occurring constituents in vegetation, soil, freshwater sediment, and freshwater fish and bivalve tissues.
  - Metal leaching and acid rock drainage.
  - Small pools.
  - Fish.
  - Macroinvertebrates and periphyton.
  - Iliamna Lake studies.
  - Marine studies.
- **Appendix G, Quality Assurance Project Plans.** This appendix contains the annual quality assurance project plans (QAPPs). These QAPPs specify detailed field sampling and laboratory analytical protocols, as well as quality assurance/quality control requirements and data quality assessment procedures for the Pebble Project.

1.9 EBD Formats

The EBD has been produced in three formats: electronically online, electronically on DVD, and printed on paper.

1.9.1 Electronic Versions

Electronic versions of the EBD in portable document format (PDF) are online and on DVD. For ease of navigation, each chapter in the electronic versions has bookmarks corresponding to the entries in the tables of contents. In addition, hyperlinks in the PDF files allow readers to jump to cited tables, figures, and other cited elements.

1.9.1.1 Online EBD

The complete EBD is available online at pebbleresearch.com. The entire EBD or individual chapters may be read and/or downloaded there in PDF format. Please note that some navigational functions, including certain hyperlinks, may not be available in the online version. The website that provides access to the online EBD also includes basic instructions for how to access and navigate through a PDF file.

1.9.1.2 EBD on DVD

A DVD containing the complete EBD was delivered with each paper copy of the EBD (see below). In addition, individual DVDs containing the EBD were distributed to a limited number of recipients. In Bristol Bay communities, contact the tribal council, ANCSA (Alaska Native Claims Settlement Act) corporation, and/or the municipal government to find out where the nearest DVD is housed. The DVD includes a READ ME file that provides basic instructions on how to access and navigate through a PDF file.

1.9.2 Paper Version

Paper versions of the EBD are available for review at a limited number of locations. In Anchorage, a copy is housed at the Alaska Resources Library and Information Service (ARLIS) in the Consortium Library on the University of Alaska, Anchorage, campus at 3211 Providence Drive (907-272-7547). In Bristol Bay communities, contact the tribal council, ANCSA Corporation, and/or the municipal government to determine if a particular community has chosen to have a paper copy.

Please note that some very large appendices, a small number of figures, and a few other elements are available only in the electronic versions. A few tables and figures contain too much detail to be large enough for easy reading when printed—these few elements are more easily read in the electronic versions.

1.10 References

PB Consult Inc. 2004. Revised Southwest Alaska Transportation Plan. Prepared for the Alaska Department of Transportation and Public Facilities, Central Region.

Rieger, S., D.B. Schoephorster, and C. E. Furbush. 1979. Exploratory Soil Survey of Alaska. U.S. Department of Agriculture, Soil Conservation Service. Washington, D.C.: U.S. Government Printing Office.

TABLES

TABLE 1-1
Baseline Study Disciplines and Associated Consultants

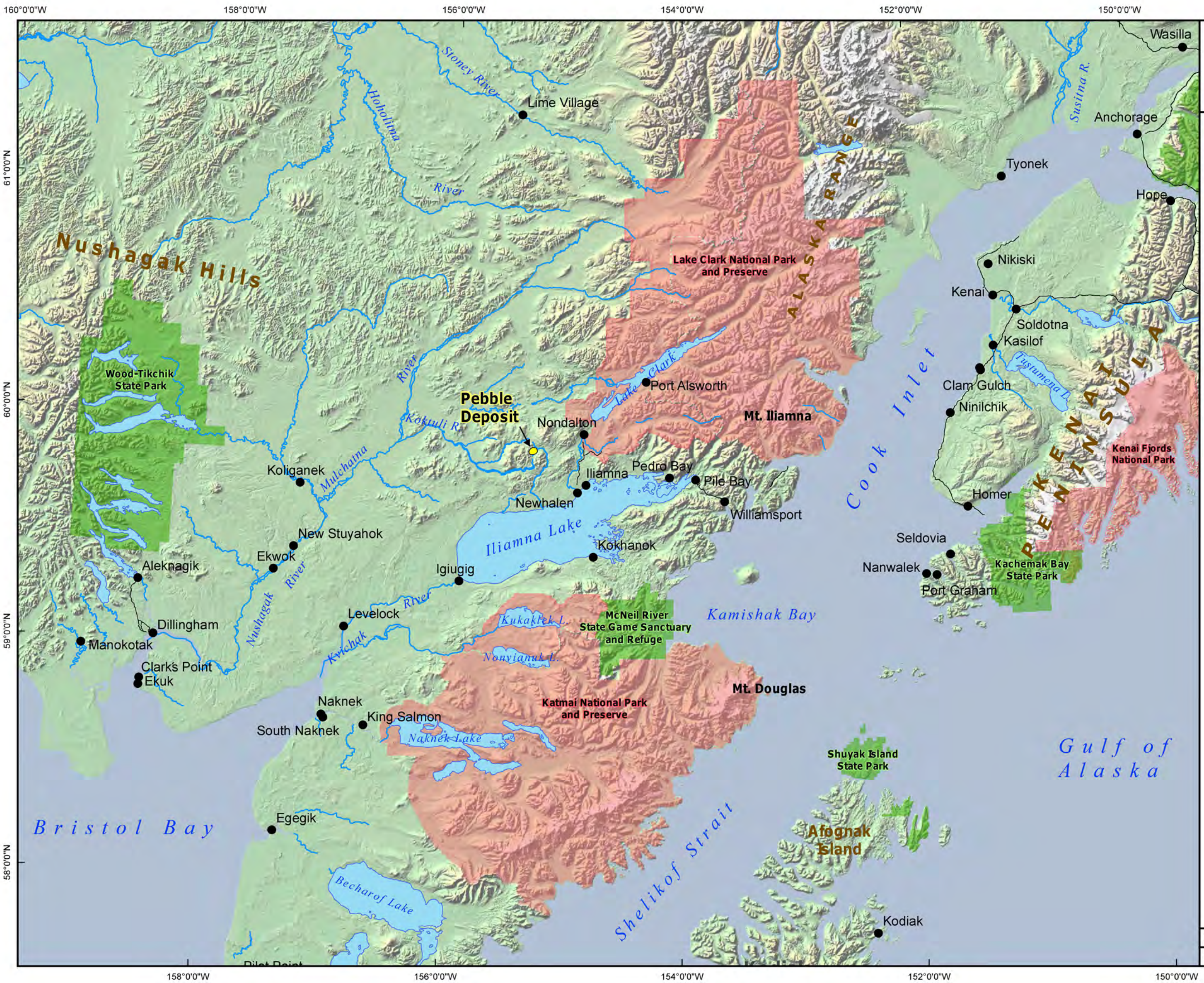
Discipline	**Consultant(s)**
Climate and Meteorology	Hoefler Consulting Group, CH2M Hill
Geology and Mineralization	Knight Piésold, Thomas Hamilton, SLR International Corp.
Physiography	Knight Piésold
Soils	Three Parameters Plus, Inc.
Geotechnical Studies, Seismicity and Volcanism	Knight Piésold, Water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

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

FIGURES

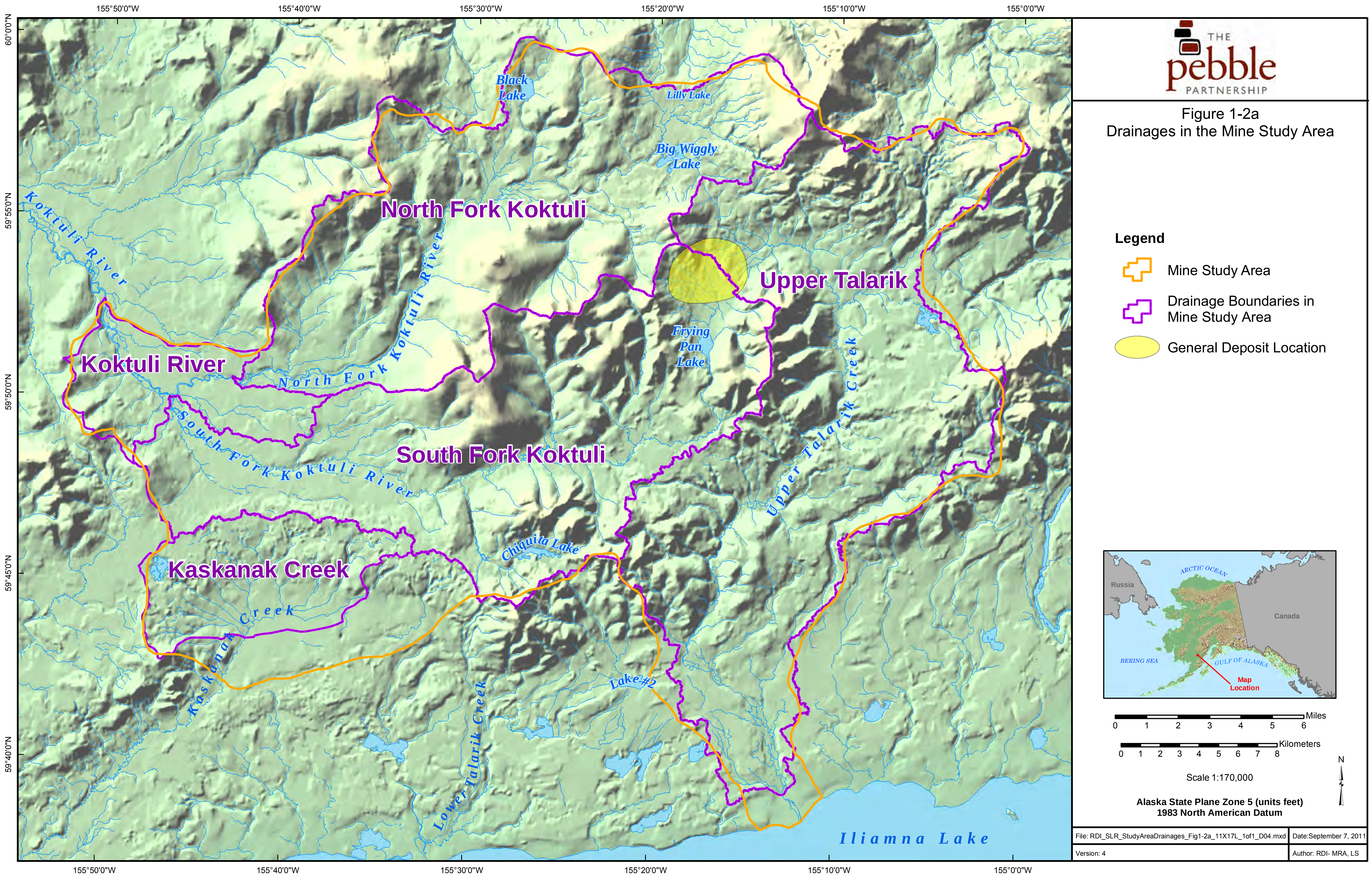
THE pebble PARTNERSHIP

Figure 1-1
Pebble Project Environmental Baseline Studies Regional Map



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

File: RDI_ND_PEBANC_1Fig1-1_1X17L_1of1_D02mxd	Date: September 13, 2011
Version: 2	Author: JG-PLP, LS-RDI



THE pebble PARTNERSHIP

Figure 1-2a
Drainages in the Mine Study Area

Legend

Mine Study Area

Drainage Boundaries in Mine Study Area

General Deposit Location

Scale 1:170,000

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

File: RDI_SLR_StudyAreaDrainages_Fig1-2a_11X17L_1of1_D04.mxd
Date:September 7, 2011
Version: 4
Author: RDI- MRA, LS

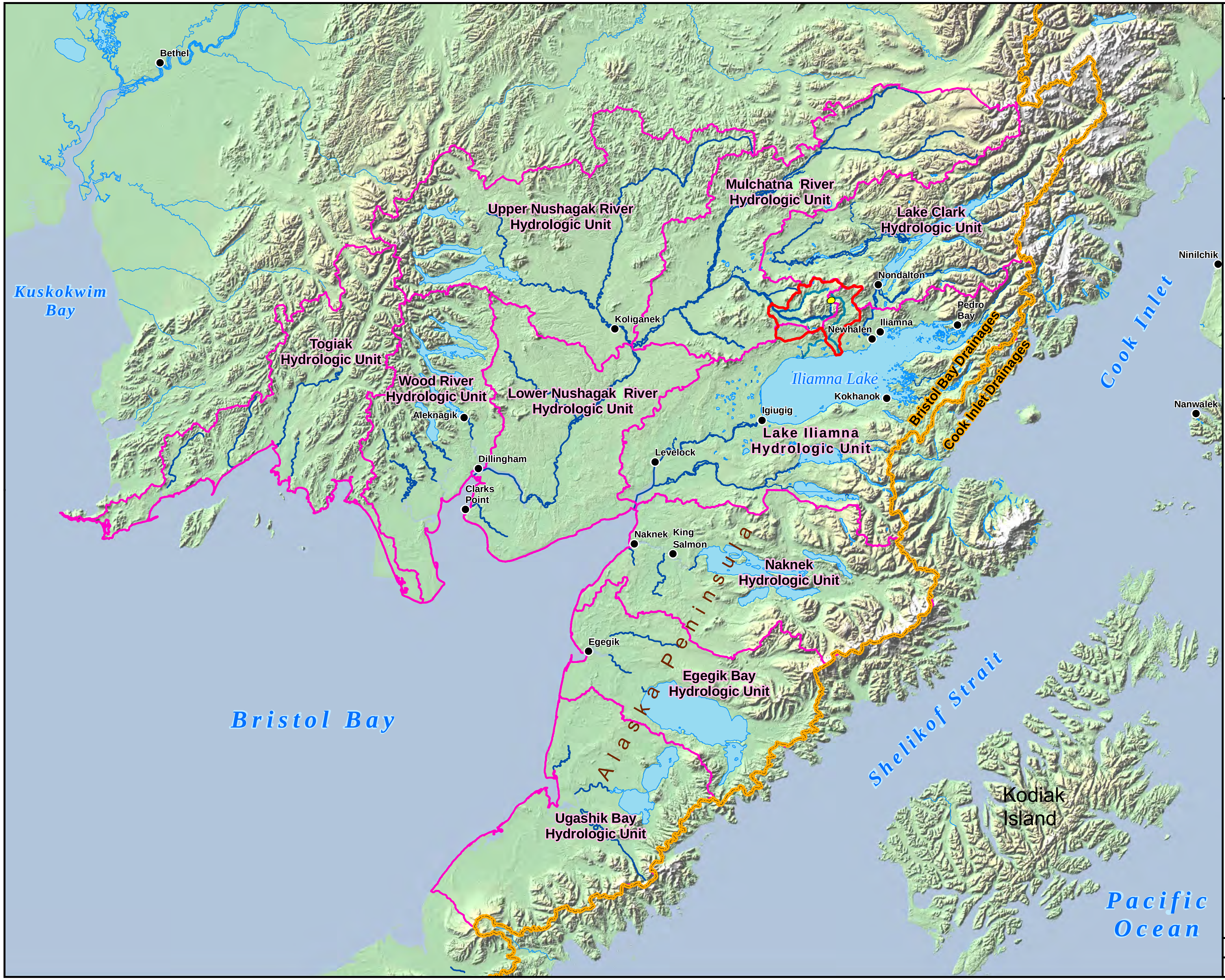


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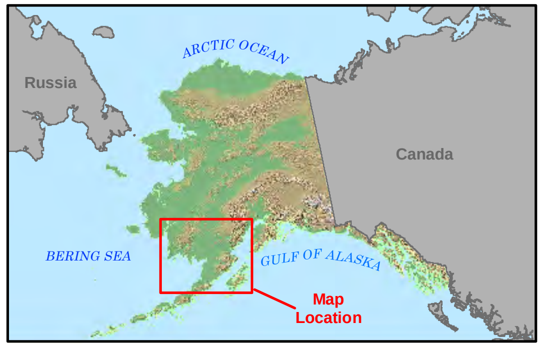
Figure 1-2b
Hydrologic Units within the Bristol Bay Watershed

Legend

- Mine Study Area
- USGS, EROS Sub-basin Hydrologic Unit Boundaries of the Bristol Bay Watershed
- Bristol Bay/Cook Inlet Drainages Boundary
- Major Rivers Draining into Bristol Bay
- General Deposit Location
- ● Communities

Source for sub-basin units: U.S. Geologic Survey, Earth Resources Observation and Science Center. 1994. Alaska Hydrologic Units 1:250,000 mapping.



Scale 1:2,000,000

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

File: RDI_SLR_StudyAreaDrainages_Fig1-2b_11X17L_1of1_D01.mxd	Date:September 13, 201
Version: 1	Author: RDI- MRA, LS

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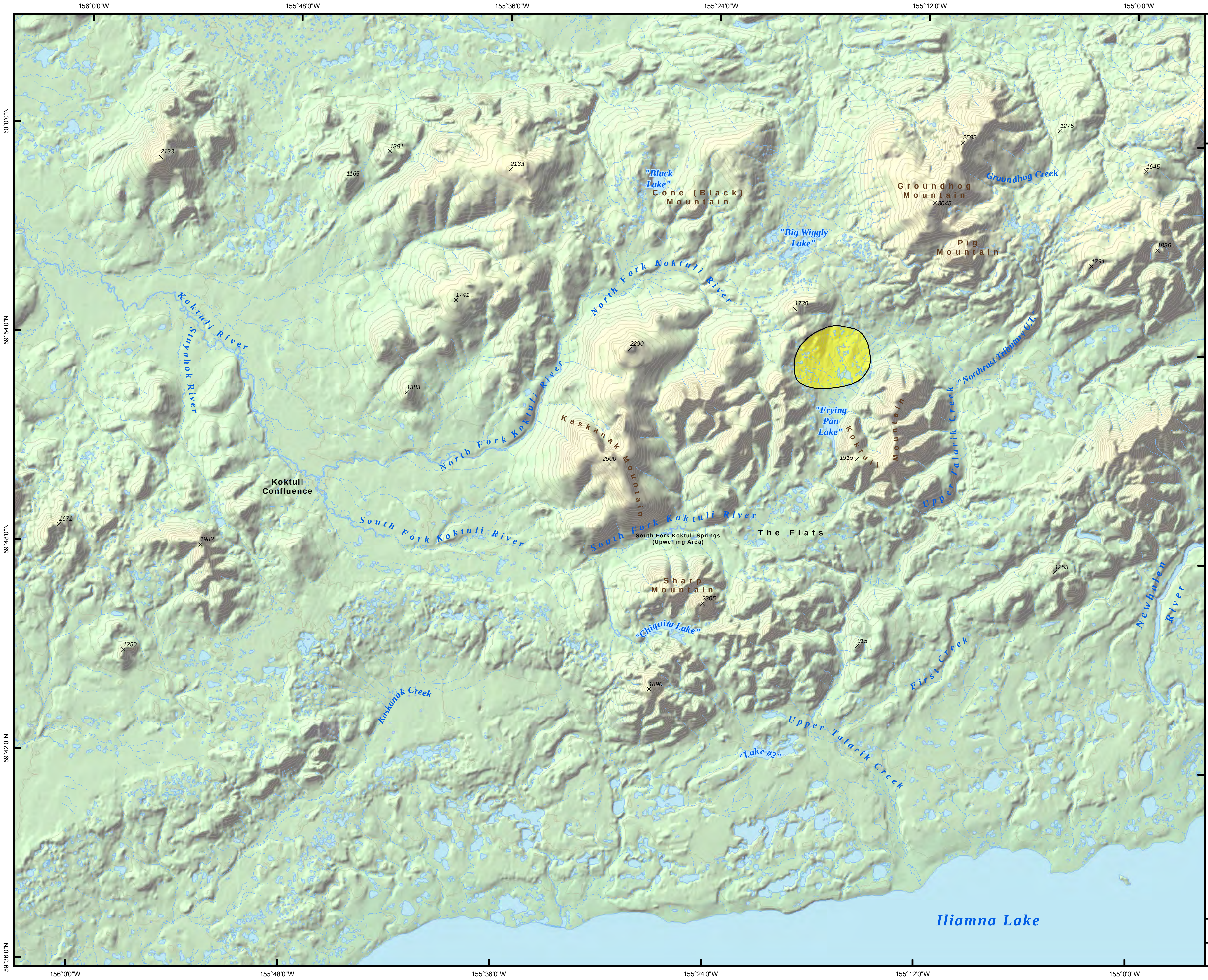
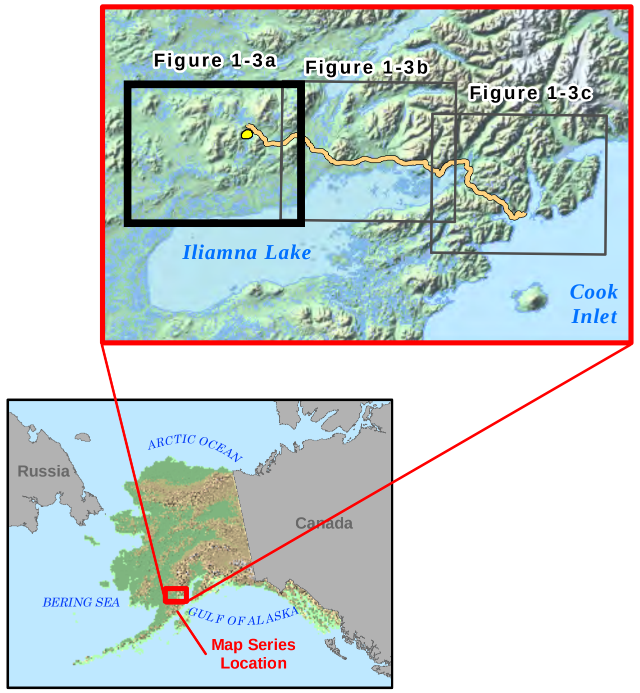
Figure 1-3a
Place Names



Legend

🟨 General Deposit Location

× Reference Elevation



Scale 1:200,000

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

File: RDI_HDR_Placename_Fig1-3_11x17_1of3_D02.mxd	Date: September 11, 2011
Version: 2	Author: HDR - MC, RDI - LS

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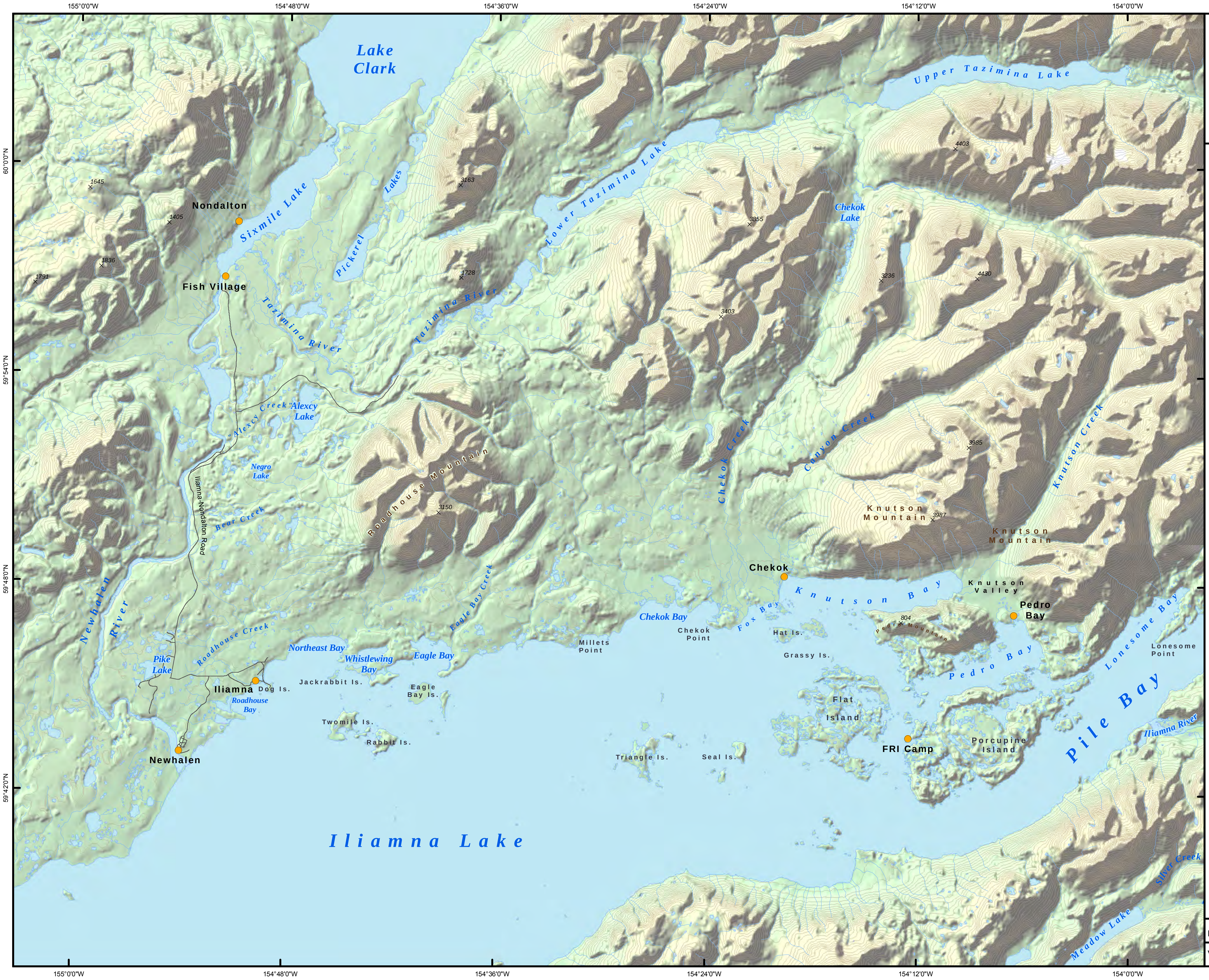


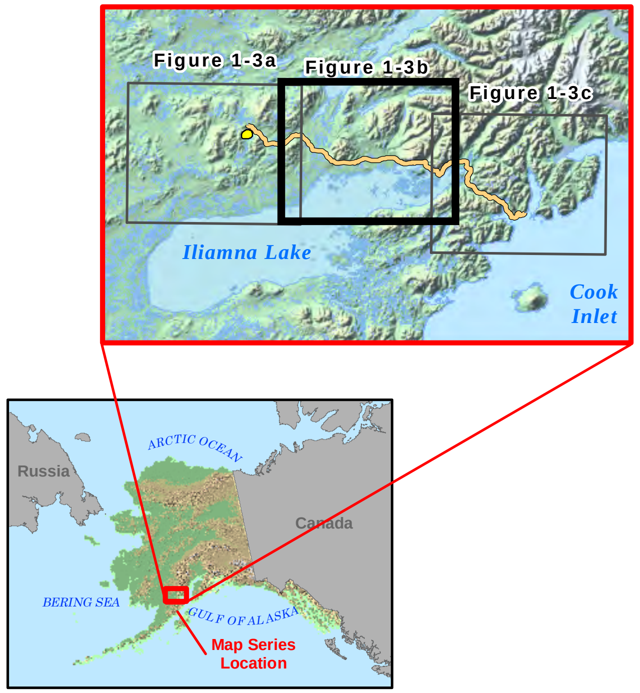
Figure 1-3b
Place Names

Legend

● Communities

— Existing Roads

× Reference Elevation



0 2 4 6 8 Miles

0 2 4 6 8 10 Kilometers

N

Scale 1:200,000

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

File: RDI_HDR_Placename_Fig1-3_11x17_1of3_D02.mxd	Date: September 11, 2011
Version: 2	Author: HDR - MC, RDI - LS

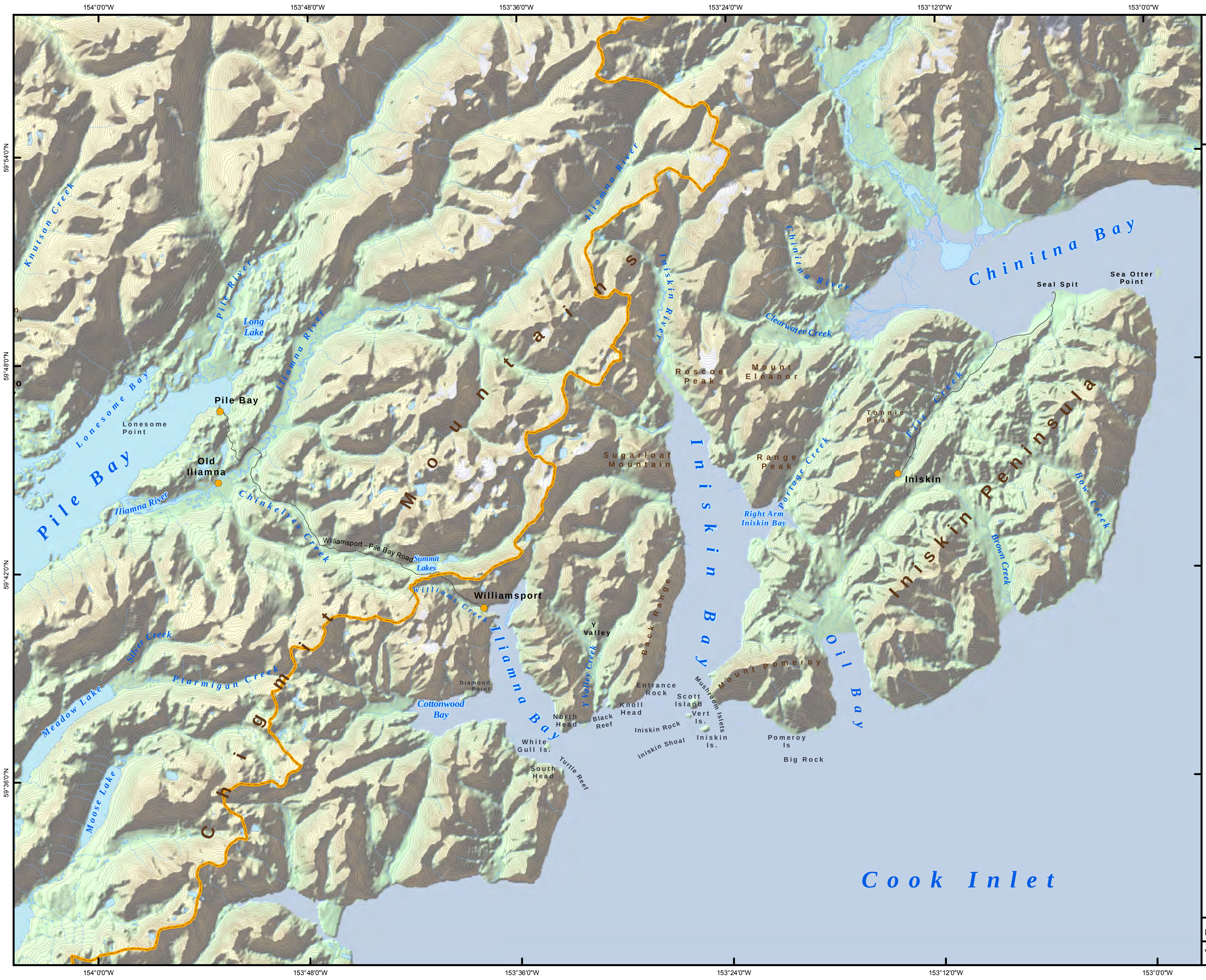


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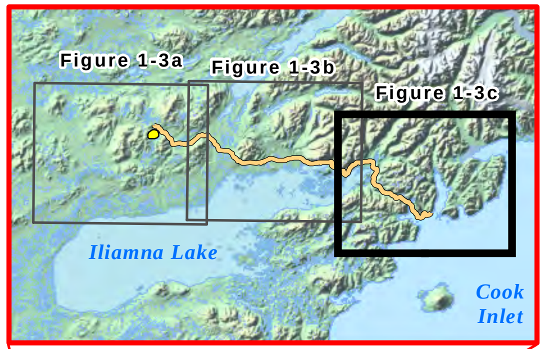
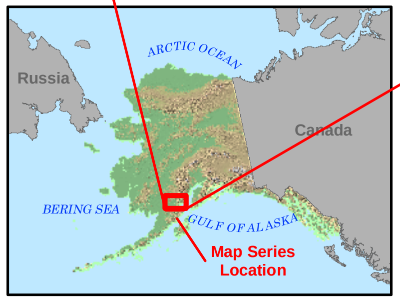
Figure 1-3c
Place Names

Legend

- ● Communities
- ▬ Bristol Bay/Cook Inlet Drainages Boundary
- — Existing Roads
- × Reference Elevation





0 2 4 6 8 Miles

0 2 4 6 8 10 Kilometers

N

Scale 1:200,000

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

File: RDI_HDR_Placename_Fig1-3_11x17_1of3_D02.mxd	Date: September 11, 2011
Version: 2	Author: HDR - MC, RDI - LS

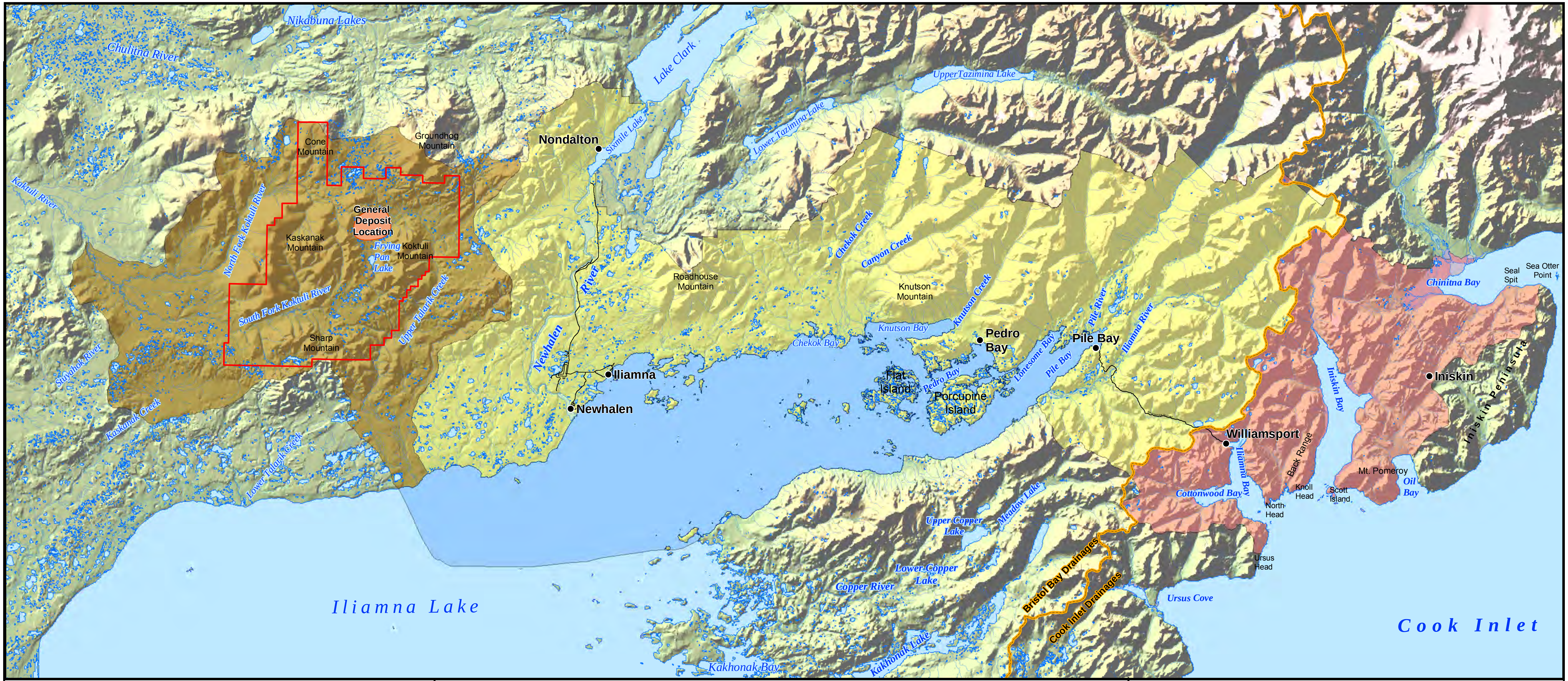


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Figure 1-4
Pebble Project
Environmental Baseline Studies
Generalized Study Areas

File: RDI_PLP_StudyAreas_Fig1-1_11X17L.1of1_D01.mxd

Date: September 12, 2011

Version: 2

Author: PLP - JG, RDI - LS

Legend

🟧 General Deposit Location

□ Pebble Claim Block

🟫 Mine Study Area

🟨 Bristol Bay Transportation Corridor Study Area

🟥 Cook Inlet Study Area

🟦 Iliamna Lake Study Area

— Bristol Bay/Cook Inlet Drainages Boundary

● Communities

— Existing Roads

Scale 1:400,000

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

2. CLIMATE AND METEOROLOGY

2.1 Introduction

The meteorological data-collection program has gathered representative meteorological surface data in accordance with the guidance for Prevention of Significant Deterioration (PSD) air-quality permit requirements. Meteorological surface data were collected at six locations in the mine study area. These stations—Pebble 1, Pebble 3, Pebble 4 (previously Pebble 2), Pebble 5, Pebble 5A, and Pebble 6—are located at sites surrounding the Pebble Deposit (Figure 2-1). Installation of monitoring stations began in October 2004. Meteorological monitoring first began in January 2005 at Pebble 1.

The transportation-corridor study area is climatologically similar to the mine study area. Because of this similarity, no additional baseline meteorological studies were conducted in the transportation-corridor study area.

The scope of work for the meteorological study in the mine study area was to measure and report the following meteorological parameters:

- Wind speed.
- Wind direction.
- Wind direction standard deviation (sigma theta).
- Temperature.
- Precipitation.
- Evaporation.

The specific parameters measured at each monitoring station are summarized in Table 2-1.

2.2 Results and Discussion

The wind direction is bimodal in the vicinity of the Pebble Deposit (Pebble 1, see Figure 2-1), generally from the northwest or from the east-southeast or southeast. The wind direction in the vicinity of Frying Pan Lake (Pebble 4) is influenced by the terrain, with a northerly and north-northeasterly component rather than a northwesterly one. The wind-direction patterns in the mine study area are not consistent with the wind-direction pattern observed at the Iliamna airport. Non-calm wind conditions are typical for the mine study area, with calm conditions observed only 1.89 percent of the time at Pebble 1. The wind can be strong;wind speeds in the mine study area were generally higher than at the Iliamna airport.

The temperature pattern in the mine study area was similar to the pattern at the Iliamna airport, although temperatures in the mine study area were usually lower. Hourly mean temperatures ranged from a minimum of -35.3 ° C (-31.5°F) on January 2006 at Pebble 1 to a maximum of 24.3°C (75.7°F) recorded both at Pebble 3 in May 2006 and at Pebble 4 in July 2006.

Generally, more precipitation was observed in the mine study area during the months of August, September, and October than during other months. Monitoring station Pebble 4 recorded the highest total monthly precipitation of 310.2 millimeters (12.2 inches) in September 2007. The highest total monthly evaporation recorded was 111.7 millimeters (4.4 inches) in June 2005 at Pebble 1. Variation and missing data in the current precipitation and evaporation record impede data comparisons among and within stations.

The mine study area is in a transitional climatic zone with strong maritime influence. Summer temperatures are moderated by the open waters of Iliamna Lake, the Bering Sea, and Cook Inlet. Winter temperatures are more continental because of the presence of ice on Iliamna Lake and sea ice in Bristol Bay. Winter weather systems typically travel into the region from the Bering Sea to the west, from along the Aleutian Island chain to the southwest, and from the Gulf of Alaska to the south. Depending on the season, weather systems consist of cool to cold air that is saturated with moisture, resulting in frequent clouds, rain, and snow. Less frequent wintertime incursions of frigid, stable arctic air masses bring shorter periods of clear but very cold conditions to the region. In the summer, incursions of very warm air masses from interior Alaska can cause atmospheric instability, which results in the development of cumulus clouds and occasional thunderstorm activity.

TABLE 2-1
Meteorological Parameters Measured at each Monitoring Station

	STATION						
Parameter	**Pebble 1**	**Pebble 2**	**Pebble 3**	**Pebble 4**	**Pebble 5**	**Pebble 5A**	**Pebble 6**
Wind Speed	X (at 10 m)	X (at 3 m)	X (at 3 m)	X (at 10 m)	X (at 10 m)	X (at 10 m)	X (at 10 m)
Wind Direction	X (at 10 m)	X (at 3 m)	X (at 3 m)	X (at 10 m)	X (at 10 m)	X (at 10 m)	X (at 10 m)
Wind Sigma Theta	X (at 10 m)	X (at 3 m)	X (at 3 m)	X (at 10 m)	X (at 10 m)	X (at 10 m)	X (at 10 m)
2 m Air Temperature	X	X	X	X	X	X	X
10 m Air Temperature	X			X	X	X	X
Solar Radiation [a]	X			X	X		X
Barometric Pressure [a]	X			X	X		X
Relative Humidity [a]	X			X	X		X
Precipitation	X	X	X	X	X		X
Evaporation	X (summer)	X (summer)		X (summer)	X (summer)		X (summer)

Notes:

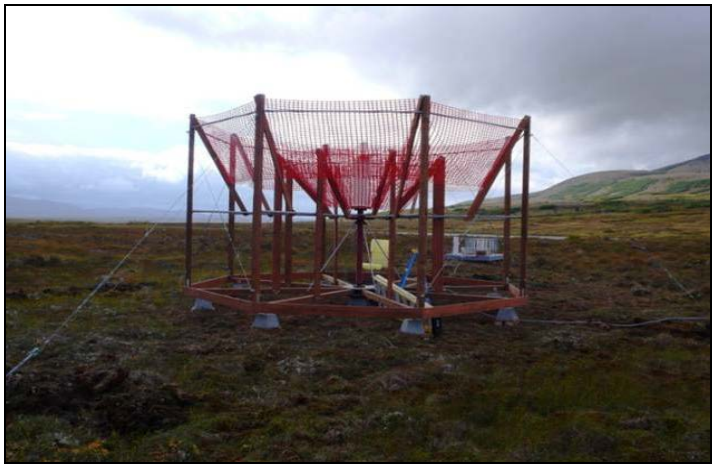
a. These parameters are not discussed in the meteorology chapter of the environmental baseline document, but are included in the data reports in the appendices to that chapter.

m = meters above grade.

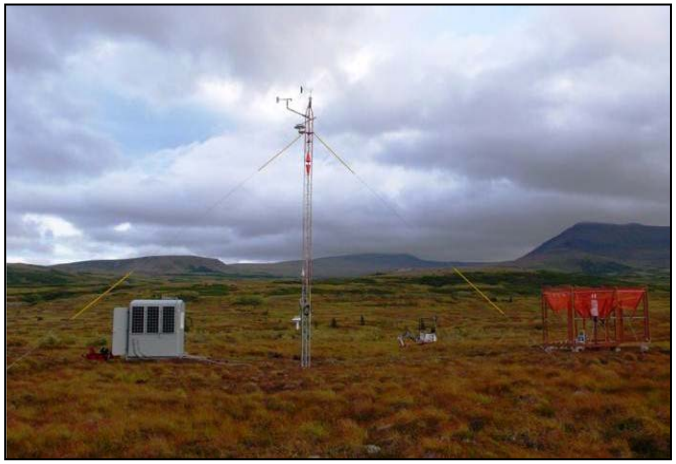
“X” indicates a monitored parameter.

Temperature Sensor at 2 Meters above Grade in the Mine Study Area, February 2007

Pebble 4 Meteorological Monitoring Station in the Mine Study Area, July 2006



Precipitation Gauge with Wyoming Wind Screen in the Mine Study Area, September 2007



Pebble 6 Meteorological Monitoring Station in the Mine Study Area, September 2007

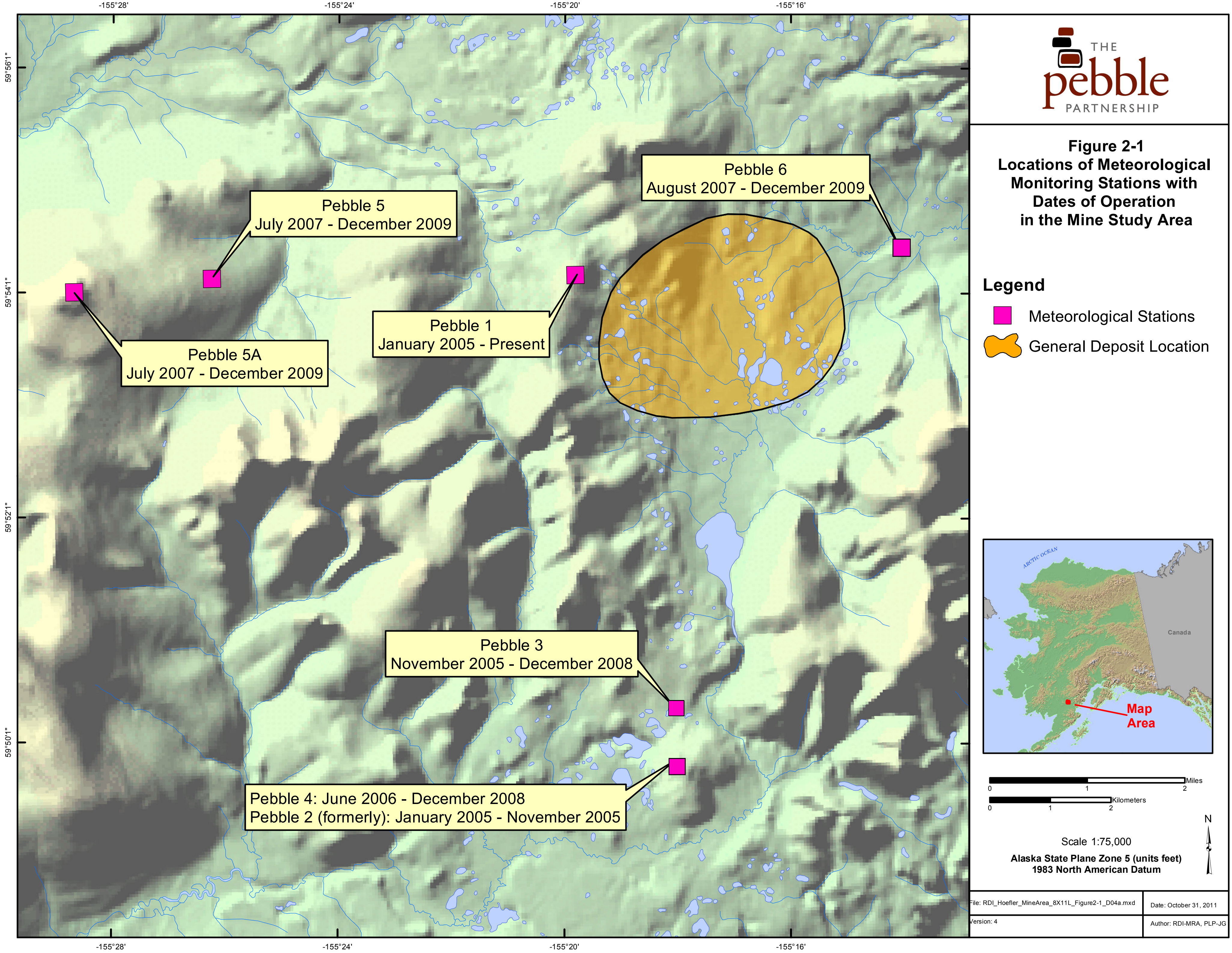


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Figure 2-1
Locations of Meteorological Monitoring Stations with Dates of Operation in the Mine Study Area

Legend

🟪	Meteorological Stations
🟧	General Deposit Location

Scale 1:75,000

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

File: RDI_Hoefler_MineArea_8X11L_Figure2-1_D04a.mxd	Date: October 31, 2011
Version: 4	Author: RDI-MRA, PLP-JG

3. GEOLOGY

3.1 Introduction

This chapter discusses the baseline study of the geology and mineralization characteristics of the mine study area. The study consolidates existing geological data and exploration data collected through 2008. The mine study area is illustrated in Figure 1-4 in Chapter 1. The baseline geology study had an emphasis on the mine study area and included a review of information from exploration drilling programs, geophysics, geotechnical site investigation programs (which included drilling and test-pitting), and aerial-photograph interpretation. Geologic information for surrounding areas was obtained from desktop studies and reviews of existing published information.

3.2 Results and Discussion

3.2.1 Regional Geology

The mine study area lies within the northern circum-Pacific orogenic belt with a complex structural setting created by an active continental margin. The structure of the mine study area is broadly defined by northeast-trending faults related to translational motion along the Lake Clark Fault. The Lake Clark Fault lies on a lithotectonic boundary between the Peninsular Terrane to the east and the Kahiltna Terrane to the west. The mine study area lies within the Kahiltna Terrane, just northwest of the contact with the Peninsular Terrane.

3.2.2 Surficial Geology—Mine Study Area

Four different episodes of glaciation have been recognized in the mine study area and have produced unconsolidated surficial deposits a few to several tens of meters thick that cover most of the lower elevations (Detterman and Reed, 1973). Bow-shaped glacial drift ridges, meltwater deposits with abundant kettle depressions, broad glaciofluvial deposits, elongate valley deposits, and meltwater channels dominate the surficial geology.

Rubble formed by frost action covers many of the gently rounded hilltops and upland surfaces in the study area. Lobes of thin, water-logged sediments slide over less permeable materials on the upper part of hills. These lobes pile up on the mid-slopes of valleys. Glacial drift deposits, which were deposited by ice that moved in a south to southwesterly direction, are found at lower elevations.

3.2.3 Bedrock Geology—Mine Study Area

Bedrock types in the mine study area include a bedded sequence of Jurassic to Cretaceous, mainly andesitic, sedimentary rocks; contemporary mafic extrusive and subvolcanic rocks;

Cretaceous intrusive rocks of diverse composition; and stratified Tertiary volcanics, sedimentary rocks, and subvolcanic dykes.

A key feature of the area is a north-northeast-trending belt of stocks, sills, and dykes of diverse composition that include pyroxenite, gabbro, diorite, monzodiorite, monzonite, syenomonzonite, and granodiorite, as well as bodies of felsic to intermediate intrusion breccia. This belt has been traced for 22 kilometers in the study area. It cuts the andesitic sedimentary rocks on the eastern and southern margins of the Kaskanak Batholith and is localized along a potentially major northeast-trending structure of crustal scale that extends beyond the Pebble Deposit. Magmatic hydrothermal activity in this belt has produced many gold, copper-gold, and copper-gold-molybdenum mineral occurrences that have a close spatial and temporal relationship to more felsic intrusive phases.

3.2.4 Structural Geology—Mine Study Area

The general deposit location is divided into three main zones: the Pebble West Zone, the Central Zone, and the Pebble East Zone. These zones manifest distinct combinations of geological and hydrothermal characteristics. The primary structural feature of the Pebble West and Central zones is a broad, M-shaped convex upward fold. This fold is defined by the distribution of diorite and granodiorite sills in the gently to moderately dipping sedimentary rocks in the Central Zone. Fold axes plunge gently to the southeast. Folding has not yet been recognized in the Pebble East Zone.

Tertiary faults and shear zones are evident in drill core and from surface mapping. The general deposit location is cut by numerous brittle faults. Seven major fault zones (ZA to ZG) have been identified in the area of the general deposit location from drill-core data. A narrow, steeply sided, depressed segment of crust, bounded by faults, trending northeast subparallel to the regional Lake Clark structural zone extends along the valley northwest of Koktuli Mountain.

3.2.5 Deposit Geology

Based on the available data, the deposit is a copper-gold-molybdenum, calc-alkalic porphyry system and covers an area of approximately16 square kilometers. Each of the three main zones has distinct geological and hydrothermal characteristics.

The Pebble West Zone is dominated by a multiphase, intrusive complex that contains abundant intrusion breccias. These rocks were intruded into gently deformed andesitic sedimentary rocks and were subsequently intruded by granodiorite stocks and sills whose later-stage fluids produced potassium-silicate alteration and high-grade copper-gold-molybdenum mineralization.

The Central Zone and the Pebble East Zone are dominated by hornfelsed volcanosedimentary strata that were intruded by two main diorite sills. The Central Zone contains mineralization of moderate grade. The Pebble East Zone contains intense potassium-silicate alteration and high-grade copper-gold-molybdenum mineralization.

3.2.6 Surficial Geology—Transportation-corridor Study Area

A brief inspection of aerial photographs of the transportation-corridor study area was conducted. The Quaternary surficial deposits in the study area largely consist of glacial drift and glaciofluvial deposits, with fluvial deposits present near stream channels and a few localized swamp deposits. There are also areas of loose accumulations of rock and soil debris deposits, and scattered bedrock outcrops are common.

3.3 References

Detterman, R.L., and B.L. Reed. 1973. Surficial Geology of the Iliamna Quadrangle, Alaska. U.S. Department of the Interior, Geological Survey Bulletin # 1368-A.

Boulders and rubble caused by frost action, mine study area.

Bedrock outcrop in mine study area, looking northwest to Cone Mountain.

Typical bedrock cores from exploration/geotechnical drilling.

4. PHYSIOGRAPHY

4.1 Introduction

This chapter discusses the physiographic characteristics of the Bristol Bay drainages study areas, including topography, landforms, and stream drainage patterns. Permafrost conditions also are discussed.

The Bristol Bay drainages study areas (mine study area and transportation-corridor study area) run generally eastward from the North Fork Koktuli River area to the Bristol Bay/Cook Inlet drainages boundary (Figure 1-4 in Chapter 1). The physiography discussion of the mine study area is based on a review of published information, information gathered from field reconnaissance studies during 2004 to 2008, and topographical information obtained from Eagle Mapping Ltd. The physiography discussion of the transportation-corridor study area is based on information obtained from Resource Data Inc.

4.2 Results and Discussion

The physiography of the Bristol Bay drainages has been strongly influenced by bedrock geology and by the erosion, transport, and deposition of surficial materials by Pleistocene glaciers and glacial meltwater. The Bristol Bay study areas are divided into three physiographic divisions within the U.S. Geological Survey Iliamna Quadrangle: Nushagak-Big River Hills, Nushagak-Bristol Bay Lowlands, and the southern part of the Alaska Range division (Detterman and Reed, 1973). The portions of these physiographic divisions contained within the Bristol Bay study areas are described below:

- The Nushagak-Big River Hills division encompasses the mine study area and the transportation-corridor study area west of Roadhouse Mountain.
- The Alaska Range division encompasses the transportation-corridor study area east of Roadhouse Mountain and along the north shore of Iliamna Lake to the boundary between the Bristol Bay drainages study areas and the Cook Inlet drainages study area. This division includes a strip of relatively flat terrain along the shore of Iliamna Lake, as well as the rugged mountains to the north and east of the lake.
- The Nushagak-Bristol Bay Lowlands division encompasses the lowland areas at the western end of Iliamna Lake and south of the Nushagak-Big River Hills division, including the village of Iliamna. Technically, this division does not encompass any of the mine study area or the transportation-corridor study area; however, the eastward extension of the same terrain type along the north shore of Iliamna Lake forms part of the transportation-corridor study area in the Alaska Range division.

4.2.1 Mine Study Area

As noted above, the mine study area is located in the Nushagak-Big River Hills division, which consists of low, rolling hills separated by wide, shallow valleys with sinuous drainage channels. The elevation in the vicinity of the mine study area varies from approximately 580 feet at the confluence of the south and north forks of the Koktuli River to 3,074 feet on Groundhog Mountain. The deposit area is in the pass between the South Fork Koktuli River and Upper Talarik Creek and lies at approximately 1,000 feet in elevation.

Glacial and fluvial sediments of varying thickness cover most of the mine study area at elevations below approximately 1,400 feet, whereas the ridges and hills above 1,400 feet generally exhibit exposed bedrock or have thin veneers of surficial material (Hamilton and Klieforth, 2010). The hills tend to be moderately sloped with rounded tops. The valley bottoms are generally flat, with some topographic anomalies that are explained by the glacial history of the surficial materials, as follows:

- The main stream channels are sinuous and their floodplains contain wetlands and oxbow lakes.
- Glaciofluvial terraces of outwash sediments occupy parts of the main valleys and take the form of flat to gently sloping benches or terraces situated above the adjacent floodplains.
- Glaciolacustrine deposits occupy the upper parts of the three main valleys and are represented by flat, poorly drained terrain. Frying Pan Lake is a shallow residual waterbody with a maximum depth of approximately 3 feet, located in the glaciolacustrine basin in the upper part of the South Fork Koktuli River valley.
- Extensive areas of glacial drift deposits occur along lower hillslopes and near the headwaters of the main stream valleys and are characterized by undulating terrain and numerous kettle lakes.

Photos 4-1 and 4-2 (following Section 4.3) illustrate some of the key physiographic features described above.

South of the mine study area, the Nushagak-Bristol Bay Lowlands comprises relatively flat-lying topography with abundant wetlands and ponds along the north shore of Iliamna Lake. The village of Iliamna lies in this division.

4.2.2 Transportation-corridor Study Area

The transportation-corridor study area is located within the Nushagak-Big River Hills, Nushagak-Bristol Bay Lowlands, and the southern part of the Alaska Range division, as described above.

The transportation-corridor study area traverses the following sequence of terrain types, some of which are illustrated in Photos 4-3 and 4-4:

- Flat to moderately undulating terrain in the Nushagak-Big River Hills division from the deposit area to Roadhouse Mountain.
- Flat to gently sloping terrain along the north shore of Iliamna Lake from Roadhouse Mountain to Canyon Creek.
- Mountain slopes and colluvial terrain along the north shore of Iliamna Lake from Canyon Creek to Pile River.
- Narrow valley-bottom and mountain-slope terrain in Chinkelyes Creek valley.

Major stream crossings in the transportation-corridor study area are the Newhalen River, which flows in a relatively stable, entrenched channel; Chekok Creek, which is relatively small and stable; Canyon Creek, Knutson Creek, the Pile River, and the Iliamna River, which have braided or meandering channels within actively eroding floodplains; and Chinkelyes Creek, which has a relatively stable lake-outlet channel.

4.2.3 Permafrost Conditions

The mine and transportation-corridor study areas lie in a zone of sporadic permafrost (Ferrians, 1965). The distribution of permafrost in the sporadic zone is patchy and complex, and permafrost-free terrain is common in this zone. Any permafrost in the study areas is most likely relict permafrost from previous periods of glaciation, because current climatic conditions do not support the aggradation of permafrost. Permafrost has not been encountered in previous site investigation and exploration programs in the mine study area.

4.3 References

Detterman, R.L., and B.L. Reed. 1973. Surficial Geology of the Iliamna Quadrangle, Alaska. U.S. Department of the Interior. Geological Survey Bulletin # 1368-A.

Ferrians, O.J. 1965. Permafrost Map of Alaska. U.S. Geological Survey.

Hamilton, T.D., and R.F. Klieforth. 2010. Surficial geologic map of parts of the Iliamna D-6 and D-7 quadrangles, Pebble Project area, southwestern Alaska: Alaska Division of Geological & Geophysical Surveys Report of Investigation 2009-4, scale 1:50,000.

PHOTO 4-1. Mine study area, view to the south toward Frying Pan Lake, July 2004.

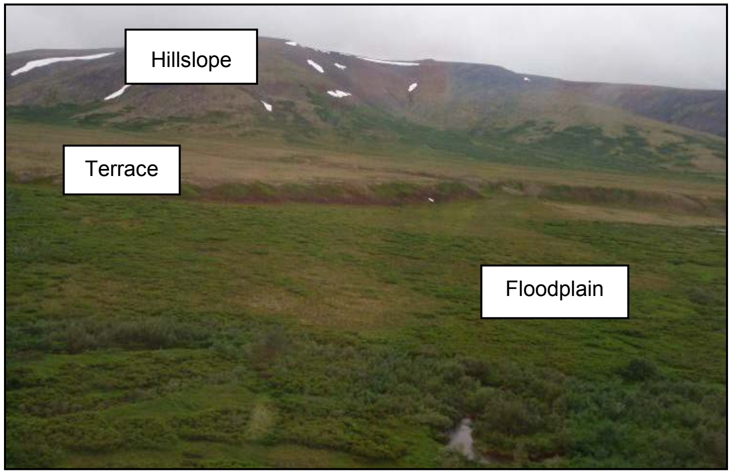

PHOTO 4-2. Mine study area, typical view across the South Fork Koktuli River valley showing floodplain, glaciofluvial terrace, and hillslope terrain, July 2008.

PHOTO 4-3. Transportation-corridor study area, typical mountain slope along the north shore of Iliamna Lake between Knutson Creek and Pile River, July 2008.

PHOTO 4-4, Transportation-corridor study area, typical braided channel pattern in the Pile River near the mouth, July 2008.

5. SOILS

5.1 Introduction

The overall Pebble Project study area within the Bristol Bay region comprises both a mine study area and a transportation corridor study area (EBD Figure 5-1). The soils study for this area had one main component: to gain an understanding of the general types of soils that occur within the area.

The objectives of the Bristol Bay Region soils study included:

- Review historical soils data from the region to determine the typical and common soil types occurring in the overall study area.
- Summarize the soil map unit descriptions provided by the *Exploratory Soil Survey of Alaska* (ESS) (Rieger et al., 1979) for the overall study area.

5.2 Results and Discussion

The study area was glaciated during the Pleistocene and is in relatively close proximity to several active volcanoes in the Alaska Range. The soil parent materials are influenced by volcanic ash and the nearest source is Augustine Volcano, about 70 miles southeast of the study area.

A comprehensive literature review provided information on existing soil survey coverage for the study area. It also provided information relative to properties of volcanic-ash derived soils in Alaska.

The study area is covered by the broad-scale *Exploratory Soil Survey of Alaska* (ESS) (Rieger et al., 1979). Soil investigations are also available for the village of Nondalton (Hinton and Neubauer, 1965) and for Chisik Island (Clark and Ping, 1995). Both of these areas are near or within the Pebble Project study area.

The three existing publications describe the prevalent soil types in or near the study area and indicate that many of the soils in the study area are influenced to some degree by volcanic ash within the parent materials. The ESS classifies the dominant soils of the area as typic cryandepts and describes their ash-influenced, or andic, properties. The Nondalton and Chisik Island soil investigations also describe similar ash-influenced soils. Each of these publications provides soil classification terminology based on the version of *Soil Taxonomy* (USDA, 1999) current at the time of publication. The soil descriptions and data presented were used to determine how the earlier soil classifications would translate to the 2006 classification system (Soil Survey Staff, 2006).

5.3 References

Clark, M. H., and C. L. Ping. 1995. Soil Survey Investigation. Chisik Island Tuxedni Wilderness Area Alaska.

Hinton, R.B., and L.A. Neubauer. Undated [1965]. Soils of the Nondalton Area, Alaska. Unpublished report by Soil Conservation Service, U.S. Department of Agriculture, Palmer, Alaska.

Rieger, S., D.B. Schoephorster, and C. E. Furbush. 1979. Exploratory Soil Survey of Alaska. USDA-SCS. Washington, D.C.: U.S. Government Printing Office.

Soil Survey Staff. 2006. Keys to Soil Taxonomy,10th Edition. USDA-NRCS. Washington, D.C.: U.S. Government Printing Office.

USDA-Natural Resources Conservation Service. 1999. Soil Taxonomy. A Basic System of Soil Classification for Making and Interpreting Soil Surveys. 2nd ed. AH 436, Washington, D.C.

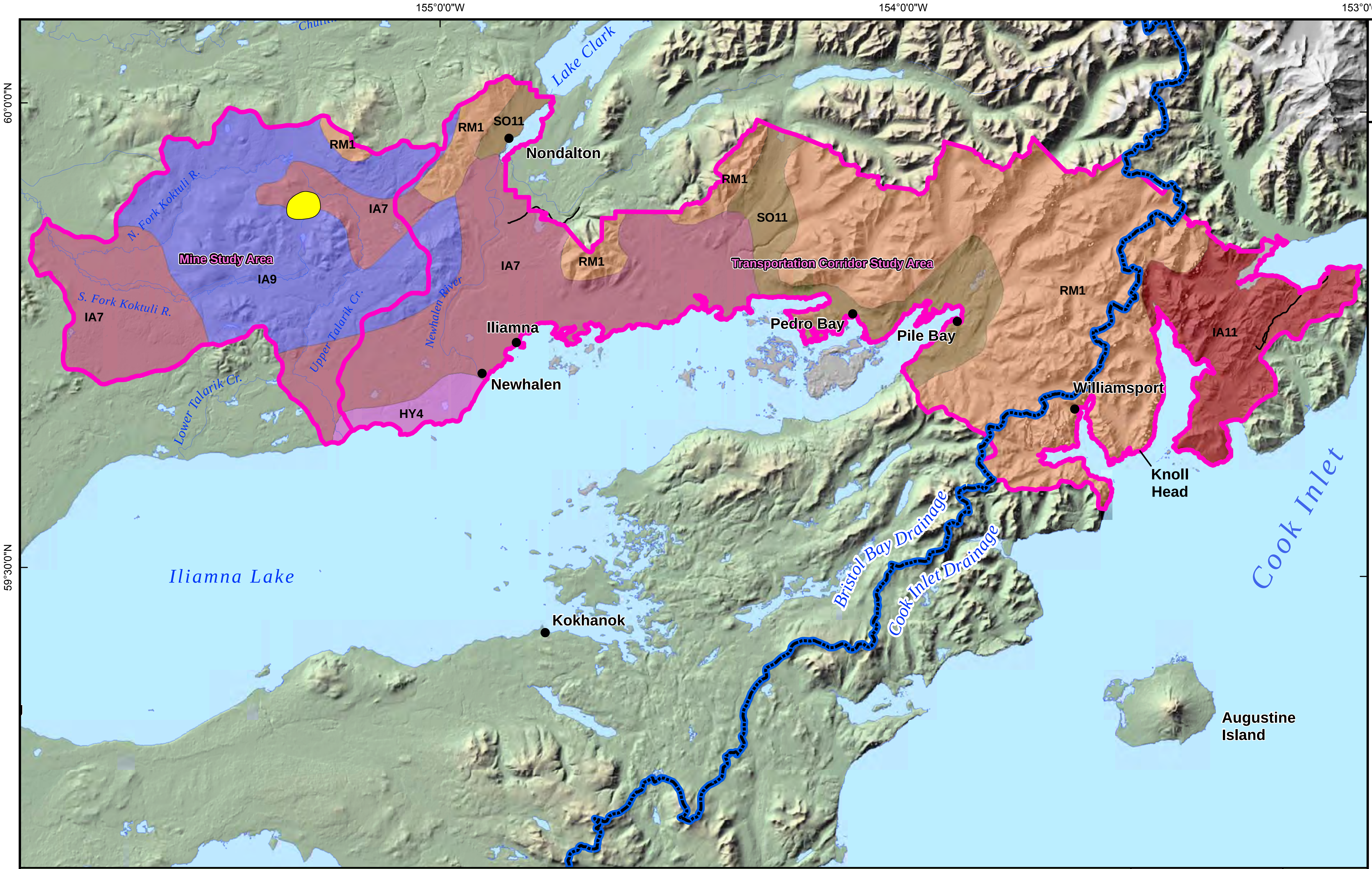

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Figure 5-1
Bristol Bay and Cook Inlet Drainages Exploratory Soil Survey

Legend

🟨 General Deposit Location

▬ Bristol Bay/Cook Inlet Drainage Divide

▭ Study Areas

Soil Types

🟪 HY4 - Pergelic Cryofibrists, nearly level

🟥 IA11 - Typic Cryandepts, very gravelly, hilly to steep-rough mountainous land association.

🟥 IA7 - Cryandepts, very gravelly, nearly level to rolling-Pergelic Cryofibrists, nearly level.

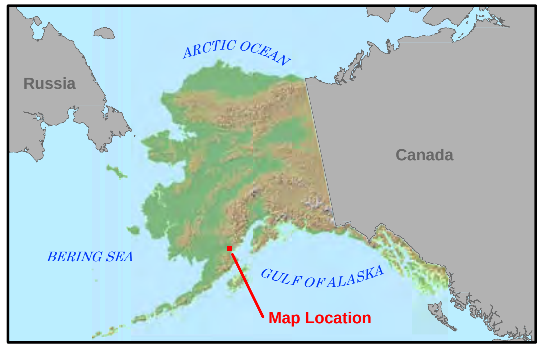
🟦 IA9 - Typic Cryandepts, very gravelly, hilly to steep association

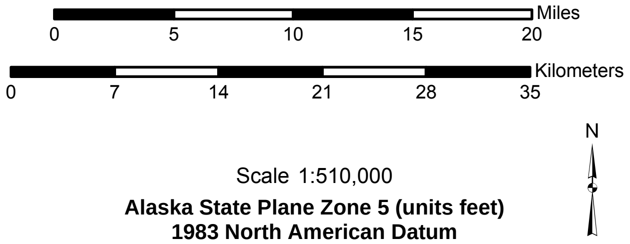
🟧 RM1 - Rough mountainous land

🟫 SO11 - Humic Cryorthods, very gravelly, hilly to steep-Pergelic Cryofibrists, nearly level association.

NOTES:
Based on *Exploratory Soil Survey of Alaska*, Sheet Number 19 (USDA SCS, 1979). The map is a broad-based inventory of soils and nonsoil areas that occur in a repeatable pattern on the landscape and that can be cartographically shown at the 1:1,000,000 scale.

These data compiled in 1971 by the U.S Department of Agriculture, Soil Conservation Service, and coorperating agencies.





Scale 1:510,000

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

				Acres by Drainage		Total Acres
STUDY AREA	CODE	DESCRIPTION	LAND FORM	Bristol Bay	Cook Inlet	
Mine Study Area	HY4	Pergelic Cryofibrists, nearly level association.	Broad, nearly level, wet lowland neat large lakes and coastal areas.	1,251		1,251
	IA7	Typic Cryandepts, very gravelly, nearly level to rolling-Pergelic Cryofibrists, nearly level association.	Rolling plains bordering Iliamna Lake. Inactive and active stream channels, uplifted beaches, hilly terminal moraines, and glacial outwash plains.	105,227		105,227
	IA9	Typic Cryandepts, very gravelly, hilly to steep association	Low rounded mountains, moraine-covered mountain foot slopes and foothills.	154,723		154,723
	RM1	Rough mountainous land	Steep rocky slopes, ice fields, and glaciers.	3,463		3,463
Transportation Corridor Study Area	HY4	Pergelic Cryofibrists, nearly level association.	Broad, nearly level, wet lowland neat large lakes and coastal areas.	14,384		14,384
	IA11	Typic Cryandepts, very gravelly, hilly to steep-Rough mountainous land association.	Steep mountainous areas, dissected by streams and braided rivers, glacier fed.		73,944	73,944
	IA7	Typic Cryandepts, very gravelly, nearly level to rolling-Pergelic Cryofibrists, nearly level association.	Rolling plains bordering Iliamna Lake. Inactive and active stream channels, uplifted beaches, hilly terminal moraines, and glacial outwash plains.	155,145		155,145
	IA9	Typic Cryandepts, very gravelly, hilly to steep association	Low rounded mountains, moraine-covered mountain foot slopes and foothills.	17,981		17,981
	RM1	Rough mountainous land	Steep rocky slopes, ice fields, and glaciers.	248,146	71,380	319,526
	SO11	Humic Cryorthods, very gravelly, hilly to steep-Pergelic Cryofibrists, nearly level association.	Mountain foot slopes and moraine hills, small streams, sloping valleys, and nearly level muskegs.	72,458		72,458
Grand Total				772,777	145,324	**918,101**

155°0'0"W
154°0'0"W

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Date: December 27, 2010
Version: 3
Author: RDI-DWR, LS

6. GEOTECHNICAL STUDIES, SEISMICITY AND VOLCANISM

6.1 Introduction

This chapter describes the baseline geotechnical characteristics for the mine study area and the seismicity characteristics of the Bristol Bay drainages study area. There are no active volcanoes located within the Bristol Bay drainages study area, but the study area could be affected by volcanoes located near Cook Inlet. Regional volcanism associated with the Cook Inlet volcanoes is presented in Chapter 30. Geotechnical characteristics comprise aspects of surficial geology, overburden and bedrock geology, hydrogeology, physiography, topography, and soils as they pertain to engineering design. Geotechnical information of interest includes rock mass characterization and classification of bedrock; the depth, composition, and characteristics of overburden (surficial materials and organic soils); and the presence and movement of groundwater within these materials. The description of geotechnical conditions within the study area is based on geotechnical site investigations from 2004 to 2008. The description of seismic characteristics is based on a desktop overview of available regional information.

6.2 Methods

The mine study area was geographically divided into reference areas, shown on Figure 6-1. The 2004 to 2008 geotechnical site investigation programs involved test pitting, overburden and bedrock drilling, piezometer/well installations, in situ testing, and geophysical surveys throughout the study area. The results of the site investigations were related to surficial geology and physiography to develop linkages between landscape features and subsurface characteristics.

A review of current publications and historical data on the tectonics and seismicity of the region and the Bristol Bay drainages study area was completed. The review included technical publications from the United States Geological Survey (USGS) and, Alaska Department of Natural Resources among others.

6.3 Results and Discussion

6.3.1 Geotechnical Investigations

Geotechnical site investigations were completed between 2004 and 2008.

6.3.1.1 Pebble West Area

The Pebble West Area comprises the western part of the Pebble Deposit Area, located on the drainage divide between the South Fork Koktuli River and Upper Talarik Creek. The area is terraced with many small ponds and kettled moraine features resulting from the Brooks Lake glaciation (Detterman and Reed, 1973). The overburden generally consists of glaciofluvial, glaciolacustrine, and glacial drift deposits. Tertiary basalt, basalt breccia, volcaniclastic matrix-supported breccia/conglomerate, and mudstone/siltstone/wackes were encountered. Depth to the groundwater table is relatively close to the surface but is variable because of topographic variation and aquifers at different elevations. Hydraulic conductivity test results were in the low to very low range (10^{-7} to 10^{-3} cm/s) in the bedrock and overburden.

6.3.1.2 Pebble East Area

The Pebble East Area comprises the eastern part of the Pebble Deposit Area, located on the drainage divide between the South Fork Koktuli River and Upper Talarik Creek. The subsurface overburden materials consist of glaciofluvial, glaciolacustrine, and glacial drift deposits composed of sand and silt with varying amounts of gravel, silt, and clay. Seismic refraction data have revealed a buried paleochannel that runs in a northeast to southwest direction along the western side of Koktuli Mountain. The bedrock encountered in the vertical geotechnical drillholes in the Pebble East Area consisted of weathered Tertiary rhyolite, Tertiary basalt and basalt breccia, bedded andesites, and Tertiary volcaniclastic breccia/conglomerate. The piezometric surface ranged from above or very near the ground surface to depths of approximately 65 feet below ground because of topographic variation and aquifers encountered at differing elevations. Hydraulic conductivity test results were in the low to very low range (10^{-7} to 10^{-3} cm/s) in the overburden and at the overburden/bedrock contact.

6.3.1.3 Upper Talarik Creek Area

The Upper Talarik Creek Area is located north of the Pebble Deposit Area. The Upper Talarik Creek Area is a wide, relatively flat valley containing many streams and small, seasonal lakes that feed into the upper reaches of Upper Talarik Creek. A surficial layer of topsoil was typically encountered. The overburden is predominantly composed of sand with varying amounts of silt and gravel. Overburden in the west bordering Area E was largely composed of sand and gravel deposits. The bedrock encountered consists of Tertiary sandstone/wacke/conglomerate, Tertiary volcaniclastic breccia/conglomerate, Tertiary basalt, Cretaceous siltstone (bedded andesite), granodiorite, and diorite. Piezometric water levels ranged from above surface to approximately 40 feet below the surface as a result of aquifers at different elevations and topographic variation. Hydraulic conductivity test results of the overburden/bedrock contact were in the low range (10^{-5} to 10^{-3} cm/s).

6.3.1.4 Area E

Area E consists of a broad valley located immediately west of the Pebble Deposit Area. The overburden consists of a veneer of glacial drift beneath a thin layer of topsoil, comprising predominantly sands and gravels with varying amounts of silt. The bedrock varied from Cretaceous monzonite/granodiorite and siltstone to Tertiary sediments and intrusives. The piezometric surface ranged from above ground surface to approximately 85 feet below surface as a result of encountering aquifers at different elevations and variation in topography. Hydraulic conductivity test results were in the low to very low range (10^{-7} to 10^{-3} cm/s).

6.3.1.5 North Fork Koktuli River Area

The North Fork Koktuli River Area is a wide, relatively flat valley located approximately four miles northwest of the Pebble Deposit Area. The overburden was deeper in the north with a thick layer of organics. Thinner overburden was encountered farther to the south and closer to the edge of the valley. The overburden materials encountered were generally compact, with gravel and cobbles present. The bedrock types encountered were Tertiary andesite, Tertiary basalt, and Tertiary mudstone/siltstone/wacke. The groundwater levels ranged from approximately 14 to 31 feet below ground surface as a result of topographic variation and aquifers at differing elevations. Hydraulic conductivity test results were in the low range for the overburden materials. Hydraulic conductivity test results were in the very low range (10^{-7} to 10^{-5} cm/s) in the more competent bedrock.

6.3.1.6 Area G

Area G is a valley surrounding a northward-draining tributary of the North Fork Koktuli River, located approximately five miles west of the Pebble Deposit Area. Topsoil varies from a thin veneer at higher elevations to a thicker layer at lower elevations and is often intermixed with rubble formed by frost action at higher elevations. The overburden is largely composed of sand and gravel with varying proportions of silt and is largely frost action rubble, glacial drift, and loose accumulations of rock and soil debris. Bedrock in the northern part is primarily of volcanic origin and mostly composed of monzonite/granodiorite of the Kaskanak Batholith with some basalt, gabbro, pyroxenite, and Tertiary sediments. Bedrock in the southern and eastern part includes Cretaceous granodiorite/monzonite, Tertiary rhyolite, basalt, volcaniclastic fragmented rocks, and brecciated Tertiary sediments and volcanics. The piezometric surface ranged from above the ground surface to a depth of 85 feet below ground surface; a result of differing elevations of aquifers and topographic variation . Hydraulic conductivity test results were in the low to medium range in the overburden/ bedrock contact. The hydraulic conductivity in the bedrock in the north is medium to low (10^{-5} to 10^{-1} cm/s). The bedrock of the south exhibited generally low hydraulic conductivity (10^{-5} to 10^{-3} cm/s).

6.3.1.7 Area L

Area L is a southward-draining tributary valley to the South Fork Koktuli River, located approximately six miles southwest of the Pebble Deposit Area. The topsoil ranges from 0 to 5 feet thick and consists of dark brown silt, sand, gravel, and cobbles. The overburden varies from 0 to 105 feet with the thicker overburden in the valley bottom areas. The overburden deposits consist of sand and/or gravel with varying amounts of finer materials. Glacial drift, loose accumulations of rock and soil debris, frost action rubble, and bedrock are found at surface in this area. The bedrock encountered is of igneous and volcanosedimentary origin. Bedrock types encountered include granodiorite, monzonite, and monzodiorite of the Kaskanak Batholith; and Tertiary siltstone, rhyolite, andesite, dacite, volcaniclastic breccia, basalt, and brecciated basalt. The piezometric surface varies from above ground surface to approximately 205 feet below ground surface because of topographic variation in this area and differing elevations of aquifers. Hydraulic conductivity test results were in the low to medium range (10^{-5} to 10^{-1} cm/s) in the bedrock.

6.3.1.8 South Fork Koktuli River Area

The South Fork Koktuli Area is located approximately six miles south to southwest of the Pebble Deposit Area. A surficial layer of topsoil covers most of the area, and overburden thickness is highly variable. The overburden is predominantly sand and gravel. The materials consist of glacial drift, stream deposits, and loose deposits of rock and soil debris. The depth to bedrock varies from approximately 10 to greater than 390 feet deep. The bedrock composition is variable: granodiorite, monzonite, basalt, sandstone, siltstone/mudstone, dacite, and andesite. The groundwater levels ranged from 5 to 136 feet below ground surface because of differing aquifer elevations and variation of the topography. This area is underlain by predominantly sand and gravel with high hydraulic conductivity. A limited number of hydraulic conductivity tests were conducted in the bedrock resulting in low range values. Hydraulic conductivity tests were conducted in overburden material; however, the groundwater recovery was too rapid to obtain accurate results, indicative of medium to high hydraulic conductivity (10^{-3} to 10 cm/s).

6.3.1.9 Area J

Area J is a long, narrow, steeply incised valley that drains southward into the South Fork Koktuli River, southwest of the Pebble Deposit Area. Topsoil covers much of the surface of this valley with frost action rubble at higher elevations. The overburden is predominantly composed of sand, grading to sandy gravel, with varying proportions of silt. The bedrock most commonly encountered in this area is Cretaceous granodiorite/diorite of the Kaskanak Batholith, Tertiary basalt and minor Cretaceous siltstone. The piezometric surface was encountered at depths ranging from slightly above ground surface to approximately 40 feet below surface. The range is a result of topographic variation and aquifers at different elevations. Hydraulic conductivity values of the bedrock were in the low range (10^{-5} to 10^{-3} cm/s).

6.3.1.10 Area A

Area A is located directly to the south of the Pebble Deposit Area. Area A is characterized by four different geomorphic domains.

Valley Bottom—The Valley Bottom is characterized by relatively flat topography with extensive swamp/wetlands present. The thickness of the overburden across the Valley Bottom varied between approximately 100 and 185 feet. The peat thickness varied between 1 and 15 feet, while the thickness of the more recent glaciofluvial deposits varied between 15 and 30 feet. The materials encountered in the drill holes consist primarily of sand and gravel with varying amounts of silt, clay, and cobbles. The bedrock is primarily igneous in origin, varying from granodiorite/diorite to Tertiary rhyolite and Tertiary dacite/latite. The piezometric surface was generally encountered at or within 10 feet of the ground surface. Topographic variation and aquifers at differing elevations account for the range.

Southern Upland Area—The overburden is predominantly composed of glacial drift and glaciofluvial deposits and there are many kettle depressions. The overburden depth ranged between approximately 7 and 390 feet below ground surface, the depth increasing southward. The bedrock encountered includes both sedimentary and volcanic units. The sedimentary units varied from mudstone/siltstone to breccia. Andesite, monzodiorite, latite, granodiorite, diorite, and basalt dikes are the volcanic units encountered. The groundwater levels ranged from approximately 30 to 140 feet below surface. The groundwater level range is due to topographic variation and aquifers encountered at different elevations. Hydraulic conductivity test results were low (10^{-5} to 10^{-3} cm/s) in the bedrock and overburden.

Lower/Mid Side Slopes—Overburden materials encountered typically consisted of sand and gravel with varying amounts of silt. The bedrock was primarily diorite and granodiorite; however, dacite, andesite, Tertiary basalt, volcaniclastic breccia, siltstone/mudstone, and wackes were also encountered. The piezometric surface was variable, ranging from above ground surface to depths of approximately 38 feet below ground. The range of is the result of aquifers being encountered at different elevations and the variation of the topography in this area. Hydraulic conductivity tests were conducted in the bedrock resulting in values in the low range (10^{-5} to 10^{-3} cm/s). Hydraulic conductivity test results ranged from low to medium (10^{-5} to 10^{-1} cm/s) in at the overburden/bedrock contact and in the bedrock.

Upper Side Slopes—A veneer of loose accumulations of soil or rock debris or glacial drift overlies frost shattered bedrock. The bedrock along the Upper Side Slopes consists of granodiorite/diorite /monzonite, and bedded andesites. Groundwater was typically encountered approximately 0 to 90 feet below the ground surface. The range of groundwater depth is due to topographic variation and aquifers being encountered at different elevations. Hydraulic conductivity test results ranged from extremely low to medium in the bedrock.

6.3.2 Regional Seismicity and Faulting

A fault is defined as a planar fracture or discontinuity in a volume of rock that can range from less than an inch in length to many miles long as is often found along the boundaries of tectonic plates. Active faults are moving over time due to building stresses. Inactive faults had movement along them at one time but have no evidence of movement or associated seismic activity within the Holocene epoch. Alaska is the most seismically active state in the United States, and in 1964 it experienced the second largest earthquake recorded worldwide. The seismicity of southern Alaska is associated with interplate subduction earthquakes, intraplate earthquakes in the subducted oceanic plate, and shallow crustal earthquakes within the North American continental plate (Figure 6-2).

6.3.2.1 Alaska-Aleutian Megathrust Subduction Zone

Historically, the level of seismic activity is highest along the south coast of Alaska, where earthquakes are generated by the Pacific plate subducting under the North American plate. Evidence suggests these tectonic plates are locking as they pass each other, building up pressure that can sometimes be released as large Magnitude 8 to 9+ earthquakes. This seismic source region is known as the Alaska-Aleutian Megathrust. There have been a large number of deeper earthquakes along the south coast of Alaska and extending northwards, in addition to the shallow earthquakes associated with the subducting plate boundary and crustal faulting. Intraplate subduction earthquakes are typically generated by a normal faulting mechanism in the subducted oceanic lithosphere. These deep earthquakes have potential to cause great damage, typically affecting a large area and producing a distinctive rolling motion.

6.3.2.2 Active Fault Systems

There are a number of active and potentially active fault systems in southern Alaska related to the tectonic pressures and crustal flexure caused by the subducting Pacific plate. Active and potentially active fault systems in the Bristol Bay and Cook Inlet drainages are discussed below. Cook Inlet faults are included in this chapter because their seismicity may affect the Bristol Bay drainages study area.

The western end of the northeast-southwest trending Lake Clark-Castle Mountain fault system is located northeast of the study area. Published information indicates the Lake Clark fault terminates at the western end of Lake Clark, over 15 miles from the eastern edge of the mine study area. This distance is based on a recent study by Haeussler and Saltus (2004) who used aeromagnetic data to refine the position of the western end of the fault. Haeussler suggested that the fault may extend farther to the southwest, based on a preliminary review of regional aeromagnetic data developed by the USGS. Haeussler also indicated that there may be a southerly splay of the fault along the Newhalen River valley (east of the mine study area) toward Iliamna Lake. A detailed study of the surficial geology and geomorphology at the study area did not demonstrate any surficial evidence of fault activity in the vicinity of the study area, which is located on outcrops that likely provide resistance to fracturing of the earth’s crust. The study indicated that large Pleistocene glaciers followed zones of crustal fracture (weakness) associated with the Lake Clark fault (Hamilton et al, 2010). The mapped direction of primary glacial advance suggests that any potential extension of the Lake Clark fault may pass north and/or east of the mine study area, and would not cross the mine study area. The Castle Mountain fault system is capable of generating large earthquakes. Research studies by the USGS indicate major earthquakes have occurred along this fault about every 700 years over the last 2,700 years, and that a major (M6 to M7) earthquake may occur on the fault in the next 50 to 100 years. The potential for earthquakes of similar magnitude may also exist along the Lake Clark fault. However, unlike the Castle Mountain fault, Haeussler and Waythomas (2011) have found no known evidence of movement along the currently mapped Lake Clark fault since the last glaciation (the Holocene epoch) or evidence of historical seismicity during the last 1.8 million years, which indicates that the Lake Clark fault is not active. The Lake Clark fault is now classified by the USGS as inactive. (Haeussler and Waythomas, 2011).

Studies imply the presence of another fault northwest and parallel to the Lake Clark fault called the Telaquana fault (Haeussler and Saltus, 2004). The Mulchatna fault is farther north, trending parallel to the Lake Clark fault. The maximum potential magnitude for earthquakes generated on these two faults would likely be similar or smaller compared to the longer Lake Clark and Castle Mountain fault system.

The Bruin Bay fault runs northeast-southwest along the west shore of Cook Inlet starting from Mt. Susitna to the south shore of Becharof Lake. The fault is a major reverse fault and is predominantly buried under Quaternary deposits. The Bruin Bay fault has experienced a small number of earthquakes, the largest of which was a M7.3 event in 1943 (Stevens and Craw, 2003).

The Border Ranges fault is a major, but currently inactive, north-northwest trending fault system that crosses the Kenai Peninsula and continues southwest. The last movement on this fault occurred during the Cretaceous or early Tertiary period. This fault system likely has the potential to generate large earthquakes.

The Kodiak Island and Narrow Cape faults are part of a series of northeast-trending strike-slip faults that extend across southeastern Kodiak Island and into the northwestern Gulf of Alaska. These faults are considered to be active and capable of producing earthquakes of up to M7.5 (Wesson et al., 2007).

6.3.3 Regional Volcanism

There are no active volcanoes located within the Bristol Bay drainages study area, but the study area could be affected by Cook Inlet volcanoes. Regional volcanism associated with the Cook Inlet volcanoes is presented in Chapter 30.

6.4 References

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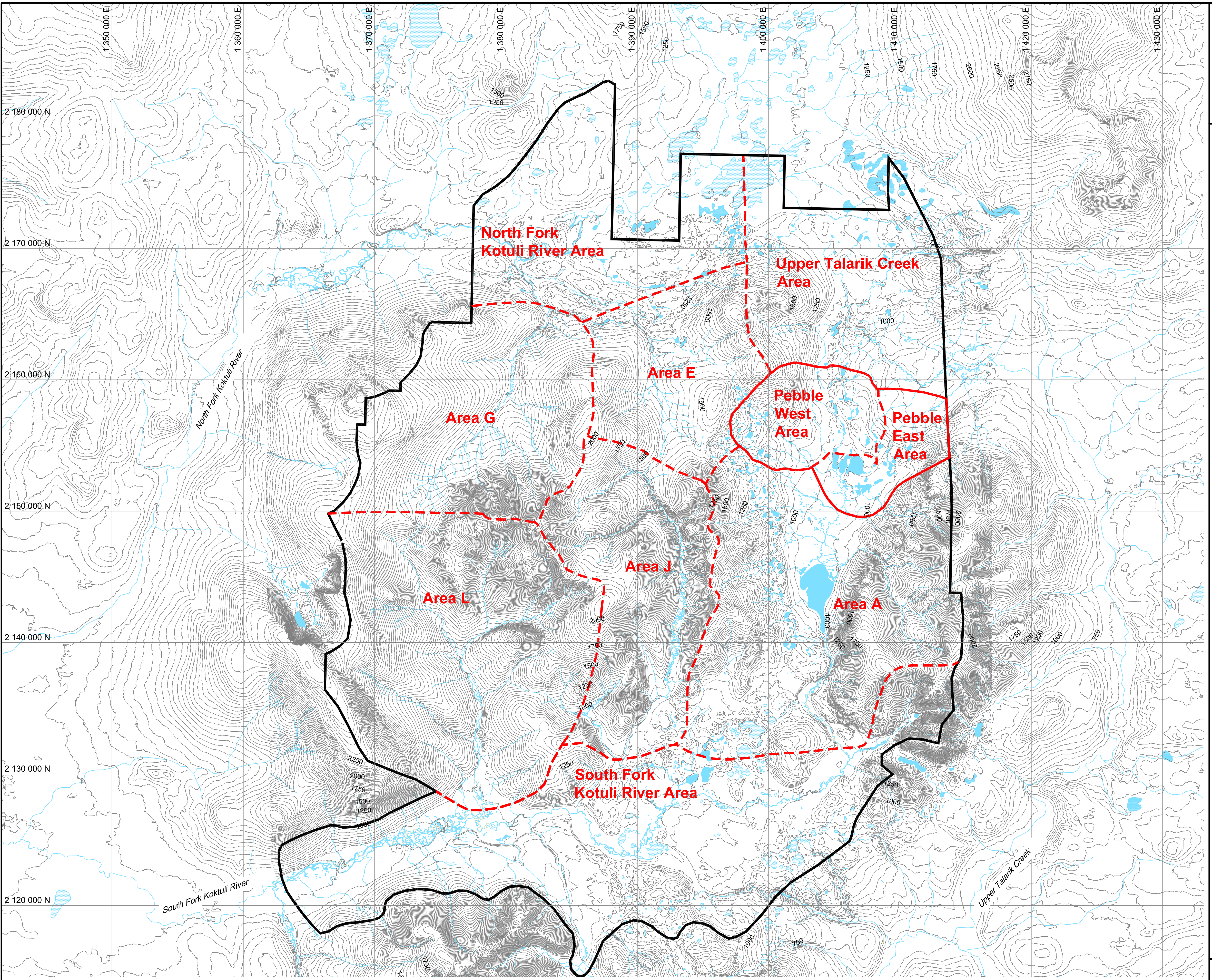


PLAN

THE pebble PARTNERSHIP

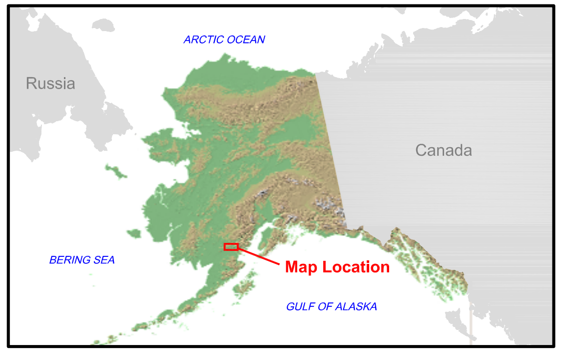
Figure 6-1
Mine Study Area and 10 Reference Areas

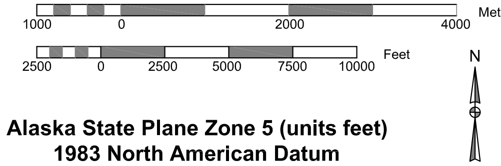
Legend

▬	Mine Study Area Boundary
- - -	Reference Area Boundaries
▬	General Deposit Location

Notes

The reference areas defined in this figure are based on KP, 2009.





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

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Version: 2008-1	Author: Knight Piesold Ltd.

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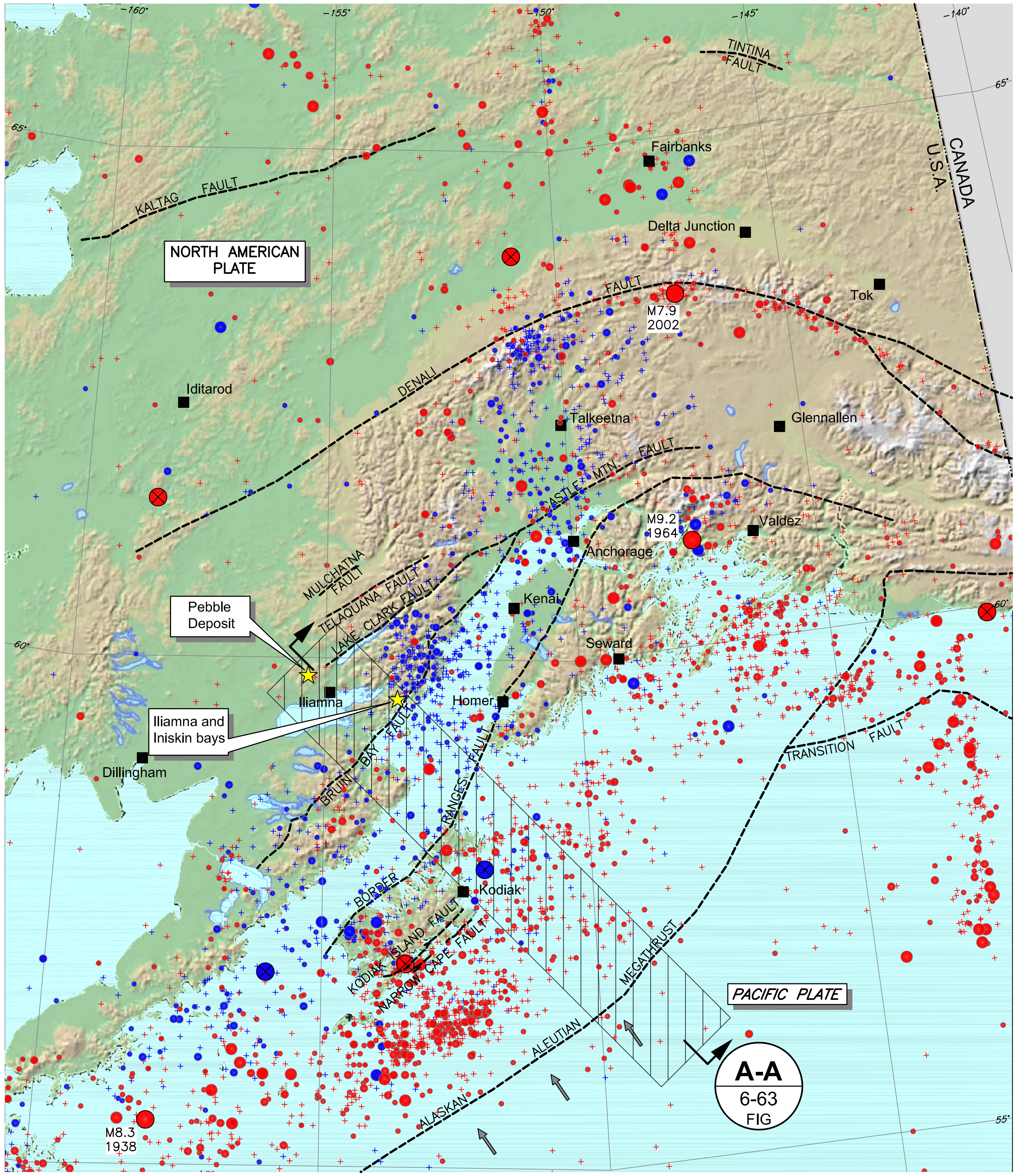


THE pebble PARTNERSHIP

Figure 6-2
Seismicity of Southern Alaska Showing Distribution of Earthquakes by Depth

Legend

- - - Active and potentially active faults

▨ Zone of recorded earthquakes included on SECTION A-A

EARTHQUAKE FOCAL DEPTH

● Depth ≤ 25 miles

● Depth > 25 miles

EARTHQUAKE MAGNITUDE

\+ 4.0 - 4.9

● 5.0 - 5.9

● 6.0 - 6.9

● 7.0 - 7.9

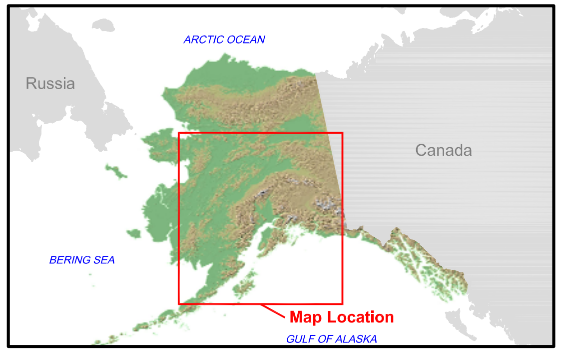
● 8.0 +

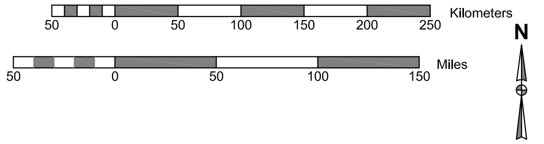
⊗ Large magnitude earthquakes recorded between 1899 & 1904

↗ Location and direction of view for Geological Section

Notes

1. Historical seismicity data supplied by geoForecaster Inc., California.





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7. SURFACE WATER HYDROLOGY

7.1 Regional Study Area

7.1.1 Introduction

The hydrological studies were designed to gather a general understanding of the regional hydrology for the Bristol Bay drainage basin along with more detailed information about the specific drainages surrounding and/or adjacent to the Pebble Deposit.

The Bristol Bay drainage basin encompasses 41,900 square miles in southwestern Alaska (Figure 1-2b in Chapter 1). The largest rivers draining into Bristol Bay are the Nushagak and Kvichak rivers. Their drainage areas – 12,700 square miles and 8,000 square miles, respectively – comprise 49 percent, by area, of the Bristol Bay drainage basin. The following information about the regional hydrology was obtained from the sources listed:

- Data from active and discontinued gaging stations in the Bristol Bay watershed obtained from the U.S. Geological Survey (USGS) website (USGS, 2010).
- Regional peak flow information from *Estimating the Magnitude and Frequency of Peak Streamflows for Ungaged Sites on Streams in Alaska and Conterminous Basins* (Curran et al., 2003).
- Active snow-course information for the Bristol Bay drainage from the Natural Resources Conservation Service website (NRCS, 2010).

7.1.2 Results and Discussion

The USGS historically has collected regional streamflow records at 24 gaging stations in the Bristol Bay drainage. As of 2008, only eight of these gaging stations were active. The paucity of regional hydrologic data prompted the Pebble Project to undertake an intensive, long-term hydrologic gaging program in the mine study area, and to collect supplementary hydrologic information in the transportation corridor study area.

The regional peak flow values for 2-year and 200-year floods were estimated by Curran et al. (2003) for eleven gaging stations in the region. The unit-discharge values for the flood estimates generally decrease with increasing basin area, as expected, but considerable other variability is also evident. The peak flow estimates are weighted values obtained using flood frequency analysis of the individual gage records and a set of regional regression equations. The regression equations had large standard errors, meaning that peak flows were not well correlated to basin characteristics across the diverse and sparsely gaged region. Therefore, the weighting procedure of Curran et al. (2003) placed more emphasis on flood estimates based on local gage records than on the regional regression estimates.

The six Natural Resources Conservation Service regional snow courses are all located along the eastern side of the Bristol Bay drainage on the lee side of the Alaska and Aleutian ranges with respect to southeasterly atmospheric flows. Thus, these snow courses are representative of lowland and foothill areas adjacent to the mountain ranges, but are not representative of the mountainous headwater areas of the larger rivers in the region.

7.2 Mine Study Area

7.2.1 Introduction

The mine study area (Figure 1-4 in Chapter 1) straddles the boundary of the Nushagak River and Kvichak River watersheds. Within the mine study area, the general deposit location straddles the watershed boundary between the South Fork Koktuli River (SK) and Upper Talarik Creek (UT) and lies close to the headwaters of the North Fork Koktuli River (NFK; Figure 7-1). The mine study area encompasses the drainages of these three watercourses, as well as the headwaters of Kaskanak Creek (KC), which is located adjacent to the lower part of the SK basin. The NK, SK, UT, and KC watersheds encompass a combined area of 373 square miles above the lower-most gaging station in each watershed. Field studies to gather more detailed information in these drainages included the following programs:

- Streamflow Gaging Program—the USGS has operated three streamflow gaging stations in the mine study area since August 2004. Pebble Project contractors have installed and operated another 26 continuous flow gaging stations during that period. The gaging stations are distributed along the main stream and tributary channels of the four watersheds in the study area and on the lower reach of the nearby Newhalen River (Figure 7-1). (Basin characteristics and periods of record for each gaging station are provided in Table 7-1.) At each continuous flow station operated by Pebble Project contractors, stage (water level) was recorded every 15 minutes during ice-free months. During ice affected flow conditions, instantaneous flow measurements were obtained at regular intervals, typically monthly, at all Pebble Project stations.
- Winter hydrographs for USGS stations SK100B, UT100B, and NK100A were estimated by the USGS using instantaneous flow measurements in conjunction with meteorological data and a general understanding of hydrograph recession patterns during winter low-flow conditions. Winter hydrographs for the stations operated by Pebble Project contractors were estimated on the basis of instantaneous wintertime flow measurements and by correlations with USGS station hydrographs.
- Low-flow measurements were collected at 55 sites along gaged channels during low-flow events, usually in late winter. Direct instantaneous measurements of peak flows were rarely possible because high-flow events are difficult to predict, short in duration, and often unsafe or impractical to measure.

Data from the streamflow gaging program supported the following studies:

- Hydrologic Analysis—a network of continuous discharge gaging stations was installed and maintained to derive an understanding of general hydrologic conditions and the seasonal and spatial variability of surface runoff throughout the study area.
- Low Flow Analysis—periods when streamflow was comprised predominantly of groundwater upwelling or baseflow (i.e., that portion of streamflow not directly attributable to precipitation or snowmelt runoff), were identified, the baseflows were measured, and observed baseflow patterns were related to groundwater flow patterns.
- Peak Flow Analysis—USGS regional regression equations for peak flows were adjusted based on the short-term peak flow records from the study area gaging stations.
- Snow Distribution Survey—snow survey locations were chosen to represent predominant slope, aspect, and elevation zones and were distributed across the main watershed and smaller subcatchment areas to correspond with gaging station locations. Baseline snow depth and density data were collected to characterize snow distribution and ablation (loss through melt, sublimation, or wind transport) in the major drainage basins of the study area for input to baseline water-balance studies including the development and calibration of a snow distribution model. Ablation rates were estimated by regularly resurveying snow course plots and plots along selected transects following the initial mid-April snow survey. Aerial photographs and satellite imagery were also used to estimate large-scale patterns of snow accumulation and ablation in the mine study area. A snow model was developed based on terrain characteristics and climate data, and model outputs were compared to the field-survey ablation estimates.

7.2.2 Results and Discussion

7.2.2.1 Hydrologic Analysis

The topography of the study area is relatively gentle, consisting of elevations ranging from around 3,000 feet on Groundhog Mountain to 46 feet at Iliamna Lake. Glacial and fluvial sediments of varying thickness cover most of the area at elevations below about 1,400 feet and play an important role in surface water runoff and groundwater storage and exchange. In several areas, subsurface flows follow former preglacial surface drainage pathways that have since been buried by subsequent sediment deposits, resulting in one known location of substantial cross-basin (SK to UT) groundwater flow.

The annual pattern of streamflows in the mine study area is characterized by high flows in spring resulting from snowmelt, low flows in early to mid-summer resulting from dry conditions and depleting snowpacks, another high-flow period in late summer and early autumn resulting from frequent rainstorms, and the lowest flows in winter when freezing occurs and most precipitation falls as snow. Figure 7-2 shows these seasonal patterns in a representative hydrograph from USGS gaging station SK100B, on the South Fork Koktuli River, for the 2004-2005 water year.

The 2004 through 2008 period of record includes a range of hydrologic conditions. The complete study-period hydrograph for Station SK100B is presented on Figure 7-3, which illustrates the range and pattern of streamflows typical of most of the gaging stations. The average volume of runoff in the spring and autumn seasons has been approximately equal throughout the period of record. The duration of spring snowmelt is shorter than the summer/fall rainstorm season, so average monthly flows are highest in May, followed by September and October. Annual maximum daily and instantaneous flows can occur in either season.

The mean annual discharge and unit runoff for each gaging station in the mine study area are shown in Table 7-1. At the USGS gaging stations located on the lower reaches of the SK, NK, and UT, the mean annual unit runoff is measured to be approximately 2.6 to 2.8 cubic feet per second (cfs) per square mile (mi^2). This equates to 35 to 38 inches of runoff depth. Elsewhere, mean annual unit runoff varied from gage to gage because of catchment topography and precipitation, cross-drainage transfers of groundwater, surface and subsurface flow exchanges along stream channels, and seasonal redistribution of snow by wind. In the KC watershed, which has relatively low terrain, the mean annual unit runoff at gage KC100A was 1.4 cfs/mi^2, or 19 inches of runoff depth. The upland tributary streams in the NK and SK watersheds demonstrated relatively high runoff, with mean annual unit runoff values at gages NK119A and SK119A of 3.2 cfs/mi^2 and 3.4 cfs/mi^2, respectively, or 43 to 46 inches of runoff depth.

Groundwater plays a prominent role in the flow patterns of all the creeks and rivers that were studied, but its role was especially notable at SK100C, which goes dry seasonally because of upstream losses of surface flow to groundwater, and at UT119A, which gains flow from the SK to such an extent that its hydrograph is dominated by baseflow. High annual unit runoff values were recorded at UT119A because much of the streamflow at that gaging station is not generated within the topographic watershed boundaries, but rather enters via subsurface pathways that cross the topographic divide. Conversely, low annual unit runoff values were recorded at SK100C because of upstream losses of groundwater to the UT watershed and the bypassing of additional groundwater beneath the gage prior to its upwelling into the channel further downstream. A small cross-basin transfer of groundwater may also occur from the upper NK watershed into the upper UT watershed, upstream of gaging station UT100E, but this is less certain than the SK to UT groundwater transfer and is considerably smaller in magnitude if it does occur. Similarly, given the very low divide between the lower reaches of the SK and the headwaters of KC, the possibility of cross-basin transfer of water in this area was investigated; however, a review of the relevant flow data did not show evidence that this phenomenon was occurring.

7.2.2.2 Low Flow Analysis

Low-flow periods occur between rainstorms in the summer and during the winter freeze period, both times when surface flows in streams are supplied entirely by groundwater discharge. During the 2004 through 2008 period of record, baseflows were higher during the summer than during the winter because of recent snowmelt recharge of aquifers and intermittent rainstorms. Baseflows were lowest in late winter, after several months without surface runoff. Average late-winter baseflow values for each gaging station are provided in Table 7-1. Spatial and temporal patterns in baseflow conditions are useful for estimating groundwater discharge rates and for inferring groundwater gains and losses along channels and between basins. Low-flow conditions are also influenced by fluctuations in surface-storage features such as lakes, ponds, and wetlands; however, changes in surface storage are minimized during the late winter freeze.

In addition to flow measurements, wintertime surveys of open water were used to determine areas of groundwater upwelling. Groundwater is several degrees warmer than surface water in the winter, and correspondingly strong upwelling areas generally do not freeze over and are visible from the air.

Gaining and losing reaches along rivers occur within all the study-area basins, though they are most pronounced in the mainstem of the SK. Each major river valley is partially filled with glacial drift and outwash with varying permeability. Conversely, each channel also regains flow where the bedrock valley narrows downstream, forcing groundwater up from the subsurface. General patterns of upwelling and percolation along all three main channels are shown on Figure 7-4, which presents the distribution of open water and dry channels in late winter of 2006. The channel sections with no flow are those in which surface flow has been lost to the subsurface (through percolation). The channel sections with open water are those in which upwelling flows have prevented the formation of ice.

7.2.2.3 Peak Flow Analysis

Peak discharges recorded at continuous discharge gaging stations occurred either as a result of spring snowmelt or autumn rainstorms. Peak flow unit runoff displayed a similar pattern to mean annual unit runoff. The maximum recorded peak flow unit runoff varied from greater than 50 cfs/mi^2 in the upland tributaries to 15 to 25 cfs/mi^2 at gages on the lower mainstem channels. The lowest peak flow unit runoffs were recorded at gages with large groundwater influences, resulting from either loss of flow or buffering of peak flows due to groundwater storage. Beaver dams also may attenuate peak flows in some smaller basins.

USGS regional regression equations were used to estimate peak flows for return periods from 2 years to 500 years at each of the continuous discharge gaging stations with three or more years of record. According to the USGS equations, the recorded mean annual peak flows for gaging stations on main stream channels have predicted return periods of 5 to 20 years. The maximum recorded peak flows at these gages, based on record lengths of 4 years (or less), have predicted return periods of 10 to 200 years. The recorded mean annual peak flows for gaging stations on steep upland tributaries have predicted return periods greater than 50 years. The maximum recorded peak flows at these gages, based on record lengths of 4 years (or less), have predicted return periods greater than 100 years

These results indicate that the regional regression equations likely underestimate peak flows in the mine study area in general and in upland tributaries within the mine study area in particular. Thus, an alternative approach to peak flow estimation was warranted. A combined local/regional approach was developed to improve the peak flow estimates. The local gage records were used to estimate the 2-year peak flow magnitudes at each gaging station. The magnitudes of larger peak flows were scaled from the 2-year peak flows according to the ratios specified by the USGS regression equations. The estimated 200-year peak flow magnitude at each gaging station is provided in Table 7-1.

7.2.2.4 Snow Surveys and Modeling

Snow accumulation and snowmelt drive streamflow patterns throughout winter and spring. As snow accumulates and surface water freezes, streamflows drop to baseflow levels. Baseflows typically drop gradually until April as groundwater levels decrease in the absence of surface input. The spring snowmelt event typically extends from mid- to late April through June.

Snow does not accumulate evenly across the study area, and it is redistributed frequently during high-wind events. Annual surveys indicated that mid-April snow depth varied from 0 at wind-scoured sites to more than 207.7 inches in deep drifts on the leeward side of ridges. The mean mid-April snow/water equivalent measured at the two study-area snow courses was 10.3 inches at Snow Course 1 and 10.4 inches at Snow Course 2.

Ablation was measured between mid-April and mid-June along the two snow courses. Regional ablation was estimated using satellite imagery taken repeatedly during the snowmelt period each year and a model that related snow-covered area as seen on the satellite images to the snow/water equivalent.

A snow distribution model was used to estimate the mean snow/water equivalent for each gaging-station drainage basin for 2006 to 2008, based on topography, wind speed and direction, and extrapolated field measurements. The modeling results are presented in Table 7-2, and the modeled spatial distribution of the snow/water equivalent in April 2007 is shown on Figure 7-5. In any given year, the basins with the highest modeled snow/water equivalent values were those located in the upper portions of the SK, NK, or UT watersheds. The basins represented by the gaging stations on the lower reaches of the SK, NK, and UT had lower snow/water equivalent values because of the inclusion of lower-elevation terrain in those basins. Station KC100A, which has the lowest-elevation basin, also had the lowest modeled snow/water equivalent each year.

An ablation model was used to estimate melt rates for each drainage basin each year, based on field survey data, satellite imagery, and meteorological data. In general, the timing of snowmelt predicted by the ablation model matches the stream hydrographs reasonably well.

7.3 Transportation-corridor Study Area

7.3.1 Introduction

The transportation-corridor study area extends along the north shore of Iliamna Lake from the Newhalen River in the west to the boundary between Bristol Bay and Cook Inlet drainages in the east (Figure 7-6). All of the streams that cross the transportation-corridor study area flow directly or indirectly into Iliamna Lake.

The objectives of the surface hydrology studies in the transportation-corridor study area were as follows:

- Characterize annual streamflows in the anadromous fish-bearing stream channels that cross the transportation-corridor study area.

- For these channels, estimate maximum and minimum flow statistics and other index flows required for aquatic habitat studies.

Hydrologic conditions are influenced by local climatic and topographic conditions. These conditions vary significantly along the transportation-corridor study area, with mountainous terrain and maritime coastal climate conditions in the east and lower-relief terrain with transitional maritime/continental climate conditions in the west.

Basin and channel characteristics and spot discharge measurements were compiled in 2004 and 2005 at 15 sites on 14 streams in the study area, including two USGS gaging stations – Roadhouse Creek (USGS Station 15300200) and Iliamna River (USGS Station 15300300) – which are collocated with Pebble Project stations (Figure 7-6). Crest gages were installed to record instantaneous stage peaks, but stage discharge rating curves were not developed and peak discharge estimates associated with the stage peaks are not presented. Basin characteristics and the periods of record during which spot discharge measurements were collected at each gaging station are provided in Table 7-3.

The USGS provides regional regression equations for estimating low-duration, high-duration, and peak flow statistics based on basin characteristics (Wiley and Curran, 2003; Curran et al., 2003). These equations were used to estimate flow statistics at each of the 15 stream gaging sites. Low-duration flows are flows that are exceeded much of the time; the USGS equations provide results for flows that are predicted to be exceeded 50 percent to 98 percent of the time. High-duration flows are flows that are exceeded relatively infrequently; the USGS equations provide results for flows that are predicted to be exceeded 1 percent to 15 percent of the time. Peak flows are extreme high flows that are predicted to be exceeded only once, on average, within specified return periods expressed in years.

7.3.2 Results and Discussion

The annual pattern of streamflows in the study area is represented by the two USGS gaging stations. Roadhouse Creek (USGS Station 15300200), located in the western part of the study area, has a mean annual basin runoff depth of 19 inches. The Iliamna River (USGS Station 15300300), located in the eastern part of the study area, has a mean annual basin runoff depth of 96 inches. The annual hydrograph at the USGS gaging station on Roadhouse Creek is dominated by spring snowmelt and autumn rainfall, with low flows in the summer and winter. The autumn rains produce greater runoff volume than spring snowmelt, on average, and the winter flows are lower than the summer flows. The annual hydrograph at the USGS gaging station on the Iliamna River is somewhat similar to the Roadhouse Creek hydrograph except that in the Iliamna River spring flows are greater than autumn flows (because of snow accumulation and melt in the higher mountainous basin) and the summer low-flow season is not as pronounced as in Roadhouse Creek (because of prolonged snow and glacier melt throughout the summer).

The low-duration flows that are predicted to be exceeded 98 percent of the time in the month of August are presented in Table 7-3. These results were computed for each gaging station according to the USGS regression equations in Wiley and Curran (2003). Most of the measured flows in August 2004 corresponded to flows that had exceedence durations of greater than 90 percent, consistent with the general observation that August 2004 was relatively dry so the streamflows during August 2004 were expected to be well below average and should be exceeded most of the time.

The estimated 200-year peak streamflow values for each gaging station, based on the USGS regression equations (Curran et al, 2003), are presented in Table 7-3. These peak flow estimates are based on the state precipitation map produced by Jones and Fahl (1994), which appears to underestimate mean annual precipitation in the eastern part of the study area (based on measured basin runoff in the Iliamna River).

The peak flow estimates based on the regional regression equations were compared to the gage records from Roadhouse Creek and the Iliamna River. The regional peak flow estimates appear to over-predict peak flows in the western part of the study area and under-predict peak flows in the eastern part of the study area, even when appropriate values of mean annual precipitation are used in the regression equations.

7.4 References

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Wiley, J.B., and J.H. Curran. 2003. Estimating Annual High-Flow Statistics and Monthly and Seasonal Low-Flow Statistics for Ungaged Sites on Streams in Alaska and Conterminous Basins in Canada. U.S. Geological Survey Water-Resources Investigations Report (WRIR) 03-4114.

TABLE 7-1
Streamflow Gaging Stations, Mine Study Area

Watershed	Station	Principal Operator	Period of Record	No. Complete Water Years	Basin Area (mi^2)	Mean Basin Elev. (ft.)	Mean Annual Discharge [a] (cfs)	Mean Annual Unit Runoff [a] (cfs/mi^2)	Estimated Baseflow [b] (cfs/mi^2)	200-Year Peak Flow [c] (cfs/mi^2)
South Fork Koktuli River	SK100A	HDR	2004-07	3	106.92	1,115	269.3	2.52	0.7	42
	SK100B	USGS	2004-08	4	69.33	1,255	191.0	2.76	0.7	57
	SK100B1	HDR	2006-07	2	54.41	1,290	113.0	2.08	0.3	-
	SK100C	HDR	2004-08	4	37.50	1,230	52.2	1.39	0.0	40
	SK100F	HDR	2004-07	3	11.91	1,270	28.1	2.36	0.5	61
	SK100G	HDR	2004-07	3	5.49	1,200	14.7	2.68	0.4	82
	SK119A	HDR	2004-08	4	10.73	1,575	36.9	3.44	0.7	293
	SK124A	HDR	2005-08	4	8.52	1,460	19.8	2.32	-	203
North Fork Koktuli River	NK100A	USGS	2004-08	4	105.86	1,280	270.3	2.55	1.0	60
	NK100A1	HDR	2007-08	2	85.34	1,340	203.8	2.39	0.6	-
	NK100B	HDR	2007-08	2	37.32	1,420	86.0	2.31	0.5	-
	NK100C	HDR	2004-08	4	24.35	1,360	52.4	2.15	0.6	48
	NK119A	HDR	2004-08	4	7.76	1,645	24.6	3.17	0.4	209
	NK119B	HDR	2007-08	2	3.97	1,430	4.8	1.21	0.0	-
Upper Talarik Creek	UT100-APC3	APC	2007-08	1	134.16	1,013	382.3	2.85	-	-
	UT100-APC2	APC	2007-08	1	110.16	965	316.9	2.88	-	-
	UT100-APC1	APC	2007-08	1	101.51	881	291.8	2.87	-	-
	UT100B	USGS	2004-08	4	86.24	1,055	231.7	2.69	1.3	43
	UT100C	HDR	2007-08	2	69.47	1,130	162.4	2.34	0.9	-
	UT100C1	HDR	2007-08	2	60.37	1,170	123.3	2.04	0.6	-
	UT100C2	HDR	2007-08	2	48.26	1,210	107.2	2.22	0.5	-
	UT100D	HDR	2004-08	4	11.96	1,110	29.5	2.47	0.7	69
	UT100E	HDR	2004-08	4	3.10	1,225	10.1	3.27	1.3	77
	UT106-APC1	APC	2008	0	14.14	713	-	-	-	-
	UT119A	HDR	2004-08	4	4.05	882	27.4	6.77	5.5	36
	UT135A	HDR	2007-08	2	20.42	1,170	41.2	2.02	0.5	-
Kaskanak Creek	KC100A	HDR	2004-08	4	25.64	605	36.1	1.41	-	37
Newhalen River	NH100-APC2	APC	2008	0	3451	-	-	-	-	-
	NH100-APC3	APC	2008	0	3412	-	-	-	-	-

Notes:

a. Mean annual discharge and unit runoff for the period of record, based on complete water years.

b. Average discharge recorded during late-winter baseflow-measurement events.

c. 200-year instantaneous peak flows were estimated using a combined local/regional approach for stations with at least three years of record.

cfs = cubic feet per second

ft = feet

mi^2 = square miles

TABLE 7-2
Snow Model Results, Mine Study Area

Watershed	Station	Basin Area (mi^2)	Mean Basin Elev. (ft.)	Modeled Mean Snow/Water Equivalent for Basin (inches)		
				04/19/06	04/09/07	04/06/08
South Fork Koktuli River	SK100A	106.92	1,115	19.5	4.5	19.3
	SK100B	69.33	1,255	21.3	5.7	21.7
	SK100B1	54.41	1,290	21.5	5.8	22.0
	SK100C	37.50	1,230	21.2	5.5	22.2
	SK100F	11.91	1,270	21.8	6.3	23.7
	SK100G	5.49	1,200	21.4	5.9	23.9
	SK119A	10.73	1,575	23.3	6.9	22.6
	SK124A	8.52	1,460	22.3	6.5	22.7
North Fork Koktuli River	NK100A	105.86	1,280	21.5	6.1	23.8
	NK100A1	85.34	1,340	22.3	6.6	25.1
	NK100B	37.32	1,420	22.8	6.6	25.8
	NK100C	24.35	1,360	22.6	6.3	26.3
	NK119A	7.76	1,645	23.8	7.5	24.8
	NK119B	3.97	1,430	22.3	6.4	25.1
Upper Talarik Creek	UT100-APC3	134.16	1,013	17.6	3.4	16.4
	UT100-APC2	110.16	965	18.4	3.9	18.0
	UT100-APC1	101.51	881	18.9	4.2	18.9
	UT100B	86.24	1,055	19.2	4.4	19.6
	UT100C	69.47	1,130	19.9	5.0	20.9
	UT100C1	60.37	1,170	20.3	5.3	21.3
	UT100C2	48.26	1,210	20.6	5.6	21.9
	UT100D	11.96	1,110	20.5	5.8	22.6
	UT100E	3.10	1,225	21.4	6.3	25.1
	UT106-APC1	14.14	713	-	-	-
	UT119A	4.05	882	18.1	2.0	17.2
	UT135A	20.42	1,170	19.9	4.8	21.5
Kaskanak Creek	KC100A	25.64	605	13.0	0.2	9.3
Newhalen River	NH100-APC2	3451	-	-	-	-
	NH100-APC3	3412	-	-	-	-

ft = feet
mi^2 = square miles

TABLE 7-3
Gaging Station Basin Characteristics, Transportation-corridor Study Area

			Drainage Basin Characteristics			
Station [a]	Stream	Period of Record	Area (mi^2)	Mean Elev. (ft)	Flow Exceeded 98% of the Time in August (cfs) [c]	200-year Peak Flow (cfs) [d]
GS-23	Chinkelyes Creek	2004-05	22.55	1,616	43	2,388
GS-3a	Iliamna River	2004-05	128.00	2,236	304	9,609
GS-4a	Pile River	2004-05	152.83	1,463	300	11,532
GS-4b	Unnamed Outlet Creek from Long Lake	2004-05	-	-	-	-
GS-6a	Unnamed Outlet Creek from Dumbbell Lake	2004-05	2.20	1,072	2	191
GS-7a	Unnamed Outlet Creek near Pedro Bay Townsite	2004-05	3.36	1,176	2	330
GS-8a	Knutson Creek	2004-05	35.70	2,300	45	2,271
GS-11a	Canyon Creek	2004-05	36.20	2,257	35	1,661
GS-12a	Chekok Creek	2004-05	50.48	1,764	45	2,097
GS-14a	Unnamed Creek East of Eagle Bay Creek	2004-05	18.34	860	9	865
GS-14b	Unnamed Creek West of Chekok Creek	2004-05	15.91	973	9	654
GS-17a	West Fork Eagle Bay Creek	2004-05	10.95	1,190	6	585
GS-18a	Unnamed Creek on South Slope of Roadhouse Mountain	2004-05	9.29	978	4	396
GS-20 [b]	Roadhouse Creek	2004-05	20.80	321	7	689
GS-20a	Upper Roadhouse Creek	2004-05	8.07	-	-	358

Notes:

a. The gaging stations are listed in order from east to west.

b. The drainage basin characteristics for GS-20 have been adopted from the USGS gage on Roadhouse Creek (Curran et al., 2003).

c. August low-duration flow statistics estimated according to Wiley and Curran (2003).

d. Peak flow statistics estimated according to Curran et al., 2003).

cfs = cubic feet per second.

ft = feet.

mi^2 = square miles.

Typical surface hydrology gage installation (SK119A).

Surface hydrology station UT100C looking upstream, August 2008.

Surface hydrology station SK100C looking downstream, July 2005.

Surface hydrology station SK100C looking downstream, August 2005.

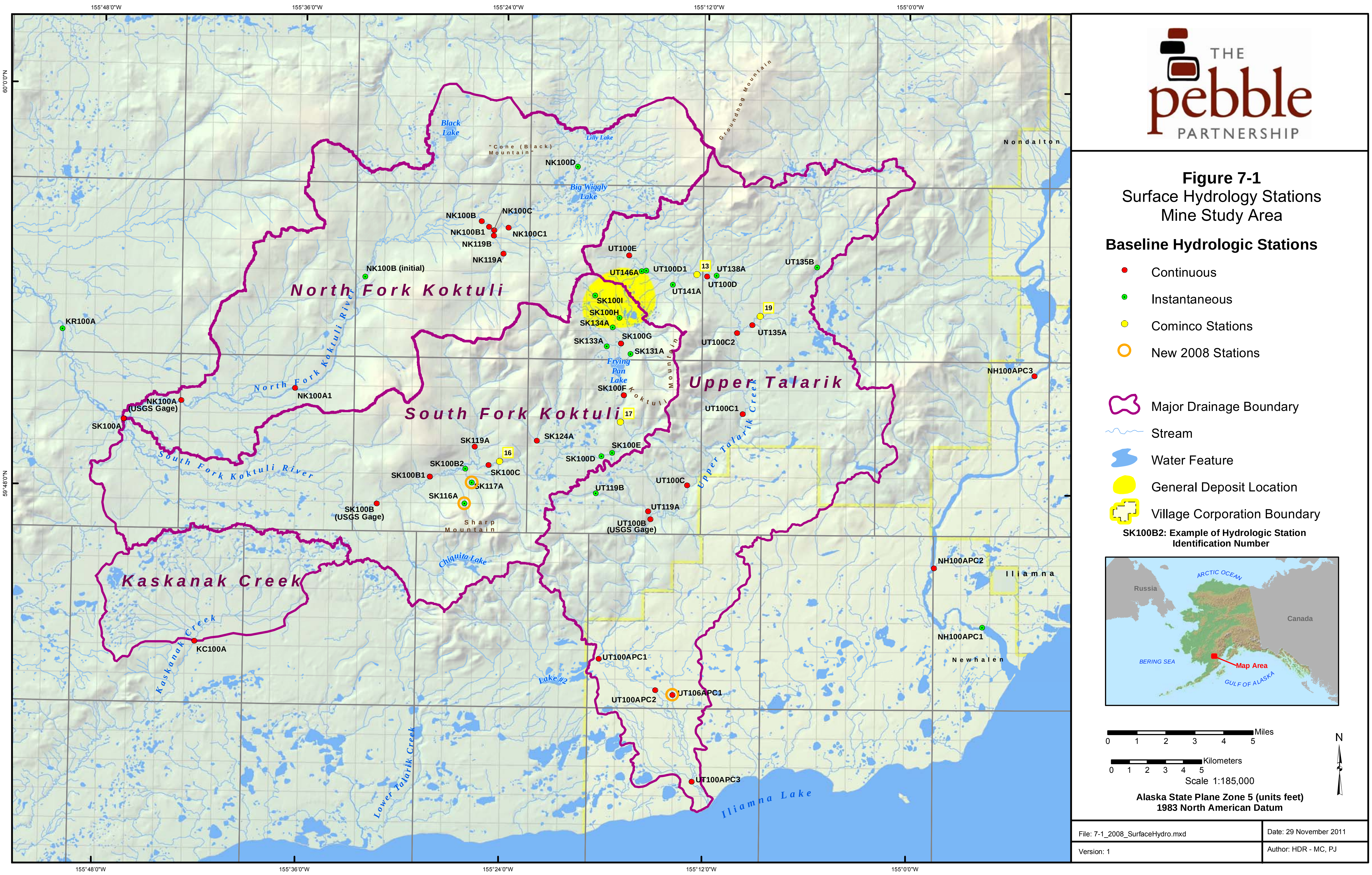


Figure 7-1
Surface Hydrology Stations
Mine Study Area

Baseline Hydrologic Stations

- ● Continuous
- ● Instantaneous
- ● Cominco Stations
- ○ New 2008 Stations

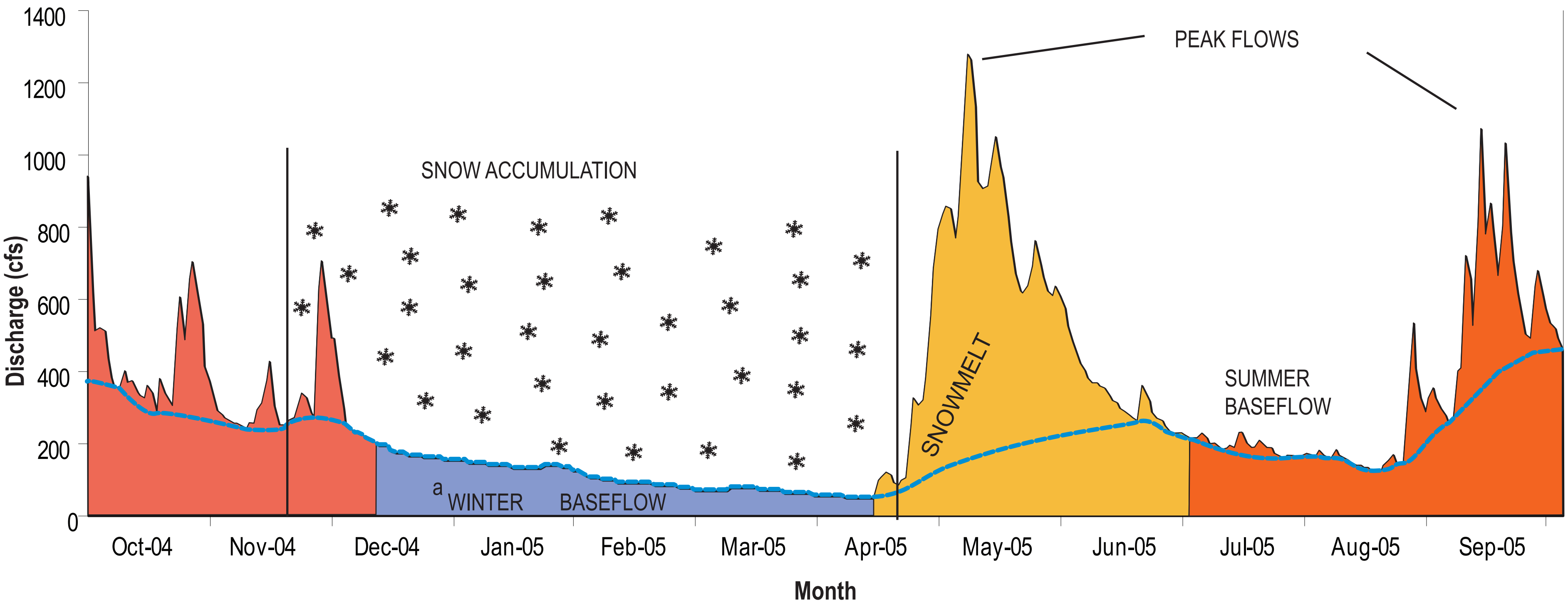
- Major Drainage Boundary
- Stream
- Water Feature
- General Deposit Location
- Village Corporation Boundary

SK100B2: Example of Hydrologic Station Identification Number

Scale 1:185,000

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

File: 7-1_2008_SurfaceHydro.mxd
Date: 29 November 2011
Version: 1
Author: HDR - MC, PJ



Notes:

a. Blue dashed line approximated baseflow

b. cfs = cubic feet per second

FIGURE 7-2

Annual Hydrograph of the South Fork Koktuli River at SK100B

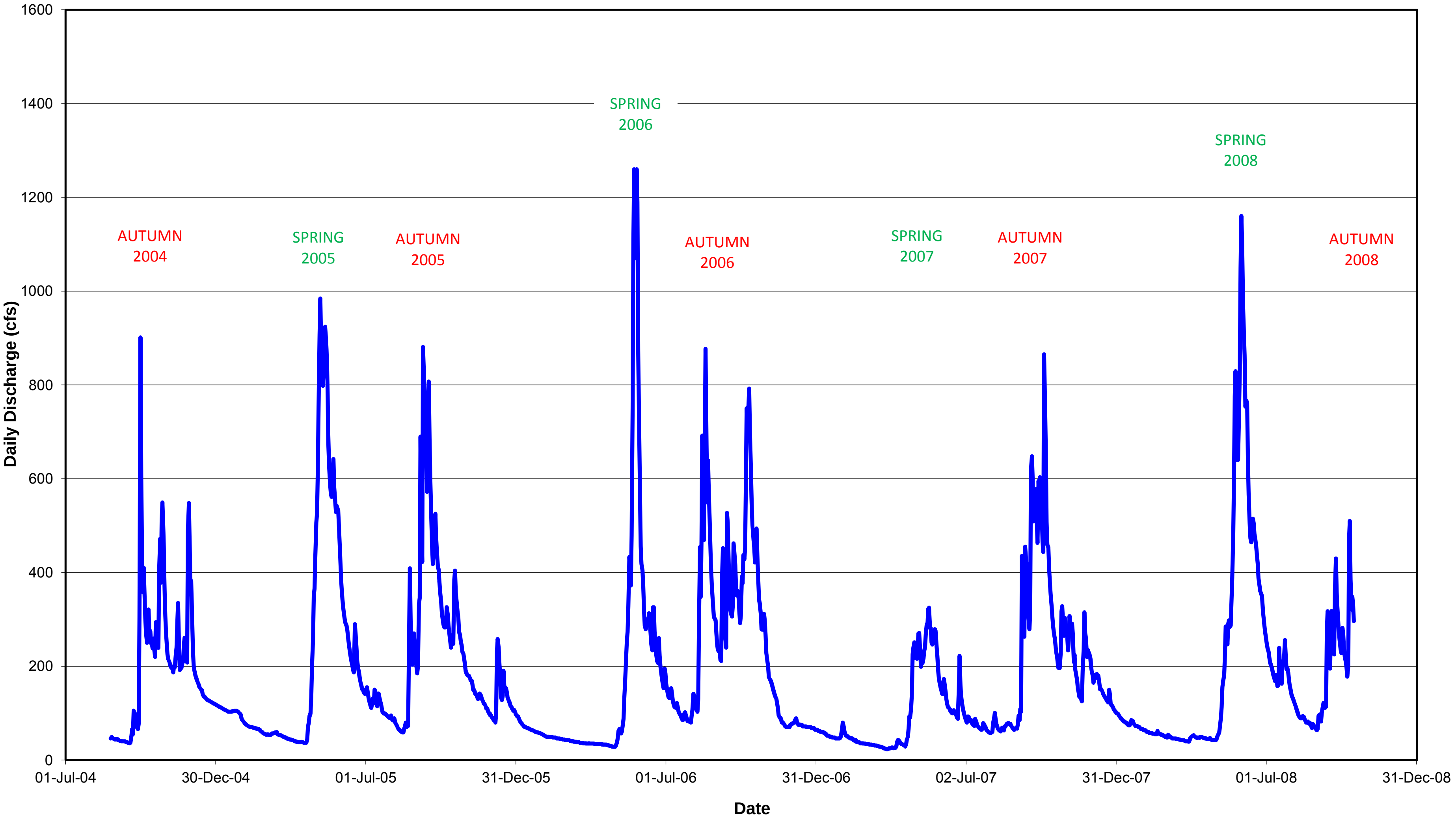
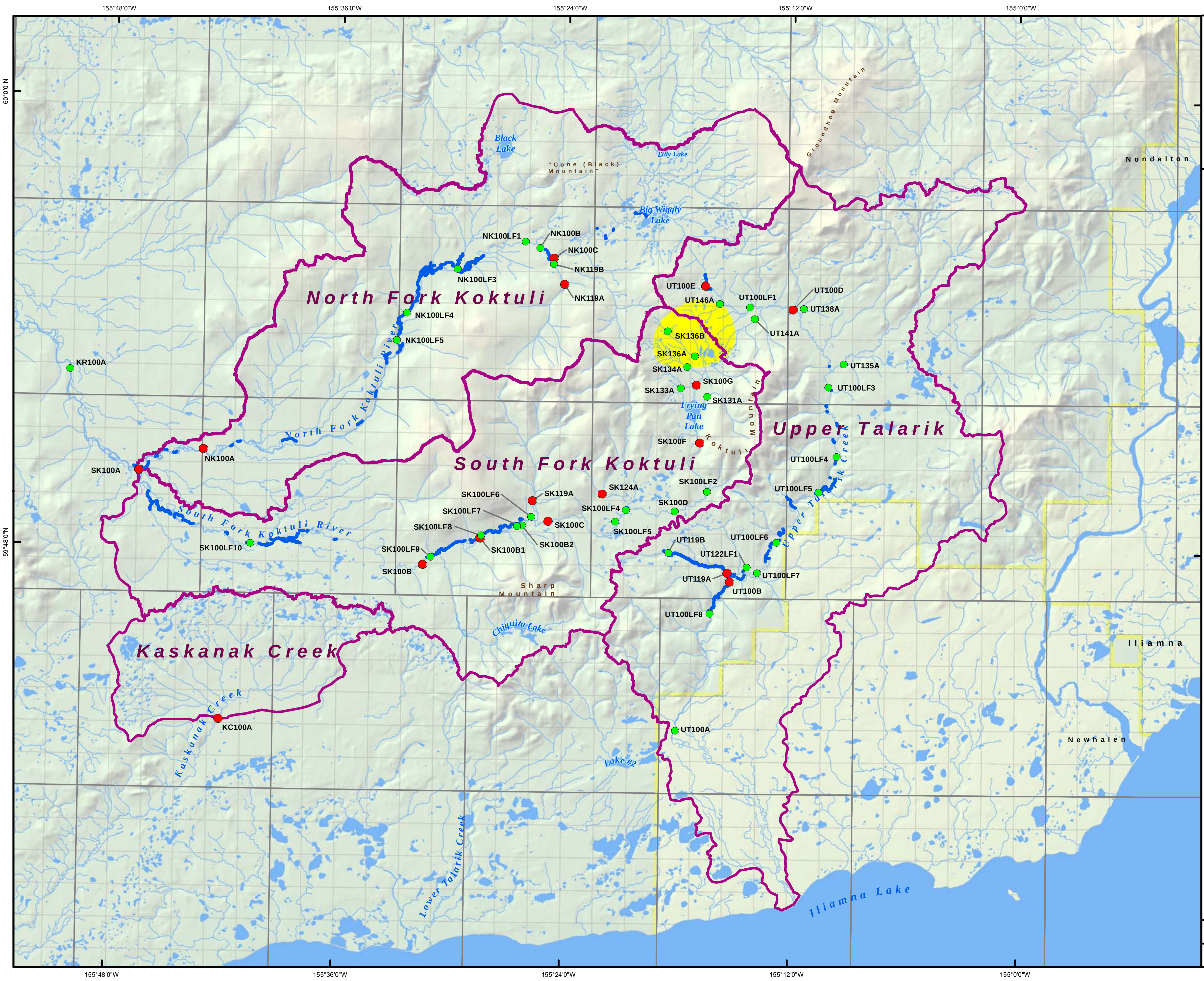


FIGURE 7-3
SK100B Hydrograph, 2004-2008



THE pebble PARTNERSHIP

Figure 7-4

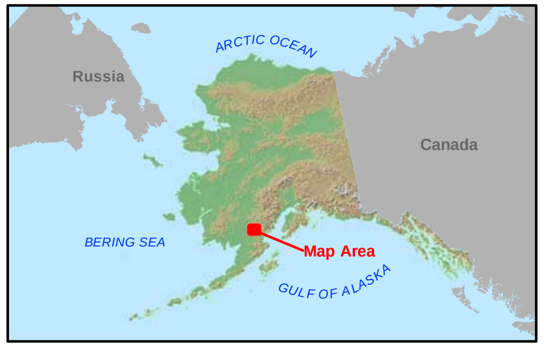
Surface Hydrology
2006 Open Water Survey Results
Mine Study Area

Open Water Survey

▬	Dry
▬	Intermittent
▬	Open Water

▢	Major Drainage Boundary
〰	Stream
▨	Water Feature
●	General Deposit Location
▢	Village Corporation Boundary

SK100B2: Example of Hydrologic Station Identification Number



Scale 1:185,000

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

File: 7-4_2006_OpenWater.mxd	Date: 29 November 2011
Version: 1	Author: HDR - MC, PJ

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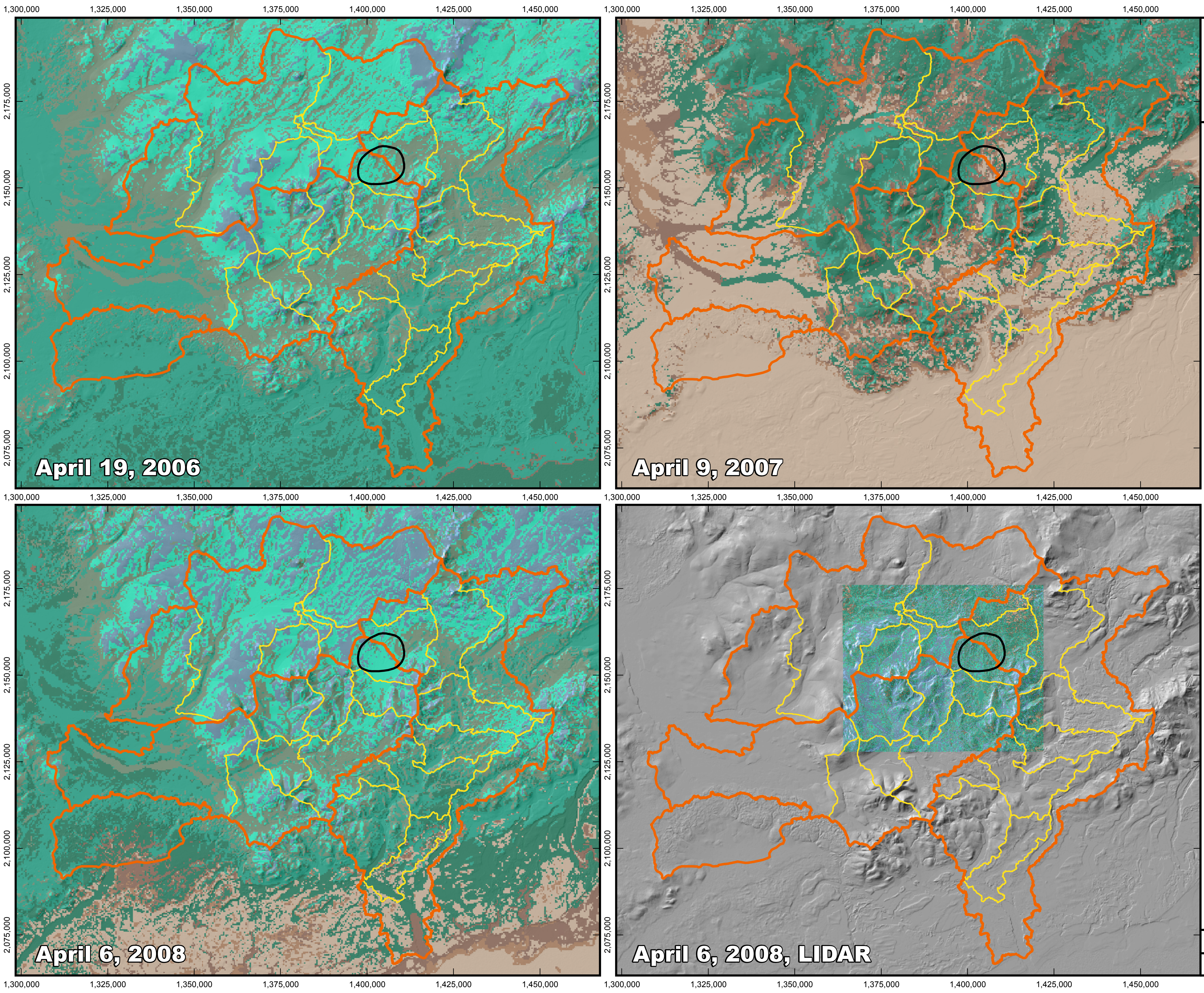
Figure 7-5
Surface Hydrology Snow Model Output, April, 2006–2008, Mine Study Area


April 19, 2006

April 9, 2007

April 6, 2008

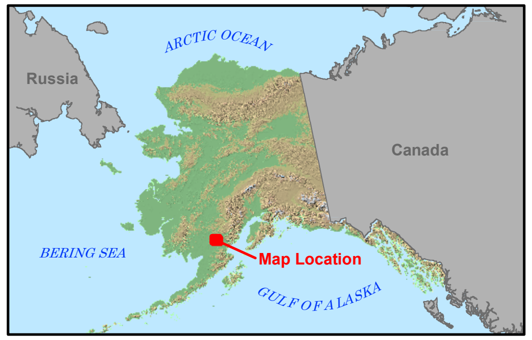
April 6, 2008, LIDAR

Legend

Snow Water Equivalent (Inches)

🟫 0 – 1.00
🟫 1.01 – 3.00
🟫 3.01 – 5.00
🟩 5.01 – 10.00
🟩 10.01 – 15.00
🟩 15.01 – 20.00
🟩 20.01 – 25.00
🟦 25.01 – 50.00
🟦 50.01 – 75.00
🟦 75.01 – 100.00
🟦 100.01 – 125.00
⬜ 125.01 – 523.00

Basin Boundary
Monitored Sub-basin Boundary
General Deposit Location



Scale 1:340,000

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

File: 7-5_SnowDistModels_06-08_PLP_EBD_Tech_Summ_v01.mxd	Date: November 16, 2011
Version: 1	Author: ABR-AZC

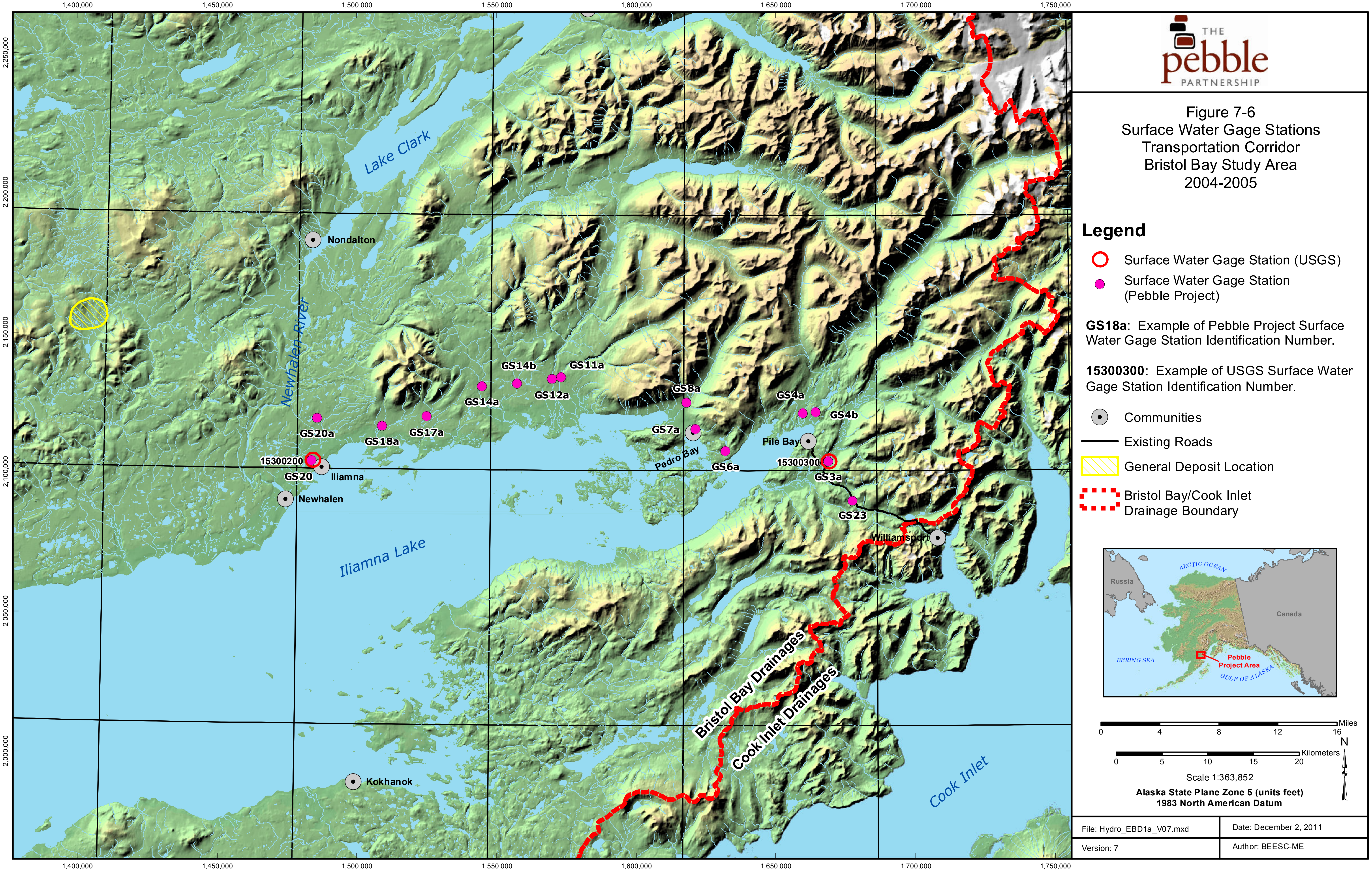


Figure 7-6
Surface Water Gage Stations
Transportation Corridor
Bristol Bay Study Area
2004-2005

File: Hydro_EBD1a_V07.mxd	Date: December 2, 2011
Version: 7	Author: BEESC-ME

8. GROUNDWATER HYDROLOGY

8.1 Introduction

The baseline groundwater hydrology study for Pebble Project was undertaken between 2004 and 2008. The study area was focused on an area within a two to six miles radius of the deposit. The current study area for groundwater hydrology is within the mine study area depicted on Figure 1-4 (in Chapter 1) and does not extend into the transportation-corridor study area. Data for parameters that are subject to seasonal variations, such as water levels and streamflows, were collected all year around. Data for other parameters that are independent of the seasons, such as aquifer properties, were collected between May and October of each year.

The objectives of the groundwater hydrology study were as follows:

- To characterize the existing groundwater flow regime and define how the local regime of the deposit area interacts with the regional groundwater system.
- To evaluate the interaction between groundwater and surface water and the potential for cross-basin transfer of groundwater.
- To develop baseline water-flow and water-chemistry models.
- To support aquatic, fish-resource, and wetlands habitat assessments.

The study program included the following elements:

- Collection of surface and subsurface geologic data.
- Examination of drilling logs.
- Installation of monitoring wells and piezometers, including multilevel well completions.
- Installation and testing of pumping wells.
- Measurement of hydrogeologic parameters such as piezometric water level and hydraulic conductivity using various testing methods, including pumping tests.
- Characterization of seeps and springs within the study area.
- Delineation of groundwater recharge and discharge zones.
- Evaluation of sub-basin drainage areas, channel lengths, annual precipitation, topographic relief, typical flow regimes, and stream characteristics.
- Characterization of groundwater quality in the bedrock and alluvial groundwater systems.

Data collection, analysis, and interpretation used procedures set forth in the Unified Soil Classification System and the American Society for Testing and Materials (ASTM) Method D 2488-00, Standard Practice for Description and Identification of Soils (Visual Manual

Procedure); ASTM Method D4044-96(2002), Standard Test Method (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers; ASTM Method D1586-99, Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils; and ASTM Method D5092, Standard Practice for Design and Installation of Monitoring Wells. All data collected were subjected to a rigorous quality assurance/quality control procedure.

8.2 Results and Discussion

8.2.1 Geologic Controls

Bedrock in the study area consists mostly of Jurassic and Cretaceous sedimentary and volcanic rocks intruded by Cretaceous granodiorite to monzonite and overlain by Tertiary sedimentary and volcanic rocks.

The upper slopes and ridges in the study area include exposures of highly fractured bedrock, talus, rubble, and solifluction deposits. This near-surface weathered zone allows enhanced local-scale groundwater recharge. The zone of weathering is variable but may be typically up to about 50 feet thick.

In general, below the near-surface weathered zone, the hydraulic conductivity of most bedrock units decreases with depth. However, zones of elevated permeability, associated with geologic structures, can occur at deeper levels (Figure 8-1). Structures are interpreted to exhibit enhanced hydraulic conductivity along their direction of strike and reduced conductivity across strike. Therefore, fault zones oriented perpendicular to the local groundwater-flow direction may potentially act as hydraulic barriers, while some of the structures oriented parallel to the groundwater-flow direction may act as local-scale conduits. Faults with elevated permeabilities terminate within the study area where they are cross-cut by other faults, there is a change in the rock properties, or the fault pinches out.

The overall pattern of cross-cutting geologic structures in the study area has resulted in the formation of groundwater compartments, particularly within the deeper groundwater system, where the effects of weathering are less. This condition is typical of bedrock groundwater systems developed in crystalline, volcanic, and metamorphic rock settings. The local and intermediate flow systems dominate the overall groundwater regime. Most groundwater flow occurs at shallow levels within the overburden and shallow bedrock.

The lower slopes and valley bottoms are in-filled with glacial deposits, with some surficial alluvial deposits. These glacial landforms include end, lateral, and recessional moraines; ground moraines; outwash sands and gravels; and glaciolacustrine deposits. Of the alluvial deposits, outwash sands and gravels are typically observed to have the highest hydraulic conductivity. Highly fractured bedrock up to 50 feet thick is present below the overburden deposits.

Within the overall alluvial sequence, three distinct permeable and extensive glacial sand and gravel deposits are of particular note, as follows:

- Along the South Fork Koktuli River south of Frying Pan Lake (”The Flats,” see Figure1-3a in Chapter 1). These deposits include a sand and gravel moraine, and sand and gravel outwash deposits (Figure 8-2).
- In the North Fork Koktuli River valley downstream of the terminal moraines of the Kvichak Stade (Figure 8-3).
- East of Upper Talarik Creek where there are extensive outwash and glacial-contact sand and gravels (Figure 8-4).

There are also a number of distinct areas where low-permeability surficial deposits occur. Extensive low-permeability lacustrine deposits underlie the glacial Frying Pan Lake basin and create widespread marsh areas. Similar low-permeability lacustrine deposits are present in the North Fork Koktuli River and Upper Talarik Creek drainages. Buried lacustrine deposits serve to limit the flow of groundwater from the South Fork Koktuli “Flats” area to Upper Talarik Creek.

8.2.2 Groundwater Flow

Analysis of the baseline data set indicates that bedrock groundwater flow within the study area is generally localized. There is no evidence of regional-scale groundwater flow within any of the bedrock units. Bedrock groundwater recharge typically occurs over areas of higher ground, and groundwater flow follows the local topography towards the adjacent valley floors, where much of the bedrock groundwater percolates into the overlying alluvial deposits. This interpretation is supported by the presence of high groundwater levels beneath the bedrock ridges and the numerous high-flow seeps that are observed along the side slopes of the adjacent valleys (Figure 8-1). Upward hydraulic gradients typically occur in the lower parts of the valleys, further indicating the presence of local bedrock groundwater discharge into the alluvial deposits (Figure 8-3). Furthermore, the chemistry of the groundwater in the deep bedrock groundwater system has higher concentrations of total dissolved solids (TDS) than that measured in the shallow groundwater. Elevated concentrations of TDS can be attributed to the groundwater having a long contact time with the surrounding rock and can be used to infer that such groundwaters have longer residence times than waters with low TDS, that is, shallow groundwaters.

Alluvial groundwater in the three main valleys in the study area (North Fork Koktuli, South Fork Koktuli, and Upper Talarik) generally flows downslope as underflow below the axis of the valley. Contiguous permeable overburden units fill each of the three drainages. The majority of groundwater flow occurs within the overburden deposits. Groundwater underflow down the valleys is much lower where the alluvium is dominated by lower permeability deposits (silts and clays). In these areas, the groundwater system discharges to surface water, leading to gaining streamflow reaches. Conversely, where the alluvial deposits become more permeable downstream or where the profile of the valley widens, the surface water system can leak into groundwater, leading to losing stream reaches.

The upper reaches of tributaries have limited groundwater storage capacity, and therefore, streamflows in the upper reaches are typically flashy, with low late-winter baseflows. Further downstream, the sustained winter baseflows for the main water courses indicate that considerable groundwater is contained in storage within the main parts of the valleys. Baseflows are higher where a substantial thickness of permeable alluvium is present upstream. The overall nature of the baseflow patterns indicates that most of the groundwater storage on site occurs within the alluvium and that most bedrock units demonstrate limited groundwater storage potential.

The average annual groundwater recharge rates for the North Fork Koktuli, Upper Talarik, and South Fork Koktuli watersheds are 11, 16, and 23 inches per year, respectively. Variation in recharge rates within the watersheds reflects differences in the surficial geology. Within each of the drainages, the surficial geology varies from low-permeability glaciolacustrine deposits to high-permeability glacial outwash and ice-contact deposits. The large differences in the permeability, coupled with variations in the topographic gradient, result in estimated localized recharge rates within each drainage that vary from 5 to 47 inches per year (including leakage from streams).

The largest cross-catchment flow in the study area occurs from Area 5 in South Fork Koktuli to Area 7 in Upper Talarik Creek (Figure 8-5) and is estimated to be about 6 inches per year or about one-third of the total underflow within Area 5. Except for this cross-catchment flow, over 95 percent of the water that recharges the groundwater system within each of the three main drainages discharges within that drainage.

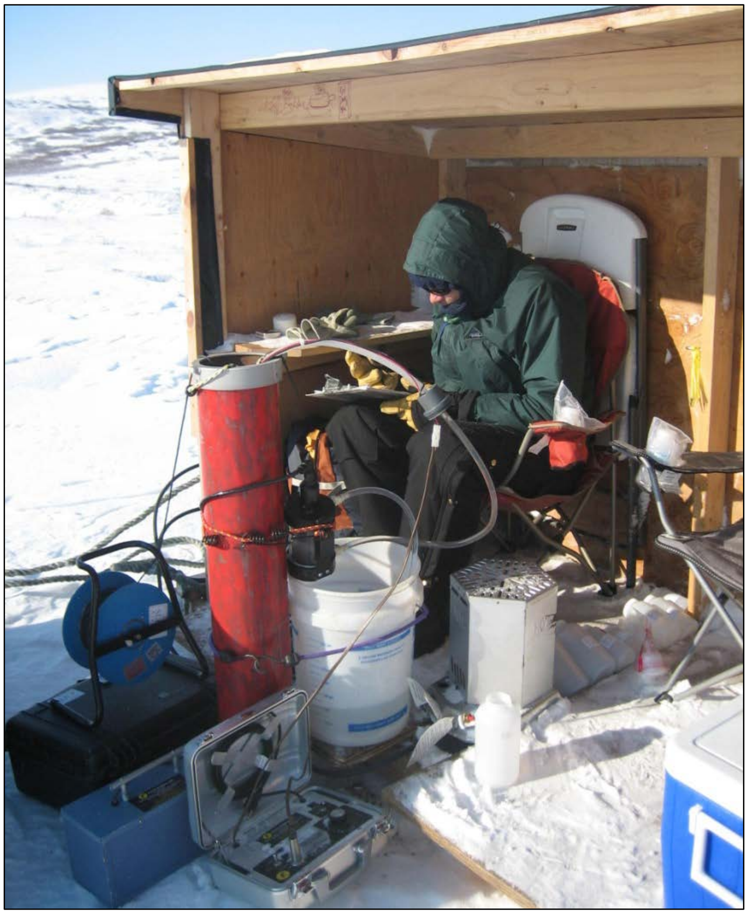
The largest seasonal changes in piezometric levels are between 10 and 20 feet. These mostly occur beneath the bedrock ridges and areas of higher ground. In these areas, the seasonal changes in groundwater storage are large because of the high recharge rates. The drainable porosity and storage potential of the bedrock are low. The similar amplitude of the piezometric variations from year to year indicates that the groundwater system is in a state of dynamic equilibrium and that the net change in groundwater storage from one year to the next is small, varying only in response to year-to-year changes in precipitation patterns.

In summary, the overall groundwater flow system in the study area is characterized as follows:

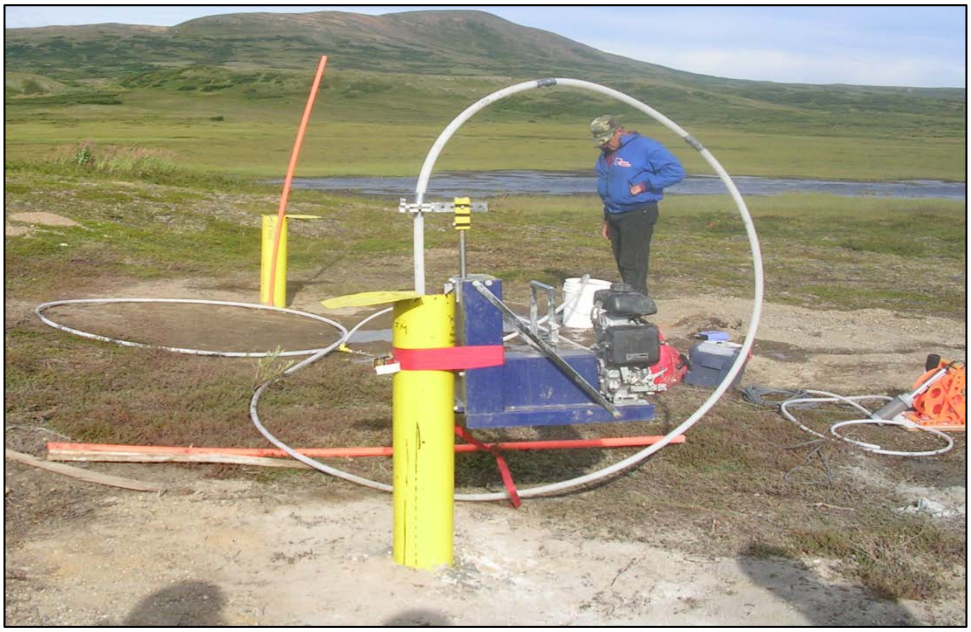
- The overall bedrock groundwater flow pattern is localized and is dominated by the upper 50 feet of the bedrock. Flow occurs from the margins of the valley downslope towards the valley floor.
- Groundwater within the valley floors moves as underflow in a downslope direction beneath the axis of the valleys, predominantly within overburden deposits.
- Analysis of the baseline data indicates that, except for some cross-catchment flow between the South Fork Koktuli River and Upper Talarik Creek, over 95 percent of the water that recharges the groundwater system within each of the three main drainages discharges within that drainage.

A South Fork Koktuli River groundwater discharge area.

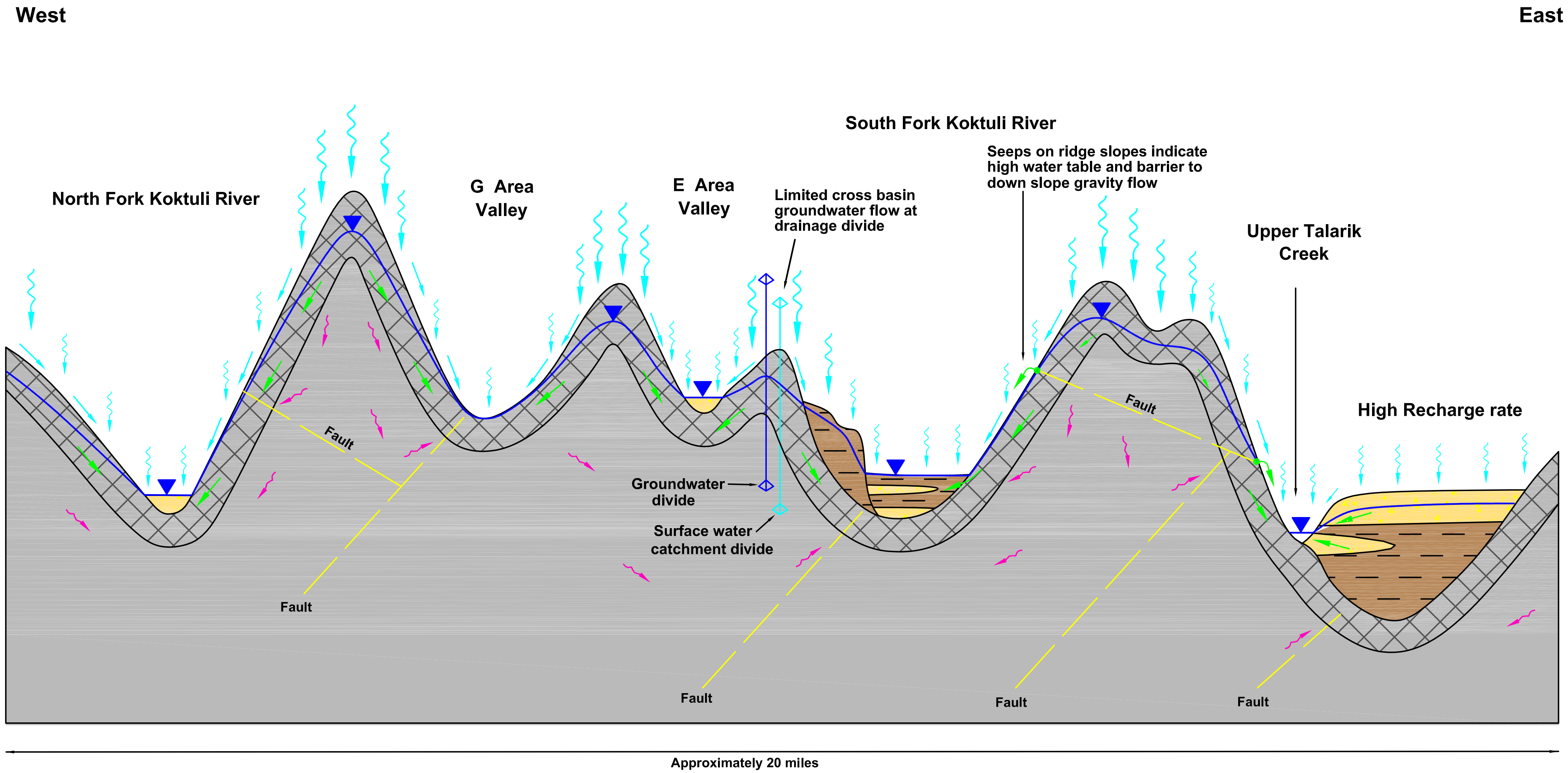
Spring within a closed depression between the South Fork Koktuli River and Upper Talarik Creek.



Winter groundwater sampling.



Well development prior to a response test at a monitoring well.



Note:
Most groundwater flow occurs at shallow depths.
(Alluvial groundwater flow vectors are perpendicular
to the section and therefore are not shown).

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Figure 8-1
Schematic Representation of Site-Wide Groundwater System

Legend

- 🟨 Sand and gravel
- 🟫 Silt and clay
- ▨ Fractured bedrock
- ⬜ Bedrock
- ↓ Recharge
- → Seasonal surface runoff
- ↗ Spring
- → Shallow bedrock groundwater flow
- ↗ Minor deep bedrock groundwater circulation
- — Potentiometric surface - alluvium
- ▼ Water Table
- ⬦ Groundwater divide
- ⬦ Surface water catchment divide

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Version 1 2	Date: Nov, 2011

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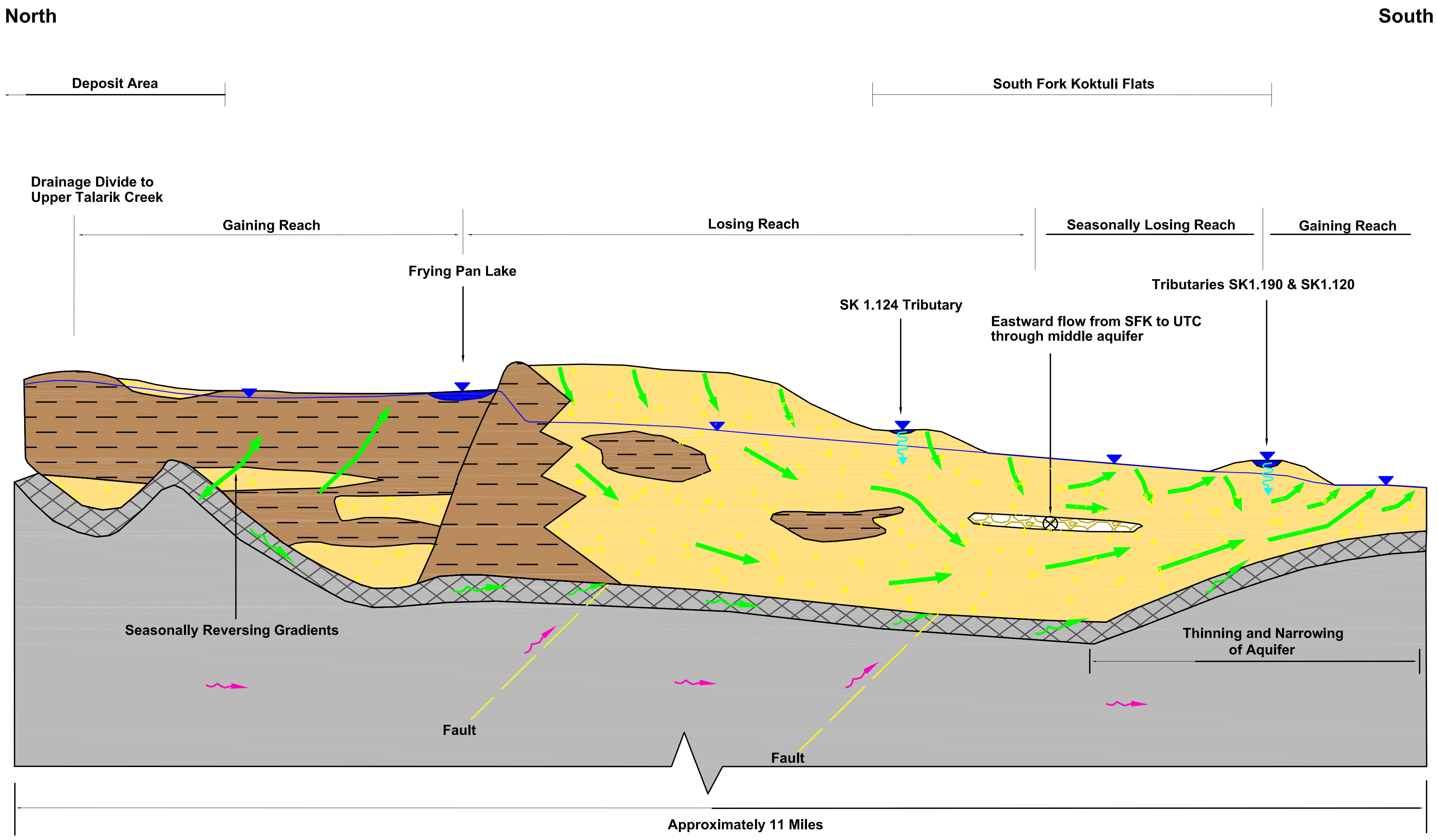

Figure 8-2
Schematic Representation of Groundwater-Surface Water Interaction Along South Fork Koktuli River

Legend

🟨 Sand and Gravel

🟫 Silt and clay

▨ Weathered Bedrock

⬜ Bedrock

↗ Groundwater Flow

▼ Water Table

⊗ Direction of Groundwater Flow into Page

↓ Groundwater Recharge

→ Minor deep bedrock groundwater circulation

Project No: 7126	Author: SWS-PP
Version: 2	Date: Nov, 2011

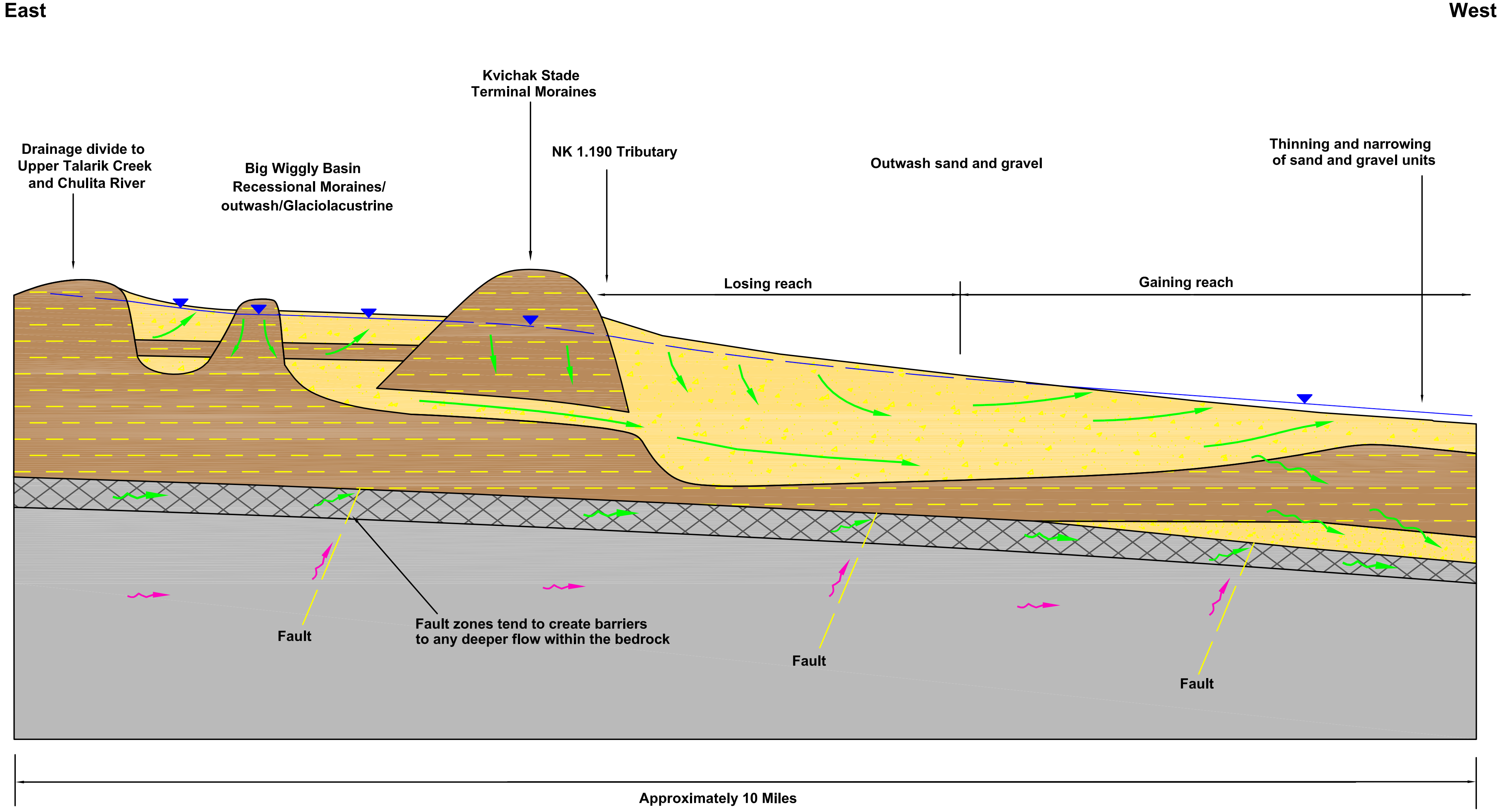

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Figure 8-3
Schematic Representation of Groundwater Surface Water Interaction Along North Fork Koktuli River

Legend

- 🟨 Sand and Gravel
- 🟫 Silt and clay
- ▨ Weathered Bedrock
- ⬜ Bedrock
- ➚ Groundwater Flow
- — Potentiometric surface - bedrock
- ⤳ Minor deep bedrock groundwater circulation

Project No: 7126	Author: SWS-PP
Version: 2	Date: Nov, 2011

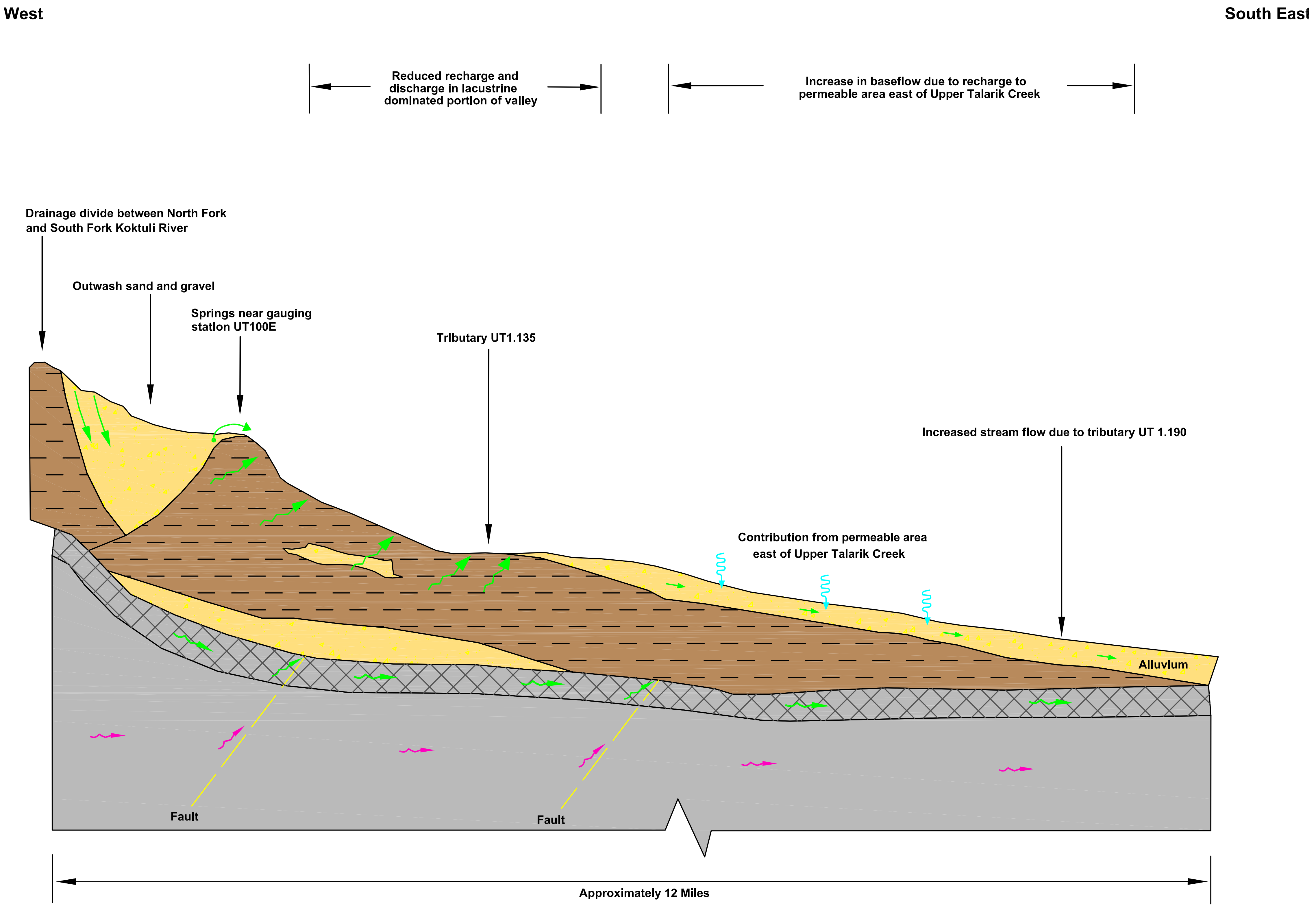

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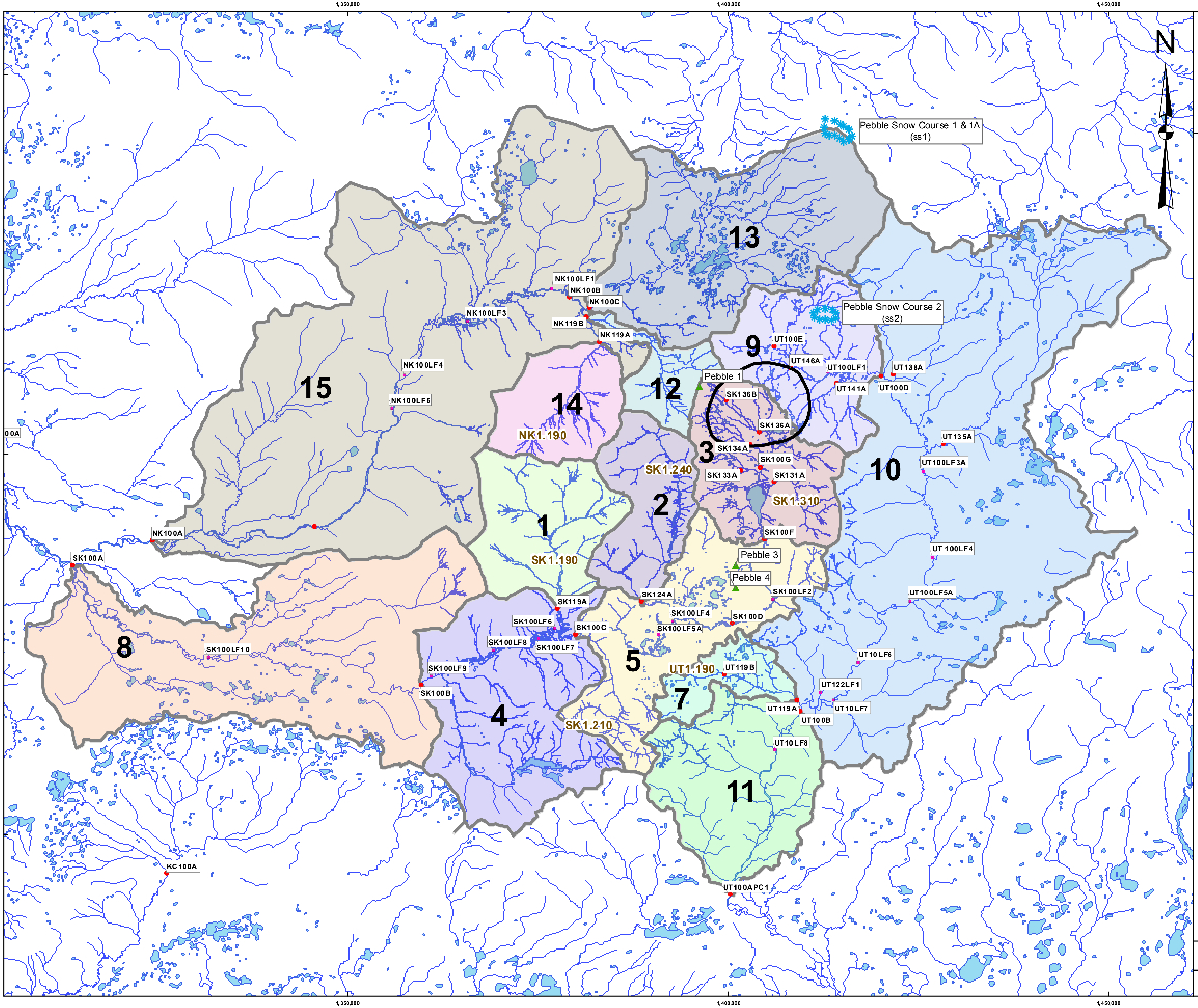
Figure 8-4
Schematic Representation of Groundwater-Surface Water Interaction Along Upper Talarik Creek

Legend

- 🟨 Sand and Gravel
- 🟫 Silt and clay
- ▩ Weathered Bedrock
- ⬜ Bedrock
- ↗ Groundwater Flow
- ↷ Spring
- ↓ Groundwater Recharge
- → Minor deep bedrock groundwater circulation

Project No: 7126	Author: SWS-PP
Version: 2	Date: Nov, 2011



Z:\Pebble_7126_2010\GIS\MXDs\T4000\Figure 8-1-14 Stream Gaging Stations and Watershed Boundaries.mxd

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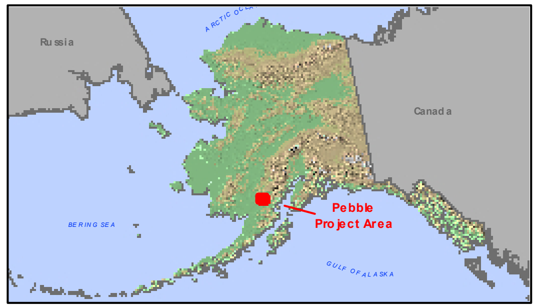
Figure 8-5
Stream Gaging Stations and Watershed Boundaries

Legend

✱	Snow Course Station
▲	Meteorological Station
●	Stream Gaging Station
▪	Low Flow Stream Gaging Station
▭	General Deposit Location
🟦	Lakes
—	Rivers



Feet: 0 6,100 12,200 18,300 24,400 30,500

Meters: 0 2,000 4,000 6,000 8,000 10,000

Scale 1:155,600

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

Project No: 7126	Date: November, 2011
Version: 1	Author: SWS-BL

9. WATER QUALITY

9.1 Introduction

The water quality study was undertaken to collect baseline data to provide scientific documentation of the naturally occurring constituents (NOCs) present, their concentrations, and their variability in surface water and groundwater. Water quality data for rivers, lakes, and seeps were collected in the mine study area throughout a 392-square-mile area that includes the North Fork Koktuli River (NFK), South Fork Koktuli River (SFK), Upper Talarik Creek (UT), and Kaskanak Creek (KC) drainages (Figure 1-2a in Chapter 1). NFK and SFK drain into the Nushagak River, which discharges to Bristol Bay. KC drains into the Kvichak River, south of Iliamna Lake. UT drains into Iliamna Lake, which in turn drains into the Kvichak River. Water quality data also were collected from streams that traverse typical areas of the transportation-corridor study area and from Iliamna Lake.

Field work was conducted from 2004 through 2008. Samples were analyzed for physical parameters, dissolved and total major ions, nutrients, dissolved and total trace elements, cyanides, and dissolved organic carbon. Selected surface water samples were also analyzed for organic compounds.

To assist with the data interpretation, data were plotted on box and whisker diagrams, time series diagrams, spatial diagrams, and Piper diagrams and were analyzed with statistical tests. To provide context, the data also were compared with the most stringent Alaska Department of Environmental Conservation (ADEC) water quality criterion for each parameter.

9.2 Results and Discussion

9.2.1 Mine Study Area—Surface Water

A comprehensive network of stations was established in the mine study area for sampling surface water from streams, lakes, and seeps. Stream samples were collected from 44 locations during 50 sampling events from April 2004 through December 2008. Lake and pond samples were collected from 19 lakes once or twice per year during 2006 and 2007. Seep samples were collected from 11 to 127 sample locations, depending on the year, two to five times per year. Altogether, over 1,000 samples were collected from streams, more than 600 samples from seeps, and approximately 50 samples from lakes.

The surface water in the mine study area was characterized by cool, clear waters with near-neutral pH that were well oxygenated, low in alkalinity, and generally low in nutrients and other trace elements. Water types ranged from calcium-magnesium-sodium-bicarbonate to calcium-magnesium-sodium-sulfate. Water quality occasionally exceeded the maximum criteria for concentrations of various trace elements. Additionally, cyanide was occasionally present in detectable concentrations; there were consistently detectable concentrations of dissolved organic carbon; and no detectable concentrations of petroleum hydrocarbons, polychlorinated biphenyls (PCBs), or pesticides were found.

Some differences in water quality between watersheds and some trends in water quality along streams were noted. Sulfate, copper, zinc, nickel, and molybdenum concentrations were greatest in the SFK, consistent with the headwaters of this river passing through the deposit area and multiple sample locations present in this area. Significantly higher concentrations of copper, molybdenum, nickel, zinc, and sulfate were present in the SFK than in the NFK, consistent with the SFK's proximity to the deposit area. Total dissolved solids (TDS), pH, sodium, alkalinity, hardness, nitrogen (total nitrate+nitrite), and nickel concentrations were greatest in the UT drainage. The UT, which in the uppermost reach passes through a portion of the general deposit area, also had significantly higher concentrations of all of these NOCs, except copper, than in the NFK. Total suspended solids, potassium, chloride, iron, and arsenic concentrations were highest in KC, while cadmium and lead concentrations were highest in the NFK drainage. These characteristics of KC and NFK likely indicate that these parameters are unrelated to the deposit area and represent water quality signatures that are distinct from the other drainage areas. The following paragraphs discuss some of the specifics of the sample results and trends.

The mean levels for TDS in streams, by watershed, ranged from 37 to 51 milligrams per liter, which is 10 percent or less of the most stringent ADEC water quality maximum criterion. Of the three streams that originate close to the deposit area, the UT and SFK had significantly higher TDS levels than the NFK. Furthermore, a decrease in the TDS levels with distance along the stream was more pronounced in the SFK and UT watersheds than in the NFK watershed. Higher TDS in the UT and SFK watersheds with decreasing trends downstream were expected, because the deposit area lies within their watersheds and the oxidation of sulfide minerals associated with the deposit would release dissolved solids. The mean levels for TDS in lakes and seeps were similar to those for streams, with values of 49 and 42 milligrams per liter, respectively.

The highest value for total suspended solids was in KC, and the lowest was in the NFK. The mean for total suspended solids in lakes and seeps was similar to that for streams.

The pH values in surface water were close to neutral. The mean pH, by watershed, for streams ranged from 6.7 to 7.0. Therefore, even though the oxidation of sulfide minerals was expected to be releasing acid in the deposit area, carbonate minerals appear to provide effective pH buffering. The mean pH values for lakes and seeps were 7.2 and 6.5, respectively. While the mean pH values fell within the range for pH specified in the most stringent ADEC criterion, 34 percent of all individual water quality samples did not meet the water quality criteria for pH. The frequency of this trend in seeps was at least double that of streams, depending on the watershed.

The alkalinity of the surface water samples was low. The mean alkalinity, by watershed, for streams ranged from 17 to 32 milligrams per liter. The mean alkalinity for lakes and seeps was 19 and 23 milligrams per liter, respectively. Alkalinity was the parameter that was most frequently detected outside the range of the most stringent ADEC criterion. In all, 43 percent of all surface water samples were below the most stringent ADEC minimum criterion for alkalinity.

The frequency with which alkalinity values for lakes and seeps were below the minimum criterion was 10 to 20 percent higher than the frequency for streams.

The mean water temperature in streams ranged from 4.0 to 4.8 ºC, depending on the watershed. The coefficient of variation was close to 1 for each watershed, indicating a high level of variability. The lakes were considerably warmer, with a mean temperature of 12 ºC, and the seeps were slightly cooler, with a mean temperature of 3.4 ºC.

Dissolved oxygen (DO) concentrations in streams were very similar in all watersheds, with mean concentrations that ranged from 10.2 to 10.5 milligrams per liter. These values are close to the theoretical solubility of oxygen of 12.3 milligrams per liter at 900 feet above sea level and a water temperature of 4 ºC. While most samples indicated high DO, 7 percent of the samples had DO concentrations lower than the most stringent ADEC minimum criterion.

The water type of most samples from the streams ranged from calcium-magnesium-sodium-bicarbonate to calcium-magnesium-sodium-bicarbonate-sulfate. The cation composition was dominated by calcium and was relatively consistent. The anion composition had a wider range, with most stream samples being dominated by carbonate. The average water type of the lakes and seeps was generally the same as the streams; however, the seeps had a slightly greater range of water types, and the distribution of water types was slightly different. Specifically, the seeps included samples with a higher proportion of sulfate, and the samples also were distributed more evenly across the spectrum of anion composition rather than being weighted toward the bicarbonate end of the spectrum.

Nutrients, which included total ammonia, nitrate+nitrite, total phosphorous, and orthophosphate, had generally low concentrations, especially in lakes and seeps. Orthophosphate was generally not present at detectable levels, with one exception in the KC watershed. Total ammonia was detected in 19 to 36 percent of all surface water samples, and mean concentrations ranged from 0.03 to 0.05 milligrams per liter, depending on whether the samples were from streams, lakes, or seeps. Nitrate+nitrite and phosphorous were detected in 66 to 98 percent of all surface water samples. Mean concentrations of nitrate+nitrite ranged from 0.1 to 0.3 milligrams per liter, and mean concentrations of total phosphorous ranged from 0.02 to 0.04 milligrams per liter. None of the nutrient concentrations exceeded the most stringent ADEC maximum criterion. The coefficients of variation for nutrients were high compared to most other parameters, often in the range of 1 to 2.

The trace elements aluminum, antimony, arsenic, barium, cadmium, copper, iron, lead, manganese, molybdenum, mercury, nickel, and zinc were detected in surface water, although at low concentrations. The frequency of detection depended on the watershed and on whether the sample was collected from a stream, a lake, or a seep. Total and dissolved aluminum, barium, copper, iron, manganese, and molybdenum were typically the most frequently detected trace elements in the streams and lakes. In streams and lakes the frequency of detection generally ranged from 85 to 100 percent. The most frequently detected elements in the seeps were generally the same as those for the streams and lakes, but the frequency of detection was lower in the seeps (53 to 99 percent rather than 85 to 100 percent). Exceptions to this general pattern included a frequency of detection for total and dissolved arsenic in KC of more than 98 percent. The trace elements arsenic, lead, nickel, and zinc had an intermediate frequency of detection, with the exception of zinc, which had a higher frequency of detection (98 percent) in lakes. Cadmium had the lowest frequency of detection. Some trace element concentrations in stream samples exceeded the most stringent ADEC maximum criteria. Copper from the SFK watershed exceeded the water quality criterion most frequently, with total copper exceeding the criterion in 42 percent of samples and dissolved copper exceeding the criterion in 34 percent of samples. In contrast, copper had one of the lowest frequencies of exceedence in other watersheds. The relatively high frequency of exceedence in the SFK watershed is probably related to the proximity of the deposit. Total aluminum exceeded the most stringent ADEC maximum criterion in 12 to 22 percent of the stream samples from the SFK, UT, and KC watersheds and in 6 percent of the samples from the NFK watershed. In contrast, dissolved aluminum exceeded the criterion in only 1 percent of the stream samples and only in the UT watershed; therefore, aluminum exceedences seem to be almost exclusively associated with suspended solids. Total lead exceeded the most stringent criterion in 8 to 16 percent of the stream samples and was generally the next most frequently exceeded criterion after total aluminum. Dissolved lead exceeded the criterion in 1 to 6 percent of the stream samples and was second only to copper for frequency of exceedence for dissolved elements. Total manganese exceeded the criterion in 15 percent of the stream samples from the SFK and UT watersheds, in 3 percent of the samples from the NFK watershed, and in none of the samples from the KC watershed. Similar to aluminum, manganese exceedences appear to be associated with suspended solids. Concentrations of total antimony, cadmium, iron, mercury, and zinc for the stream samples rarely exceeded the criteria (0.3 to 4 percent).

In samples from lakes and seeps, exceedences of the most stringent maximum criteria included total and dissolved aluminum, total and dissolved copper, total and dissolved iron, total and dissolved nickel, total and dissolved lead, total and dissolved cadmium, and dissolved manganese.

Cyanide was occasionally detected in the surface water samples. Total cyanide was detected in 2 to 15 percent of all samples, and weak acid dissociable cyanide was detected in 5 to 13 percent of all samples, depending on whether the samples were collected from streams, lakes, or seeps. Concentrations of weak acid dissociable cyanide in samples were compared with the most stringent ADEC maximum criterion and exceeded this criterion in 1 to 3 percent of the stream samples, depending on the watershed.

Dissolved organic carbon was detected in 93 to 100 percent of the stream samples, and the mean concentrations ranged from 1 to 2 milligrams per liter, depending on the watershed.

Concentrations of petroleum hydrocarbons, volatile and semi-volatile organic compounds, polychlorinated biphenyls, and pesticides were not detectable above the method reporting limit.

9.2.2 Mine Study Area—Groundwater

Thirty-nine groundwater wells of depths up to 200 feet were installed in the mine study area. One deep drillhole (DH-8417) was used for sampling at depths ranging from 640 to 4,050 feet. The results for groundwater are discussed here as median values for individual wells. Most groundwater samples from depths of 200 feet or less were typically characterized by median levels of TDS less than 100 milligrams per liter (comparable to surface water), median pH values between 5.8 and 7.4, median DO concentrations greater than 8 milligrams per liter, and concentrations of trace elements below the most stringent ADEC water quality maximum criteria. Concentrations of TDS in groundwater generally decreased with distance from the deposit area. Monitoring well MW-14D in the SFK watershed was the only well with a relatively high TDS level that was not consistent with this general pattern. Most of the groundwater samples had a composition that ranged from calcium-bicarbonate to calcium-magnesium-bicarbonate to calcium-sodium-bicarbonate. Some samples from relatively close to the deposit area had a higher proportion of sulfate, suggesting that the groundwater in this area is influenced by oxidation of the sulfide minerals that are associated with the deposit. As the sulfide minerals oxidize, iron, sulfate acid, and probably trace elements are released. The acid is neutralized by carbonate minerals such as calcite and dolomite, which release calcium, magnesium, manganese, carbonate, and usually some trace elements. This series of geochemical reactions increases the concentration of TDS and the proportion of sulfate in the groundwater.

Although sulfides appear to be oxidizing in the deposit area, the groundwater is not acidic. The lowest median pH values were 4.9 and 5.3. All other median pH values were greater than 5.8. Eight of the wells (six completed in overburden, two in bedrock) had median pH values greater than 7.0, and three of these wells (all completed in overburden) had the highest median TDS concentrations.

The DO measured in the groundwater was usually quite high. Twenty-seven of the 39 wells had median DO concentrations of 8 milligrams per liter or greater, which suggests that the aquifer solids in most of the study area do not include abundant reducing agents such as organic carbon or sulfide minerals. Short groundwater transit times through the aquifers may also help to maintain high DO concentrations. In general, the concentration of TDS was inversely correlated with the concentration of DO. TDS and sulfate concentrations were generally positively correlated with the concentration of calcium. Furthermore, the highest concentrations of iron and manganese tended to occur in samples that had a DO concentration of less than 1 milligram per liter. These correlations among parameter are all consistent with the interpretation that relatively high TDS might be due to oxidation of sulfide minerals.

The wells with relatively high TDS also generally had relatively high concentrations of arsenic, barium, and molybdenum compared with other wells in the study area. All of the wells with more than two trace metals at relatively high concentrations were located closer to the deposit area.

Early in the sampling record, several wells had decreasing concentrations over time, indicating that the geochemistry around the wells was equilibrating during that time. Well MW-14D in the SFK watershed was the only well that had many parameters with concentrations that increased consistently year to year throughout the sampling record. A few wells, such as well MW-12D, had a few parameters that increased slightly over time.

Some systematic differences in concentrations were observed with depth, as indicated by the differences in concentration between wells that were completed in overburden and those that were completed in bedrock. Specifically, the concentrations of antimony, arsenic, copper, iron, manganese, and molybdenum tended to be higher in wells in bedrock than in those in overburden. Conversely, the concentrations of DO and nickel tended to be lower in wells in bedrock than in wells in overburden.

A single round of deep groundwater samples was collected during hydraulic testing from drillhole DH-8417 at eight depths ranging from 640 to 4,050 feet. The TDS levels in these samples increased with depth from about 200 milligrams per liter from a depth of 640 feet to a range of 1700 to 2200 milligrams per liter from depths between 2000 and 4000 feet. The sample collected at 640 feet was of the calcium-bicarbonate type, similar to samples from the shallow wells located away from the deposit area. The samples collected from depths of more than 640 feet were of the sodium-calcium-sulfate type. This composition is distinct from the shallower groundwater samples, which consistently had a lower proportion of sodium and almost always had a lower proportion of sulfate.

9.2.3 Transportation-corridor Study Area—Surface Water

Sixteen surface-water sampling stations were established and sampled in the transportation-corridor study area during 2004 and 2005. The surface water sampled at these stations was characterized by low levels of TDS (2 to 126 milligrams per liter), mostly near-neutral pH (4.6 to 8.8), and high DO concentrations (9 to 19 milligrams per liter). During months when surface water samples were collected, the temperature ranged from 0.1ºC to 23ºC. The full annual range of water temperatures could not be characterized because samples were not collected during November, December, or January. The cation composition of the water samples was dominated by calcium. The anion composition was typically dominated by bicarbonate, but some samples were dominated by sulfate. The water composition at most stations was consistent between sampling events, but a few stations had an anion composition that varied over time. Concentrations of nutrients were low; specifically, most ammonia and phosphorous concentrations were below the method reporting limit. Total nitrate+nitrite averaged 1 milligram per liter. Concentrations of the trace elements aluminum, copper, lead, and zinc were above the most stringent ADEC maximum criterion in a few cases.

9.2.4 Transportation-corridor Study Area—Drinking Water Wells

Drinking water samples from the transportation-corridor study area were collected from four drinking water wells: Nondalton City Well, Newhalen Public Well #2, Iliamna Weathered Inn Well, and the Pedro Bay Tribal Council Well. Five samples were collected from each well from July 2004 through October 2005. The mean concentration of TDS, by well, ranged from 57 to 100 milligrams per liter. The water composition of the samples from the Iliamna Weathered Inn, Nondalton, and Pedro Bay wells was classified as calcium-bicarbonate, and water from the Newhalen well was classified as sodium-bicarbonate. Nutrient concentrations were low; specifically, mean concentrations of nitrite+nitrate ranged from 0.23 to 0.40 milligrams per liter, and mean concentrations of phosphorous ranged from 0.05 to 0.07 milligrams per liter. The results for most parameters were within the limits of the ADEC drinking water standards (DWS). Arsenic and field pH were the only parameters that did not meet the DWS. For total and dissolved arsenic, the results for all samples collected from the Nondalton well were above the DWS, and the results for one sample from the Pedro Bay well were above the DWS. Most of the samples collected had pH results outside the DWS range.

9.2.5 Iliamna Lake

Nine sampling sites for the Iliamna Lake study were selected based on their proximity to the transportation-corridor study area and populated villages. Not all sites were sampled every year, but samples were collected during 2005, 2006, and 2007. The sample data suggest that Iliamna Lake has water-quality conditions similar to the natural conditions of other regional lakes. Only aluminum, copper, iron, lead, manganese, zinc, and alkalinity were detected at concentrations that were outside the most stringent ADEC water quality criteria. Cation and anion dominance was generally characteristic for temperate lakes. Concentrations of major ions did not vary with depth, suggesting that the water at the sampling sites were well mixed. The concentrations of several major ions and TDS were lower earlier in the summer, peaked in September, and declined again in October. These temporary increases may be associated with the influence of inflow from streams and precipitation. Samples from Pile Bay and Knutson Bay tended to have similar concentrations, which were usually higher than samples from the other three sites.

Using a multi-probe meter to measure in situ water conditions in the North Fork Koktuli River during early spring.

Collecting water quality samples from the South Fork Koktuli River during late summer.

Collecting groundwater samples and measuring in situ water conditions in March.

10. TRACE ELEMENTS

10.1 Introduction

The trace element studies in the Bristol Bay drainages study areas were conducted to acquire baseline data on naturally occurring constituents in upland soil, terrestrial and aquatic plants, freshwater stream and pond sediment, and freshwater fish tissues. Samples of these media from all locations were analyzed for physical and chemical parameters and inorganic constituents; a subset of samples was analyzed for organic compounds as well.

The objectives of the trace element studies were as follows:

- Collect baseline data to provide scientific documentation of the existing levels of trace elements, anions, and cations in surface soil, subsurface soil, fruit (e.g., berries) and/or vegetative (e.g., leaf) tissues from terrestrial plants, aquatic vegetation, stream and pond sediment, and freshwater fish tissues.
- Evaluate the baseline data to identify major factors influencing the distributions of naturally occurring constituents.
- Evaluate naturally occurring biogenic fingerprints in surface soil associated with petroleum-range-hydrocarbon analysis.
- Determine organic content in surface and subsurface soils.

Upland soil was sampled in the summer in 2004 through 2007. Two hundred fifty-three soil samples were collected from 117 locations in the mine study area, including 16 subsurface samples collected at approximately 10 percent of these locations.

Plants also were sampled in the summer in 2004 through 2007. Fifty-one species of plants were sampled from approximately 70 locations in the mine study area; samples from terrestrial plants were collected during two seasons in 2005 through 2007 to represent early vegetative growth and late-season fruit production, while samples were collected only in autumn in 2004. Fruit and vegetative-tissue samples were evaluated separately. Aquatic plants were sampled in autumn in 2005 through 2007. Analyses were completed on 707 vegetative-tissue samples (from terrestrial and aquatic plants) and 80 fruit samples (from terrestrial plants). All plant-sampling locations were collocated with soil- or sediment-sampling locations. Plant species sampled were those known to be used as browse by animals or for subsistence purposes by humans.

Freshwater sediment sampling was conducted annually in 2004 through 2007. In the mine study area during those years, 109 samples were collected from 23 river locations (large drainages), and in 2004, 21 samples were collected from 15 locations identified as minor drainages. In 2005 through 2007, 56 samples were collected from 25 lakes and ponds. Twelve seep samples were collected from nine locations in 2005.

Fish were collected in the mine study area from the North Fork Koktuli River, South Fork Koktuli River, Upper Talarik Creek, and several large lakes. Samples were collected from lakes each year from 2004 through 2008; samples were collected from each of the three rivers in 2004 and 2005, and from a subset of these rivers in 2006 through 2008. In 2004 and 2005, 345 whole-body fish samples were collected from rivers. In 2004 through 2008, 236 muscle and 87 liver samples were collected from lakes and rivers. Six fish species were sampled: coho salmon, Chinook salmon, arctic grayling, northern pike, Dolly Varden, and whitefish.

In the transportation-corridor study area, 17 locations were sampled for soil and vegetation in 2004, and 17 soil samples, 131 vegetative-tissue samples, and 10 fruit-tissue samples were collected. For sediments, in 2004 and 2005, 55 samples were collected from three streams, and 25 samples were collected from 15 locations in five lakes. For fish, 63 whole-body samples were collected from three streams and two species (coho salmon and Dolly Varden).

10.2 Results and Discussion

The study of soil and plants in the mine study area demonstrated that concentrations of all 26 trace elements for which samples were analyzed were above detection limits in soil samples, and most elements were similarly detected in plant tissues. Elements varied widely in concentration across sampling locations and also in their relative abundance in a given location. Both landform type (e.g., talus slope, flood plain) and habitat (e.g., alpine rock, riverine willow scrub) influenced the elemental concentrations in soil and plants. Somewhat stronger relationships were observed between habitat type and chemical concentrations in vegetation than between landforms and chemical concentrations in vegetation, although consistent, significant correlations for a given category and a single chemical were not apparent. In soil, aluminum and iron were the most abundant elements, with mean concentrations of 17,644 and 20,69400 milligrams per kilogram, respectively. Both diesel-range organics and residual-range organics were detected in 13 and all 23 samples analyzed for these constituents, with mean concentrations of 209 and 2,028 milligrams per kilogram, respectively. Since no development was present in the area where these soil samples were collected, the petroleum-range hydrocarbons detected were assumed to originate from biogenic sources, as confirmed by evaluation of the analytical fingerprint. Total organic carbon was detected at an mean concentration of 6.51 percent. It also was noted that cyanide was present at low levels in most samples.

For plants, shrubs were sampled most often (300 samples) and trees least often (17 samples). All of the 26 trace elements for which samples were analyzed were detected in at least some vegetative-tissue samples. Eleven trace elements (aluminum, barium, calcium, cobalt, copper, iron, magnesium, manganese, nickel, potassium, and zinc) were present above minimum detection limits in almost all samples. Differences in elemental concentrations were apparent across plant species and between vegetative and fruit tissues of individual species. One species of moss (green terrestrial moss) had substantially higher mean concentrations of several trace elements than did other plant species. In general, mosses and lichens had higher concentrations than other plant species. It was of interest that naturally occurring cyanide was detected at low levels in 37 percent of vegetative-tissues samples and 25 percent of fruit-tissue samples. The highest concentrations of cyanide occurred in the vegetative tissues of the herb sour dock. There were significant differences in concentrations of metals, anions, and cations between vegetative and fruit tissues. Both crowberry and low bush cranberry samples shared several of the same elements with significant differences. The common elements included barium, copper, manganese, and zinc. Each of these elements, except copper, was found at higher concentrations in vegetative tissues than in fruits.

Overall, 198 sediment samples were collected in ponds, seeps, and minor drainages in the mine study area and were analyzed for trace elements, anions, and cations. All trace elements, anions, and cations for which analyses were done were detected in sediment samples. The most abundant elements in sediment were aluminum, calcium, iron, and magnesium, each with mean concentrations of over 3,500 milligrams per kilogram. Mercury was detected at the lowest concentrations in sediment (mean concentration of 0.040 milligrams per kilogram). A subset of samples from some locations was also analyzed for acid-volatile sulfide, simultaneously extractable metals, and organic constituents, to evaluate bioavailability. Evaluation of the results indicated a wide variability of concentrations in sediment among drainages and different types of waterbodies. For 11 trace elements included in a cross-drainage evaluation (arsenic, barium, cadmium, copper, lead, mercury, manganese, nickel, silver, vanadium, and zinc), concentrations were generally lowest in samples from the North Fork Koktuli River. Concentrations of arsenic, cadmium, copper, lead, manganese, silver, vanadium, and zinc were highest for the South Fork Koktuli drainage, whereas concentrations of barium, mercury, and nickel were highest for the Upper Talarik drainage. Only copper showed significant differences between all three major drainages, likely as a result of differential composition of the base rock across these drainages.

For anions and cations, sediment samples from ponds and minor drainages typically had higher concentrations than samples from other areas in the mine study area. Shallow soils transported by runoff into standing or slow-moving water are more likely to settle out as sediment, thus contributing to this trend. This was exemplified in samples where mean concentrations of cyanide were 17 times higher in samples from minor drainages relative to samples of river, seep, or pond sediments. These results are also consistent with the hypothesis that cyanide is being produced by bacteria in shallow soils. Samples from seeps had lower concentrations of cyanide than other sediment samples. Seep samples represent primarily groundwater, and thus there is no source of cyanide production in these sample locations. The different major drainages, ponds, seeps, and minor drainages had different signatures of natural levels of trace elements and anions.

The freshwater study of fish in the mine study area indicated that samples from all sampled fish species (northern pike, Dolly Varden, arctic grayling, coho and Chinook salmon, and whitefish) contained detectable levels of most of the 14 trace elements for which fish tissues were analyzed, including methyl-mercury. Some fish samples had whole-body analysis (345 samples) while for others only liver (87 samples) and/or muscle (236 samples) tissues were analyzed. Copper and zinc were present at the highest concentrations in whole-body samples across the different drainages. A wide variability of elemental concentrations was apparent over time and among drainages, fish species, and tissue types.

Trace element concentrations in whole-body samples were compared between fish species and between major drainages. Concentrations for various elements differed between species in each river and between rivers for each species. For example, the mean nickel concentrations for fish from the North Fork Koktuli River were higher than the mean concentrations for either the South Fork Koktuli River or Upper Talarik Creek in both 2004 and 2005. The combined 2004-2005 mean nickel concentration for whole-body fish samples from the North Fork Koktuli River (3.63 milligrams per kilogram) was almost five times higher than that for samples from the South Fork Koktuli River (0.76 milligrams per kilogram). Also, the variability of nickel concentrations observed in samples from the North Fork Koktuli River was not evident in samples from the South Fork Koktuli River. Additionally, copper concentrations were significantly higher in coho and Chinook salmon (whole fish) from the South Fork Koktuli River than in salmon from either of the other two major river systems. The higher copper concentrations in the South Fork Koktuli River were expected because copper-rich bedrock is located in the headwaters of that watershed. This copper-rich bedrock results in substrate that is higher in copper than the substrate in other areas. Fish take up the copper through respiration. Since higher concentrations of copper are present in the rock and surface water in this area, more copper is taken up by the fish in these areas. Elemental concentrations were typically higher in liver tissue than in muscle tissue, sometimes substantially. The different major drainages, as well as different fish species, have different signatures of natural levels of trace elements, although element uptake from sediment appears to be generally similar among rivers.

In the transportation-corridor study area, the results of soil, plant, sediment, and fish sampling and analyses were generally consistent with those described above for the mine study area. In sediment, the results indicate that ponds and streams have different signatures of natural levels of some trace elements, anions, and cations. The differences may be related to the constant movement of water in streams compared to the lack of flow in ponds. This lack of flow may allow some naturally occurring constituents to build up in sediments over time, particularly those that bind to particulates and/or are less soluble in water and thus more likely to remain in sediment. This is evident for ammonia (as nitrogen) and selenium, which were present in pond sediment at five and three times greater mean concentrations, respectively, than in rivers and for iron, potassium, manganese, and copper, which had mean concentrations in stream sediments that were more than twice their mean concentrations in ponds. For fish and plants, fewer total samples, and in particular, fewer samples for individual plant and fish species, precludes identification of clear correlations or trends. However, analysis of the data for fish demonstrated that elemental concentrations in fish from Red Creek were often different than concentrations in fish from either Bear Den Creek or Ursa Creek. Since only Dolly Varden were collected in Red Creek and only coho salmon were collected from the other two creeks, it is not possible to establish whether this difference is related to differences between the habitats or to other factors, such as species-specific differences in uptake.

Overall, analysis of the trace element data collected from 2004 through 2008 showed low concentrations of constituents as would be expected based on the general known history of the Bristol Bay drainages study area as an area with virtually no recent development. However, some constituents were detected in samples at concentrations above the most conservative level that may cause a biological response, as reported in the literature. The detected concentrations are ascribed to natural conditions and are documented as existing conditions at the time of the study.

Field sampling site overview, July 2006.

Sampling-location staking with site identification number, July 2006.

Field crew conducting vegetation survey, July 2005.

Organic mat removed, preparing for soil sample collection by removing stones and twigs, July 2006.

11. GEOCHEMICAL CHARACTERIZATION

11.1 Introduction

The objectives of the geochemical characterization program are to predict the weathering and leaching behavior of materials that would be produced during typical mining and processing. The data produced from geochemical testing can be used to predict the chemistry of pore water in mine rock and representative tailings and to evaluate ML/ARD potential in any proposed operation and closure plans for mine-waste disposal in this area.

Samples for testing were selected to ensure that all the main Pebble Deposit rock types and that any lateral, vertical, and geochemical variability were represented. To date, as of 2010, the program had included analysis of over 600 rock samples from the Pebble West Zone, almost 400 rock samples from the Pebble East Zone, and 26 samples of overburden materials. In addition, almost 60 representative tailings samples from test processing of ore composites have been characterized.

Samples have been tested for mineralogical composition, acid rock drainage (ARD) potential (acid-base accounting), chemical composition, and contaminant mobility. Tests for the latter have included water contact tests, humidity cells, leach columns, and on-site field weathering (barrel) tests to evaluate rates of oxidation, acid generation, acid neutralization, and element leaching.

11.2 Results and Discussion

11.2.1 Rock

There are two main geological divisions at the site of the Pebble Deposit. The mineralization is hosted by sedimentary and volcanic rocks of pre-Tertiary age. After the copper and gold mineralization occurred, these rocks were partially eroded and later covered by other sedimentary and volcanic rock. These later Tertiary-age rocks do not contain economic mineralization.

Acid-base accounting has determined that pre-Tertiary mineralized rocks are dominantly potentially ARD generating (PAG). The acid potential is relatively high (sulfur content is typically more than 1 percent), and neutralization potential is limited. The majority of Tertiary cover and overburden materials have sulfur contents less than 0.1 percent and significant neutralization potential. These materials are typically classified as non-PAG. Results for the East and West Zones were broadly similar. Illustrative results of acid-base accounting for samples of pre-Tertiary mineralized rocks from the East Zone are shown in Figure 11-1.

To develop an understanding of weathering and leaching processes that might affect rocks exposed during mining (e.g., pit walls, stockpiled materials, waste rock), laboratory tests included humidity cell tests and subaqueous columns (Photo 11-1). Humidity cell test data were interpreted to estimate relative acid generation and neutralization rates, which in turn were used to define site-specific acid-base accounting criteria for segregation of PAG and non-PAG wastes. Based on the current interpretations, this criterion for both pre-Tertiary and Tertiary rock would be neutralization potential / acid potential = 1.6.

A second important waste management consideration is the time or delay to the onset of ARD. The delay occurs because, while waste materials may have a potential for generating ARD, they contain acid-neutralizing minerals that are not depleted instantly. The delay duration depends on the amount and availability of reactive neutralization potential and the rate at which this neutralization potential is depleted.

Based on data generated from humidity cell tests, samples with low neutralization potential to acid potential ratios (<0.1) would become acid within 2 years, whereas with neutralization potential to acid potential ratios of 1, the calculated time would be more than 20 years. Study of the characteristics of aged core materials (e.g., paste pH) suggested slightly longer times to acidification, up to 40 years. The calculations are consistent for laboratory and field conditions after consideration of differences in temperatures and suggest that for fully oxygenated mineralized pre-Tertiary rock, a decade or several decades might be expected to elapse before the onset of acidification.

Element release rates indicated by kinetic tests were mainly a function of leachate pH rather than the element content of the samples. Leaching of copper accelerated as pH decreased; therefore, the potential for metal release is linked to the potential for acid generation, and acid-base accounting data can be used to assess the potential for copper leaching. However, for some elements (e.g., arsenic, molybdenum, and selenium), release is significant under neutral pH conditions. Tests on some samples of Tertiary rock showed relatively elevated leaching of these elements under non-acidic conditions.

Qualitatively, the trends developing in the field tests (Photo 11-2) mirror those that have been observed in the laboratory tests.

11.2.2 Metallurgical Wastes

Ore processing, if based on a conventional flotation process to recover commodity-bearing sulfide minerals (chalcopyrite and molybdenite) followed by treatment of the pyrite for recovery of gold, would result in two tailings streams: a low sulfide bulk concentrate and a pyrite concentrate.

Low-sulfide bulk flotation tailings would be expected to have low potential to generate ARD provided the sulfide content remained below about 0.2 percent. Representative tailings from the East Zone have marginally greater ARD potential compared to representative tailings from the West Zone because of the lower carbonate mineral content of the former. In laboratory tests, element leaching from these low sulfide tailings occurred at low rates, and process supernatants were found to contain low levels of potential contaminants relative to water quality standards.

The pyrite concentrate would be expected to be PAG. To date, limited testing has been performed on the representative concentrate because possible designs for a metallurgical process are still at an investigative stage.

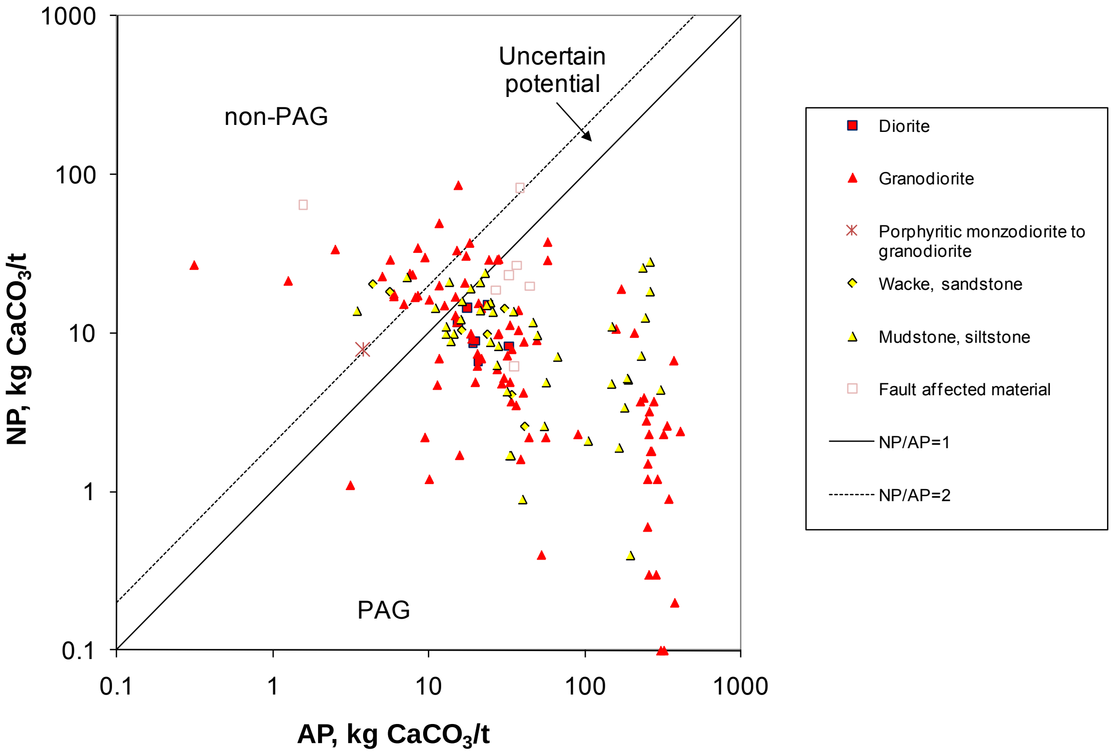


FIGURE 11-1
Acid-base accounting results for pre-Tertiary mineralized samples (Pebble East Zone)

AP = acid potential

$CaCO_3$ = calcium carbonate

kg = kilogram(s)

NP = neutralization potential

t = time

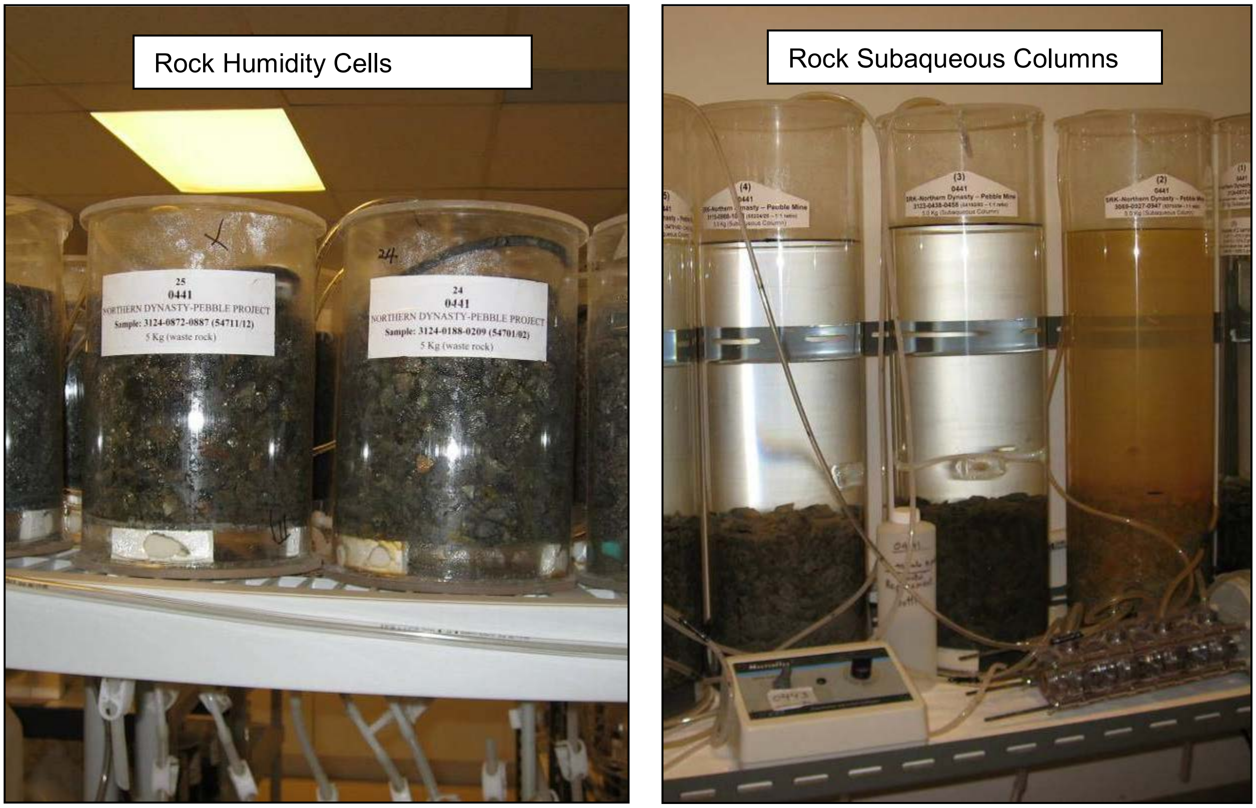


PHOTO 11-1. Laboratory tests included humidity cells and subaqueous columns.

PHOTO 11-2. Field weathering (barrel) tests were constructed on-site.

12. NOISE

12.1 Introduction

Because sound is a fundamental component of daily life, noise-monitoring surveys were conducted in and around the communities of Iliamna, Newhalen, Pedro Bay, and Nondalton (Figure 1-4 in Chapter 1, Table 12-1 below) to describe baseline noise levels and to characterize the existing noise environment.

All noise measurements were taken in accordance with guidelines from the American National Standards Institute (ANSI). Noise levels are stated in terms of decibels on the A scale (dBA). Examples of familiar sounds are shown in Table 12-2.

12.2 Results

While some sounds (e.g., floatplane takeoffs) registered very high on the dBA scale, these were only of short duration. A more useful measurement averages all sounds over a given period, e.g., an hour; therefore, the results below are reported in average hourly noise levels.

Overall, average noise levels in the four communities ranged from below 30 dBA to 63 dBA. Average noise levels on Newhalen River Road north of the Iliamna Airport ranged from 34 to 54 dBA, with noise near the airport ranging from 37 to 61 dBA. The average noise levels at the Iliamna post office, near the community medical center, ranged from 27 to 60 dBA. Noise levels near the Iliamna general store and along the shore of Iliamna Lake ranged from 32 to 62 dBA, with the highest averaged noise levels measured near the general store.

Noise levels in Newhalen ranged from 33 to 63 dBA, with the highest levels near the school. In Pedro Bay, noise levels ranged between 32 and 49 dBA. Measured wintertime noise levels in Nondalton ranged from below 30 to 51 dBA.

Overall, the measured noise levels in all four communities, and along the connecting roadways, were very similar to each other and to noise data taken in other parts of Alaska. Noise levels are in the range expected for rural areas with low population. Major noise sources included floatplanes, fixed-wing aircraft, helicopters, vehicle traffic including snow machines during winter and ATVs during summer, general construction and maintenance equipment, residential and community activities, birds, and wind. Some of the highest noise levels measured were the separate, short-term reference measurements of takeoffs by floatplanes, which ranged from 90 to over 100 dBA (classified as very loud to uncomfortably loud) along the waterfront in Iliamna.

TABLE 12-1
Sound Survey Locations, Number of Sites, and Survey Dates

Location	No. of Sites	Dates
Newhalen River Road	2	Winter: March 7, 2005 Summer: August 8 & 9, 2005
Iliamna Airport	1	Winter: March 7 & 8, 2005 Summer: August 9 & 10, 2005
Iliamna	3	Winter: March 8 – 10, 2005 Summer: August 8 & 10, 2005
Between Iliamna and Newhalen	1	Winter: March 7 & 8, 2005 Summer: August 9 & 10, 2005
Newhalen	2	Winter: March 8 & 9, 2010 Summer: August 9 & 10, 2005
Pedro Bay	4	Winter: March 8, 2005 Summer: August 11, 2005
Nondalton [a]	2	Winter: February 22 & 23, 2007

Note:

a. Wintertime survey only

TABLE 12-2
Typical Noise Sources and Equivalent dBA

Noise Source	Sound Level (dBA)	Subjective Impression
Recording studio	20	Just audible to very quiet
Soft whisper, library	30	Very quiet
Bedroom, bird calls	40	Very quiet to quiet
Light auto traffic (50 ft)	50	Quiet
Typical office	60	Quiet
Vacuum cleaner (10 ft)	70	Quiet to moderately loud
Garbage disposal (3 ft)	80	Moderately loud
Heavy truck / motorcycle (50 mph at 50 ft)	90	Moderately loud to very loud
Jet takeoff (2,000 ft)	100	Very loud
Float plane takeoff (100 ft)	110	Very loud to uncomfortably loud

Sources:

Beranek, Leo L. 1988. Noise and Vibration Control. Revised edition. Cambridge, Massachusetts: Institute of Noise Control Engineering.

U.S. Environmental Protection Agency, Office of Noise Abatement and Control. 1971. Transportation Noise and Noise from Equipment by Internal Combustion Engines. Washington DC. December.

Pedro Bay power plant as viewed from the school-ground play area.

Noise monitoring site in a Newhalen residential area.

13. VEGETATION—BRISTOL BAY DRAINAGES

13.1 Introduction

The vegetation study describes the predominant vegetation types found in the mine and transportation-corridor study areas in the Bristol Bay drainages. This information also helps to support wetland and habitat studies. The specific objectives of the vegetation study are as follows:

- Customize an existing vegetation classification system to include Project Vegetation Types amenable to photo-interpretation.
- Provide descriptions of Project Vegetation Types.
- Map Project Vegetation Types in the mine mapping area and transportation-corridor mapping area (within the respective study areas).
- Compile and document information on plant species observed.

The objectives and methodology used were essentially identical in the both the mine and transportation-corridor study areas. The vegetation study overlaps with and provides support for the wetlands study (as described below) and habitat mapping for terrestrial wildlife (Chapter 16, Section 16.1). Vegetation data were collected from 2004 through 2008 and were analyzed by Three Parameters Plus, Inc. and HDR Alaska, Inc.

Vegetation field data were collected as part of the wetland mapping program. Because the vegetation study was conducted as part of the wetland studies (Chapter 14), study sites were selected primarily to assist in the identification and mapping of wetlands and non-wetlands. Study sites also were selected to ensure data collection from each Project Vegetation Type across landscapes and soil types, as noted both on aerial photographs and while conducting field work.

Researchers analyzed vegetation data and aerial photo signatures to develop a system for describing and identifying Project Vegetation Types for the Pebble Project. This classification system (3PPI, 2008) is based on an existing standard vegetation classification system (Viereck et al, 1992; Wibbenmeyer et al, 1982) modified to accommodate interpretation of available aerial imagery. Forty-seven Project Vegetation Types have been defined in the Bristol Bay drainages study areas.

Vegetation mapping was completed for mapping areas of approximately 128,000 acres within the mine study area (Figure 13-1) and approximately 20,000 acres within the transportation-corridor study area (Figure 13-2).

Vegetation data collected at detailed-data collection plots included estimates of the percent cover of each plant species, site photographs, and initial classification of the Project Vegetation

Type. The classification system incorporated information on canopy cover, needleleaf versus broadleaf tree species, shrub height and density, and dominant species.

For clearer display on maps, the Project Vegetation Types in each study area were aggregated into 10 Grouped Vegetation Types based on the dominant structure and growth form (forested, shrub, or herbaceous), vegetation density (open or closed canopy), and average height (dwarf, low, or tall).

A list of observed vascular plant species was developed, including incidental observations of non-vascular plant species and species considered rare by the Alaska Natural Heritage Program. For rare species observations, supporting data were collected, and a plant sample (voucher specimen) was taken if the population was large enough to support loss of a specimen.

All data from the vegetation study have been entered into a relational database for the Pebble Project.

13.2 Results and Discussion

13.2.1 Mine Study Area

The mine study area is located within a continental climate characteristic of interior Alaska and consists of one ecological zone (low scrub shrub).

Researchers collected data at 16,947 sites in the mine study area. These included limited-data collection sites, detailed-data collection sites, and shrub height study sites. Researchers then compared vegetation data from the field and site photographs to aerial photo signatures to produce a vegetation map for the approximately 128,000-acre mine mapping area within the mine study area. Forty-five Project Vegetation Types were identified and described using information from 3,300 detailed-data collection plots within the mapped area.

Shrub vegetation types represented 81 percent of the area mapped, with dwarf shrub types being most common. Open water or unvegetated/sparsely vegetated land cover types represented 10 percent of the area, and herbaceous vegetation types represented about 9 percent. Forested vegetation types represented less than 1 percent of the area mapped. Table 13-1 lists the Grouped Vegetation Types for the mine mapping area, with the acreage of each and the percentage of the mine mapping area that each type comprises.

Three plant species tracked by the Alaska Natural Heritage Program have been confirmed within the mine study area.

13.2.2 Transportation-corridor Study Area

The transportation-corridor study area extends eastward from the mine study area, which has a continental climate and relatively gentle topography, and transitions to an area with a maritime climate and steep mountainous terrain. Because of these differences in climate and topography, the typical vegetation also transitions from west to east. Three ecological zones (woodland, forest, and mountainous shrubland) have been identified in the transportation-corridor study area based on scientists' observations in the field and visual review of the mapping.

Researchers collected data at 1,126 in the transportation-corridor study area. Detailed data were collected at 597 of these locations. The vegetation data collected in the field and site photographs were compared to aerial photo signatures to produce a vegetation map for approximately 20,000 acres. Forty-five Project Vegetation Types were identified in the transportation-corridor mapping area; 42 of these were the same as those found in the mine mapping area, but with different composition percentages.

Forested vegetation types represented 68 percent of the area mapped, with Open Mixed Forest being the most common type. Shrub vegetation types represented 24 percent of the mapping area. Herbaceous vegetation types and unvegetated cover types (including open water) each represented approximately 4 percent of the mapping area. Table 13-2 lists the Grouped Vegetation Types for the transportation-corridor mapping area, with the acreage of each and the percentage of the transportation-corridor mapping area that each type comprises.

Three plant species tracked by the Alaska Natural Heritage Program have been confirmed within the transportation-corridor study area.

13.3 References

Three Parameters Plus, Inc. (3PPI). 2008. Pebble Project Vegetation Type Photo Signature Guide, Draft Report. Version XVII. Palmer, AK. May.

Viereck, L.A., C.T. Dyrness, A.R. Batten, and K.J. Wenzlick. 1992. The Alaska Vegetation Classification. General Technical Report PNW-GTR-286. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. Portland, Oregon.

Wibbenmeyer, M., J. Grunblatt, and L. Shea. 1982. User's Guide for Bristol Bay Land Cover Maps. Bristol Bay Cooperative Management Plan. Alaska Department of Natural Resources and Alaska Department of Fish and Game, Anchorage, AK.

13.4 Glossary

Aerial photo signature—a unique texture, pattern, or color that vegetation has when captured in photographs taken from an airplane.

Herbaceous plants—plants that have leaves and stems that die to the soil level at the end of the growing season.

Non-wetlands—uplands and lowland areas that are neither aquatic habitats, wetlands, nor other special aquatic sites. Non-wetlands are seldom or never inundated, or if frequently inundated, they have saturated soils for only brief periods during the growing season, and if vegetated, they normally support a prevalence of vegetation typically adapted for life only in aerobic soil conditions.

Project Vegetation Types—dominant vegetation types that include typical plant-species composition and vegetation structure.

Voucher specimen—any specimen that serves as a basis of study and is retained as a reference; it should be in a publicly accessible scientific reference collection. For purposes of this study, voucher specimens of Alaska Natural Heritage Program tracked species were collected and sent to the University of Alaska, Fairbanks, herbarium for species verification.

Wetlands—areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands include swamps, marshes, bogs, and similar areas.

TABLE 13-1

Grouped Vegetation Types and their Acreages within the Mine Mapping Area, Bristol Bay Drainages

Grouped Vegetation Type	Acres [a]	Percent of Mapping Area [a]
Open/Closed Forest	438.9	0.3
Open Tall Shrub	5,143.9	4.0
Closed Tall Shrub	12,416.1	9.7
Open Low Shrub	16,758.6	13.1
Closed Low Shrub	1,612.2	1.3
Dwarf Shrub	67,579.4	52.9
Dry to Moist Herbaceous	6,706.7	5.2
Wet Herbaceous	4,695.1	3.7
Open Water	3,234.4	2.5
Unvegetated Cover Types	9,188.7	7.2
Total Mapping Area	**127,773.9**	**100.0**

a. All numbers are rounded. Apparent inconsistencies in sums are the result of rounding.

TABLE 13-2

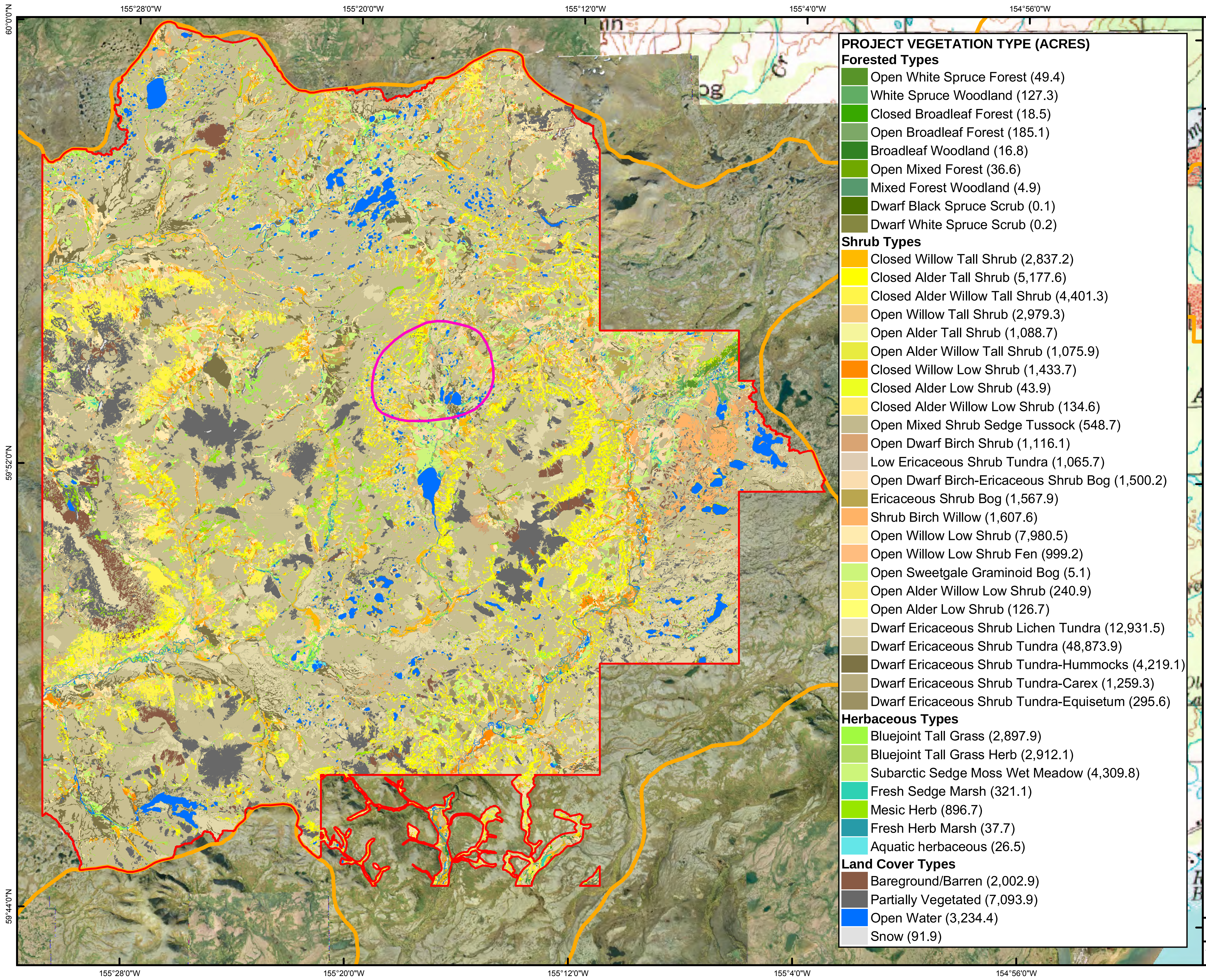
Grouped Vegetation Types and their Acreages within the Transportation-corridor Mapping Area, Bristol Bay Drainages

Grouped Vegetation Type	Acres [a]	Percent of Mapping Area [a]
Open/Closed Forest	13,627.0	68.4
Open Tall Shrub	628.2	3.2
Closed Tall Shrub	1,174.9	5.9
Open Low Shrub	1,505.6	7.6
Closed Low Shrub	61.8	0.3
Dwarf Shrub	1,407.5	7.1
Dry to Moist Herbaceous	258.4	1.3
Wet Herbaceous	523.8	2.6
Open Water	600.1	3.0
Unvegetated Cover Types	129.8	0.7
Total Mapping Area	**19,917.1**	**100.0**

a. All numbers are rounded. Apparent inconsistencies in sums are the result of rounding.

PHOTO 13-1. The most common vegetation type in the mine mapping area: Dwarf Ericaceous Shrub Tundra.

PHOTO 13-2. The most common vegetation type in the transportation-corridor mapping area: Open Mixed Forest.



PROJECT VEGETATION TYPE (ACRES)

Forested Types
- Open White Spruce Forest (49.4)
- White Spruce Woodland (127.3)
- Closed Broadleaf Forest (18.5)
- Open Broadleaf Forest (185.1)
- Broadleaf Woodland (16.8)
- Open Mixed Forest (36.6)
- Mixed Forest Woodland (4.9)
- Dwarf Black Spruce Scrub (0.1)
- Dwarf White Spruce Scrub (0.2)

Shrub Types
- Closed Willow Tall Shrub (2,837.2)
- Closed Alder Tall Shrub (5,177.6)
- Closed Alder Willow Tall Shrub (4,401.3)
- Open Willow Tall Shrub (2,979.3)
- Open Alder Tall Shrub (1,088.7)
- Open Alder Willow Tall Shrub (1,075.9)
- Closed Willow Low Shrub (1,433.7)
- Closed Alder Low Shrub (43.9)
- Closed Alder Willow Low Shrub (134.6)
- Open Mixed Shrub Sedge Tussock (548.7)
- Open Dwarf Birch Shrub (1,116.1)
- Low Ericaceous Shrub Tundra (1,065.7)
- Open Dwarf Birch-Ericaceous Shrub Bog (1,500.2)
- Ericaceous Shrub Bog (1,567.9)
- Shrub Birch Willow (1,607.6)
- Open Willow Low Shrub (7,980.5)
- Open Willow Low Shrub Fen (999.2)
- Open Sweetgale Graminoid Bog (5.1)
- Open Alder Willow Low Shrub (240.9)
- Open Alder Low Shrub (126.7)
- Dwarf Ericaceous Shrub Lichen Tundra (12,931.5)
- Dwarf Ericaceous Shrub Tundra (48,873.9)
- Dwarf Ericaceous Shrub Tundra-Hummocks (4,219.1)
- Dwarf Ericaceous Shrub Tundra-Carex (1,259.3)
- Dwarf Ericaceous Shrub Tundra-Equisetum (295.6)

Herbaceous Types
- Bluejoint Tall Grass (2,897.9)
- Bluejoint Tall Grass Herb (2,912.1)
- Subarctic Sedge Moss Wet Meadow (4,309.8)
- Fresh Sedge Marsh (321.1)
- Mesic Herb (896.7)
- Fresh Herb Marsh (37.7)
- Aquatic herbaceous (26.5)

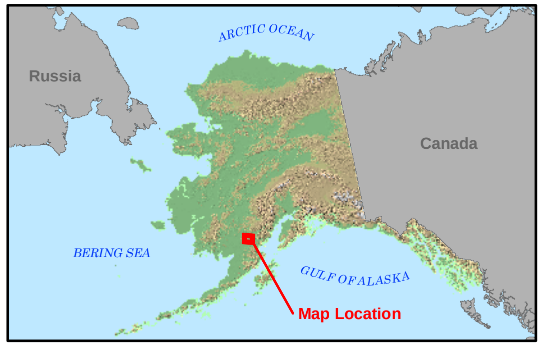
Land Cover Types
- Bareground/Barren (2,002.9)
- Partially Vegetated (7,093.9)
- Open Water (3,234.4)
- Snow (91.9)

THE pebble PARTNERSHIP

Figure 13-1
Vegetation Mapping in the Mine Study Area, 2004-2008

Legend

- Mine Mapping Area
- Mine Study Area
- General Deposit Location



Miles 0 1 2 3 4 5
Kilometers 0 1 2 3 4 5 6
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Scale 1:125,000
Alaska State Plane Zone 5 (units feet)
1983 North American Datum

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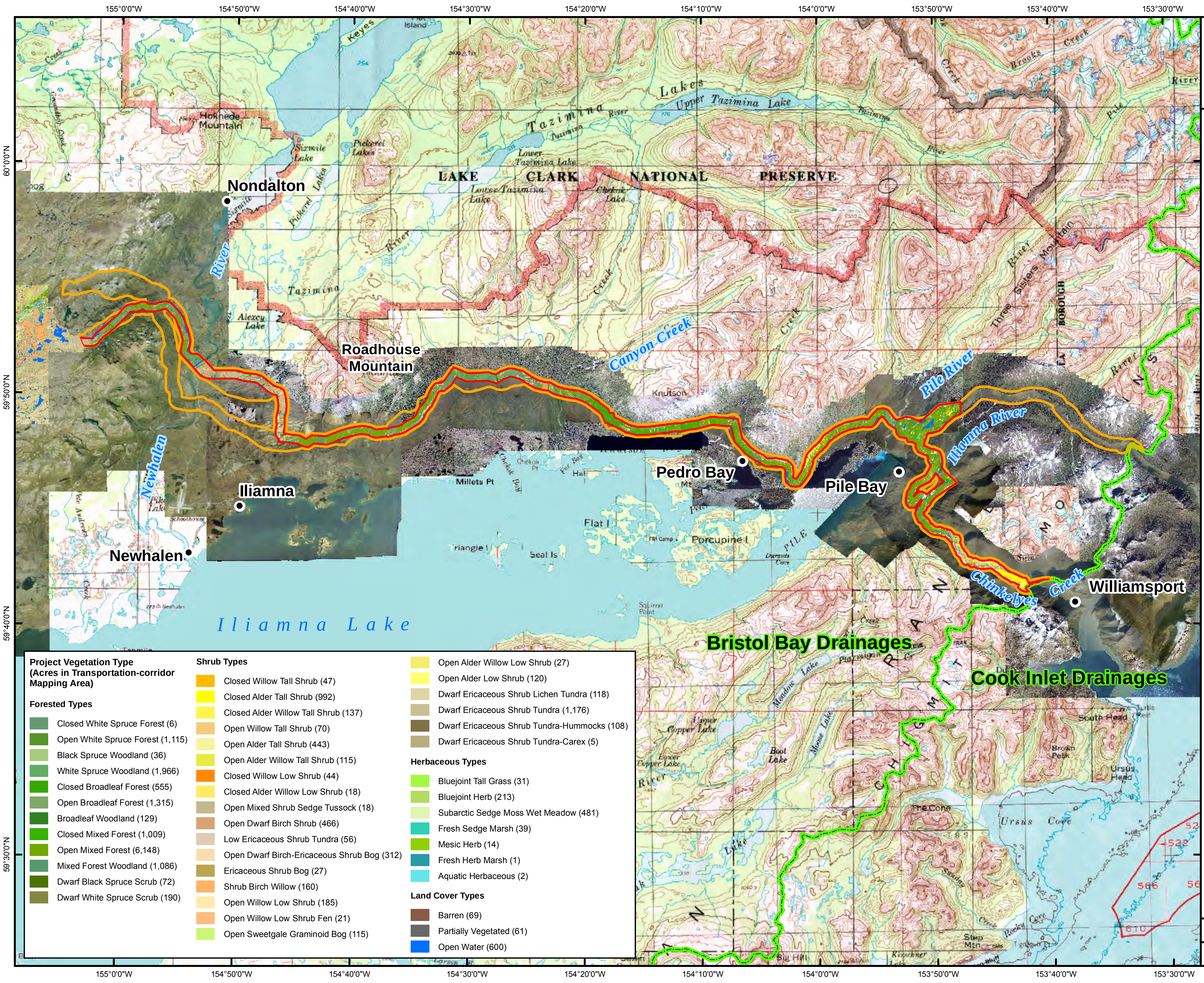
Version: 1	Author: RDI- LS

THE pebble PARTNERSHIP

Figure 13-2
Overview
Vegetation Mapping,
Transportation-corridor Mapping Area,
2004-2008



Project Vegetation Type (Acres in Transportation-corridor Mapping Area)

Forested Types

🟩 Closed White Spruce Forest (6)
🟩 Open White Spruce Forest (1,115)
🟩 Black Spruce Woodland (36)
🟩 White Spruce Woodland (1,966)
🟩 Closed Broadleaf Forest (555)
🟩 Open Broadleaf Forest (1,315)
🟩 Broadleaf Woodland (129)
🟩 Closed Mixed Forest (1,009)
🟩 Open Mixed Forest (6,148)
🟩 Mixed Forest Woodland (1,086)
🟩 Dwarf Black Spruce Scrub (72)
🟫 Dwarf White Spruce Scrub (190)

Shrub Types

🟧 Closed Willow Tall Shrub (47)
🟨 Closed Alder Tall Shrub (992)
🟨 Closed Alder Willow Tall Shrub (137)
🟧 Open Willow Tall Shrub (70)
🟨 Open Alder Tall Shrub (443)
🟨 Open Alder Willow Tall Shrub (115)
🟧 Closed Willow Low Shrub (44)
🟨 Closed Alder Willow Low Shrub (18)
🟫 Open Mixed Shrub Sedge Tussock (18)
🟫 Open Dwarf Birch Shrub (466)
🟫 Low Ericaceous Shrub Tundra (56)
🟧 Open Dwarf Birch-Ericaceous Shrub Bog (312)
🟫 Ericaceous Shrub Bog (27)
🟧 Shrub Birch Willow (160)
🟨 Open Willow Low Shrub (185)
🟧 Open Willow Low Shrub Fen (21)
🟩 Open Sweetgale Graminoid Bog (115)
🟨 Open Alder Willow Low Shrub (27)
🟨 Open Alder Low Shrub (120)
🟫 Dwarf Ericaceous Shrub Lichen Tundra (118)
🟫 Dwarf Ericaceous Shrub Tundra (1,176)
🟫 Dwarf Ericaceous Shrub Tundra-Hummocks (108)
🟫 Dwarf Ericaceous Shrub Tundra-Carex (5)

Herbaceous Types

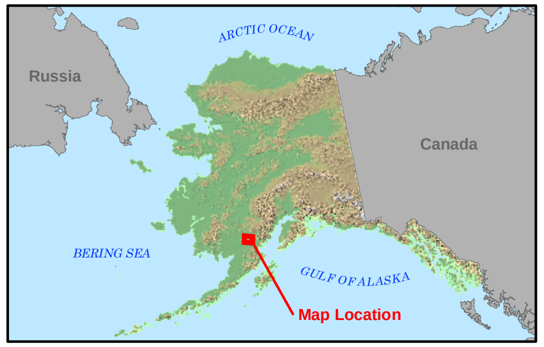
🟩 Bluejoint Tall Grass (31)
🟩 Bluejoint Herb (213)
🟩 Subarctic Sedge Moss Wet Meadow (481)
🟦 Fresh Sedge Marsh (39)
🟩 Mesic Herb (14)
🟦 Fresh Herb Marsh (1)
🟦 Aquatic Herbaceous (2)

Land Cover Types

🟫 Barren (69)
⬛ Partially Vegetated (61)
🟦 Open Water (600)

Legend

🟥 Transportation-corridor Mapping Area
🟧 Transportation-corridor Study Area
🟩 Bristol Bay/Cook Inlet Drainages Boundary
● Communities



Miles 0 2 4 6 8 10
Kilometers 0 5 10 15
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Scale 1:300,000
Alaska State Plane Zone 5 (units feet)
1983 North American Datum

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14. WETLANDS AND WATERBODIES

14.1 Introduction

A study to characterize wetlands and waterbodies and to determine their location and extent was conducted in the Bristol Bay drainages study areas. This study includes both the mine study area and the transportation-corridor study area in the Bristol Bay drainages. Data were collected throughout the two study areas; however, special emphasis was placed on a smaller mine mapping area (Figure 14-1) and transportation-corridor mapping area (Figure 14-2). The vegetation study (Chapter 13) provides data and mapping that are integral to the wetlands and waterbodies study. The study areas and mapping areas were scaled to provide coverage of potential development areas and alternative development areas as well as additional surrounding area to provide comparative context.

The objectives of the wetlands and waterbodies study are to determine and map the location and extent of wetlands and waterbodies in the mine and transportation-corridor study areas and to map the extent of human-caused disturbances of soil or vegetation.

Investigators from Three Parameters Plus, Inc., and HDR Alaska, Inc., conducted field work between 2004 and 2008. The study areas, transportation-corridor mapping area, investigators, and field work dates are the same as for the vegetation study (Chapter 13). The mine-area mapping area was smaller than for the vegetation study. Scientists evaluated wetland versus non-wetland status at field study sites representative of the major vegetation types and landforms in the study areas. Their methods at wetland determination plots followed the 1987 U.S. Army *Corps of Engineers Wetlands Delineation Manual* (USACE, 1987), which requires detailed analysis of site vegetation, hydrology, and soils. If the results of the analysis for each of those three parameters meet criteria that indicate wetland conditions, then the site is determined to be a wetland; otherwise, it is not.

Study sites were selected to sample unique vegetation signatures on aerial photographs and each major vegetation type across the full range of landscape positions. Wetland and non-wetland plots were sampled. Photo points were used to document additional wetlands and non-wetlands as a supplement to the more in-depth data-collection plots. Stream crossings and waterbodies were documented and water chemistry information was collected. If a plot was determined to be a wetland, then additional data were gathered for use in future analyses. Observations such as soil disturbance, habitat observations, or cultural sites also were recorded.

Wetland mapping used primarily a base map of 2004 and 2005 orthophotographs with 4-foot contours, derived from aerial photographs and light detection and ranging (LIDAR) imagery. Digital maps were drawn to a scale ranging between 1:1,200 and 1:1,500, and open water was drawn at 1:400. Wetland status was assigned to a polygon used in mapping after careful review of plot data, photo points, site photos, and other available data for area within the polygon. Data from plots in nearby or similar polygons also were evaluated when assigning wetland status.

Investigators collected vegetation data at the sampling plots to determine whether the vegetation was hydrophytic. The presence of hydric soil indicators was determined by digging a soil pit and recording standardized property data for each soil horizon. The soil sampling and documentation followed protocols outlined in the *Field Book for Describing and Sampling Soils* (Shoeneberger et al., 2002). Data regarding the presence of restrictive layers, soil temperature, oxidation reduction potential, and drainage class also were recorded. Data collected for wetland hydrology indicators included both surface observations and subsurface observations in the soil pit and soil profile.

During field data collection and wetland mapping, all wetlands were classified according to the hydrogeomorphic (HGM) classification system (Brinson, 1993). In addition, as part of data collection and mapping inventory for Pebble Project, wetlands and other aquatic habitats/waters were classified using Enhanced National Wetlands Inventory codes. This classification was based on *Classification of Wetlands and Deepwater Habitats of the United States* (Cowardin et al., 1979) and National Wetlands Inventory mapping conventions (USFWS, 1995). The resulting Enhanced National Wetlands Inventory mapping is much more detailed than the original National Wetlands Inventory effort for the mapping area.

Disturbance to soil and/or vegetation was noted in the mapping if there was evidence from field data or if the disturbance was visible on aerial photographs. Human-caused soil or vegetation disturbance in the study areas was minimal and appears to be limited to four-wheeler trails, campsites, roads, and building pads along existing roads.

14.2 Results and Discussion

The only previous wetland mapping in the study areas was partial and preliminary National Wetland Inventory coverage completed by the U.S. Fish and Wildlife Service in 1985. As part of the Pebble Project study, investigators collected data at approximately 17,000 locations in the mine study area and 1,126 locations in the transportation-corridor study area. Specific wetland data, including hydrology, soils, and vegetation, were collected at 1,059 plots in the mine mapping area and 597 plots in the transportation-corridor study area.

In total, 29,429.7 acres were mapped in the mine mapping area (Table 14-1) and 19,917.1 acres were mapped in the transportation-corridor mapping area (Table 14-2). Tables 14-1 and 14-2 list the mapped acreages of wetlands, waterbodies, and non-wetlands, grouped according to the U.S. Fish and Wildlife Service's National Wetland Inventory classification system, which is based largely on vegetation structure. The second and third columns in each table show the acreage of each type mapped in the Pebble Project study and the percentage of the mapping area that each type comprises. Scientists identified 9,825.6 acres of wetlands and waterbodies in the mine mapping area; thus, approximately 33.4 percent of the mine mapping area is wetlands or waterbodies. In the transportation-corridor mapping area, 2,425.6 acres were identified as wetlands or waterbodies; thus, approximately 12.2 percent of the transportation-corridor mapping area is wetlands or waterbodies. Some of the transportation-corridor mapping area has much steeper terrain than the mine mapping area, resulting in fewer wetlands and waterbodies.

The last two columns in Tables 14-1 and 14-2 list the acreages and percentages of the wetland, waterbody, and non-wetland types that had been mapped by the U.S. Fish and Wildlife Service in 1985. This National Wetlands Inventory mapping showed 21.8 percent of the mine mapping area and 9.2 percent of the transportation-corridor mapping area as wetlands or waterbodies. Comparison of the acreages shows that the Pebble Project study has identified 8.1 percent more of the combined mapping areas as wetland and waterbody acreage than did the less detail-scaled U.S. Fish and Wildlife Service effort.

According to the hydrogeomorphic wetland classification system (Table 14-3), which is based on landscape position and water source and dynamics, slope wetlands dominate the mine mapping area. This type is followed by riverine, riverine channel, flat, lacustrine, depressional, and lacustrine fringe wetland types. Slope wetlands also dominate the transportation-corridor mapping area, followed, in descending order, by depressional, riverine, flat, lacustrine, riverine channel, and lacustrine fringe wetland types.

14.3 References

Brinson, M.M. 1993. A Hydrogeomorphic Classification for Wetlands. Wetlands. Research Program Technical Report WRP-DE-4. U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS. August.

Cowardin L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C.

Shoeneberger, P.J., D.A. Wysocki, E.C. Benham, and W.D. Broderson. 2002. Field Book for Describing and Sampling Soils, Version 2.0. U.S. Department of Agriculture, Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE.

U.S. Army Corps of Engineers (USACE). 1987. Corps of Engineers Wetlands Delineation Manual. U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS.

United States Fish and Wildlife Service (USFWS). 1995. Photointerpretation conventions for the National Wetlands Inventory. National Wetlands Inventory Center, St. Petersburg, FL.

14.4 Glossary

Hydric soil—soil that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part.

Hydrophytic vegetation—vegetation typically adapted for life in saturated soil conditions.

Non-wetlands—include uplands and lowland areas that are neither deepwater aquatic habitats, wetlands, nor other special aquatic sites. They are seldom or never inundated, or if frequently inundated, they have saturated soils for only brief periods during the growing season, and if vegetated, they normally support a prevalence of vegetation typically adapted for life only in aerobic soil conditions.

Orthophotographs—digital imagery in which distortion from the camera angle and topography has been removed, thus equalizing the distances represented on the image.

Vegetation signature—a unique texture, pattern, or color that vegetation has when captured in photographs taken from an airplane.

Wetlands—those areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.

TABLE 14-1
Comparison of Wetland and Waterbody Acreages and Percentages Identified in the Mine Mapping Area by the Pebble Project Study and by the National Wetlands Inventory

	Pebble Project Mine Mapping Area		National Wetlands Inventory	
Grouped National Wetland Inventory Type	**Total Acres Mapped [a]**	**Percent of Mapped Area [a]**	**Total Acres Mapped [a]**	**Percent of Mapped Area [a]**
Total Forested Types	10.1	0.0	0.0	0.0
Total Shrub Types	6,648.5	22.6	5,036.4	17.1
Total Herbaceous Types	1,991.8	6.8	787.8	2.7
Total Wetlands Mapped	8,650.4	29.4	5,824.2	19.8
Total Waters Mapped	1,175.2	4.0	589.5	2.0
Total Wetlands and Waters Mapped	9,825.6	33.4	6,413.7	21.8
Non-Wetlands	19,604.1	66.6	21,970.0	74.7
No Mapping Coverage	n/a	n/a	1,046.0	3.6
TOTAL MAPPED	**29,429.7**	**100**	**29,429.7**	**100**

Note:

a. Apparent inconsistencies in sums within or between tables are the result of rounding.

TABLE 14-2
Comparison of Wetland and Waterbody Acreages Identified in the Transportation-corridor Mapping Area by the Pebble Project Study and by the National Wetlands Inventory

Grouped National Wetland Inventory Type	Pebble Project Transportation-corridor Mapping Area		National Wetlands Inventory	
	Total Acres Mapped [a]	Percent of Mapped Area [a]	Total Acres Mapped [a]	Percent of Mapped Area [a]
Total Forested Types	43.5	0.2	32.4	0.2
Total Shrub Types	1,244.9	6.3	786.4	3.9
Total Herbaceous Types	494.5	2.5	437.6	2.2
Total Wetlands Mapped	1,782.9	9.0	1,256.5	6.3
Total Waters Mapped	642.8	3.2	568.1	2.9
Total Wetlands and Waters Mapped	2,425.6	12.2	1,824.6	9.2
Non-Wetlands	17,491.5	87.8	18,092.6	90.8
TOTAL MAPPED	**19,917.1**	**100**	**19,917.1**	**100**

Note:

a. Apparent inconsistencies in sums within or between tables are the result of rounding.

TABLE 14-3
Hydrogeomorphic Classifications in the Bristol Bay Drainages Mapping Areas

	Mine Mapping Area			Transportation-corridor Mapping Area			Combined Mapping Areas
Hydrogeomorphic Type	**Number of Acres [a]**	**Percent of Mapping Area**	**Percent of Wetlands/ Waters**	**Number of Acres [a]**	**Percent of Mapping Area**	**Percent of Wetlands/Waters**	**Number of Acres [a]**
Slope	6,188.3	21.0	63.0	942.9	4.7	38.9	7,131.2
Riverine	2,120.4	7.2	21.6	317.5	1.6	13.1	2,437.9
Riverine Channel	511.1	1.7	5.2	199.5	1.0	8.2	710.6
Flat	469.8	1.6	4.8	263.3	1.3	10.9	733.1
Lacustrine	282.5	1.0	2.9	259.4	1.3	10.7	541.9
Depressional	222.3	0.8	2.3	430.5	2.2	17.7	652.8
Lacustrine Fringe	31.1	0.1	0.3	12.4	0.1	0.5	43.5
Total Wetlands and Waters	9,825.5	33.4		2,425.6	12.2		12,251.0
Total Non-wetlands	19,604.2	66.6		17,491.5	87.8		37,095.7
TOTAL MAPPING AREA	**29,429.7**	**100**		**19,917.1**	**100**		**49,346.8**

Note:

a. Apparent inconsistencies in sums within or between tables are the result of rounding.

A common wetland type in the mine mapping area: Subarctic Sedge Moss Wet Meadow with a grouped National Wetland Inventory classification of herbaceous. June 2006.

A common wetland type in the mine mapping area: Open Willow Low Shrub with a grouped National Wetland Inventory classification of shrub. September 2006.

A common wetland type in the transportation-corridor mapping area: Open Low Shrub Birch-Ericaceous Shrub Bog with a grouped National Wetland Inventory classification of shrub. July 2004.

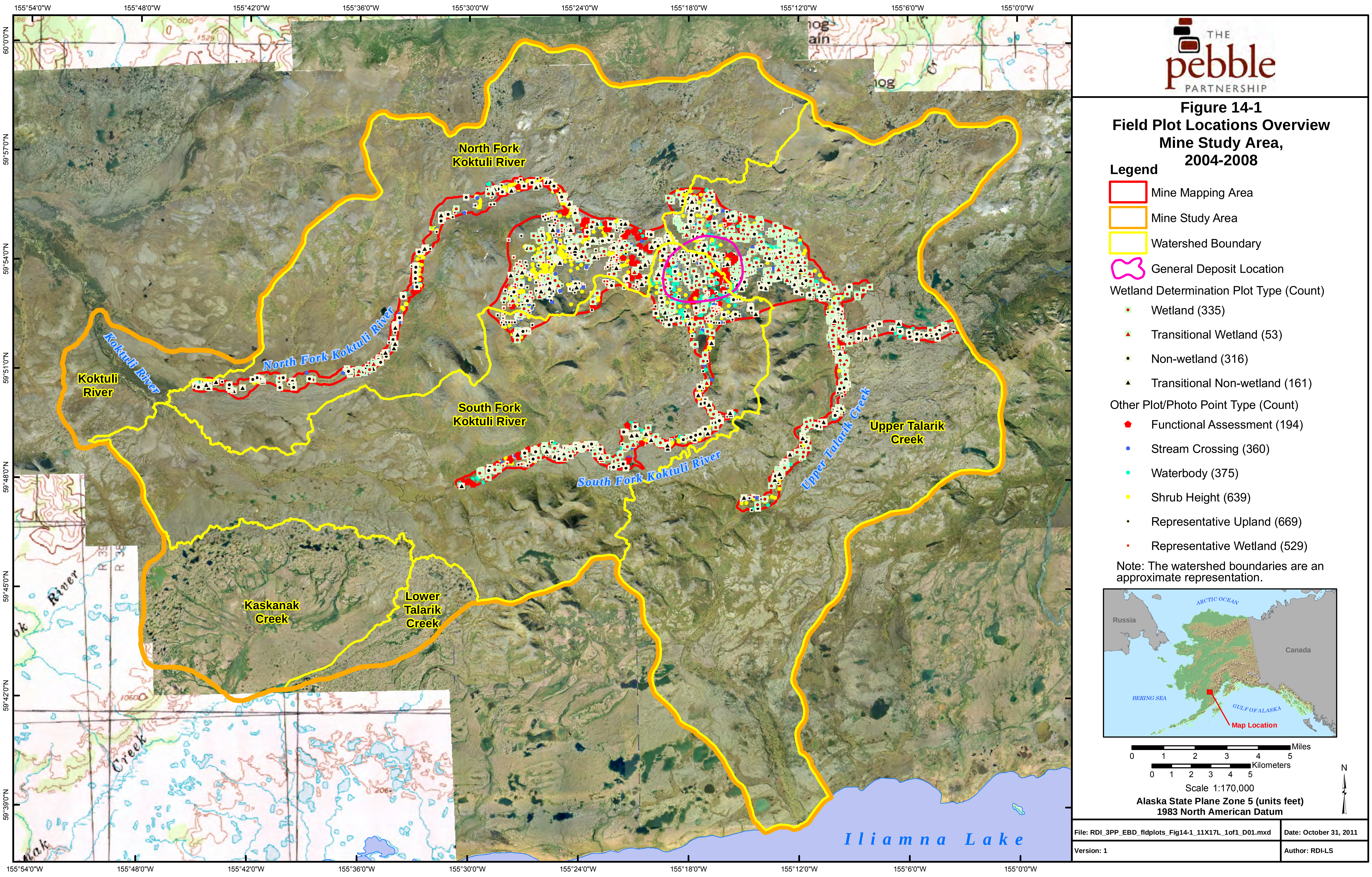

Figure 14-1
Field Plot Locations Overview
Mine Study Area,
2004-2008

Note: The watershed boundaries are an approximate representation.

Scale 1:170,000

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

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Version: 1	Author: RDI-LS

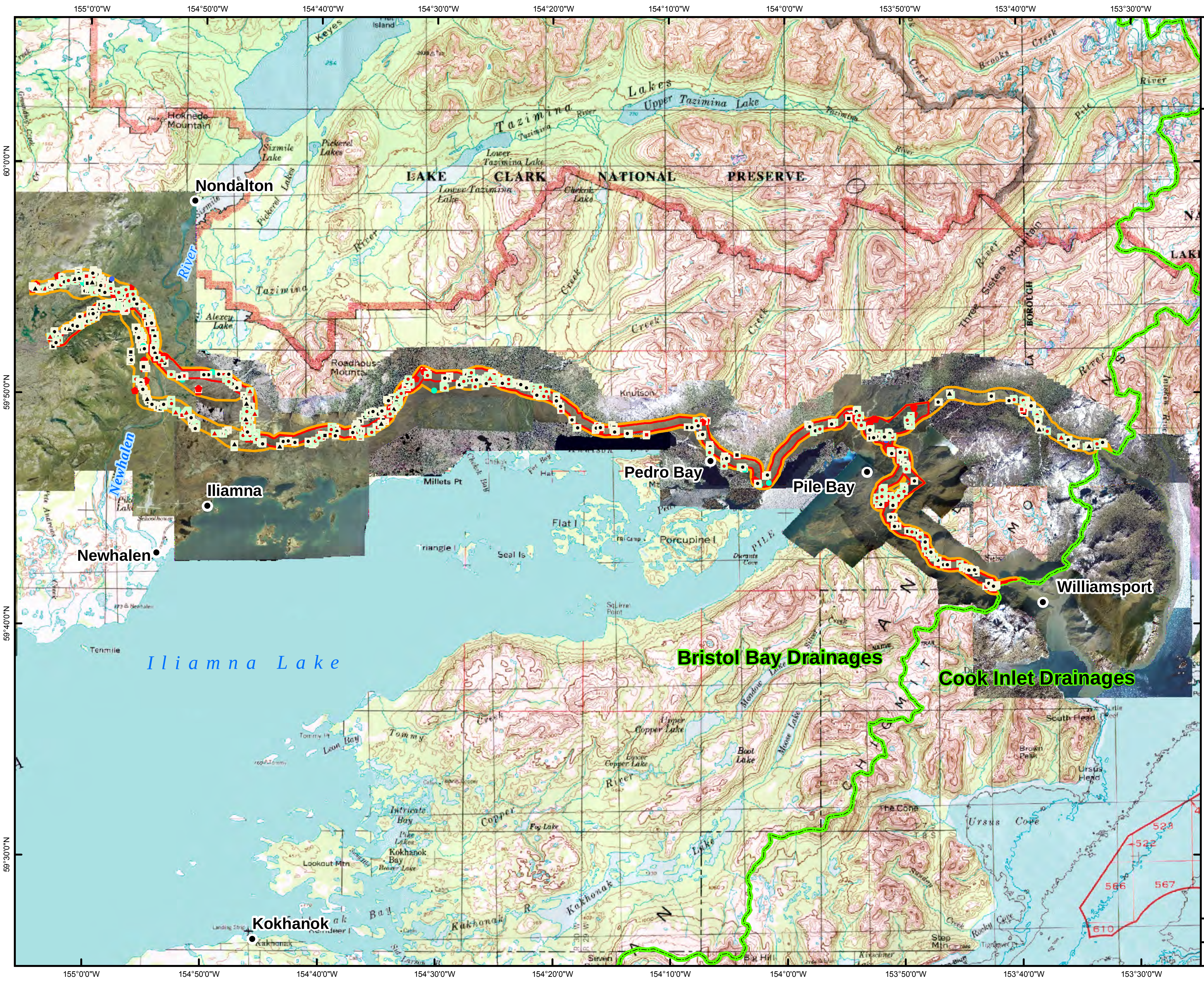


Figure 14-2
Overview
Field Plot Locations, Transportation-corridor Study Area, 2004-2008

Legend

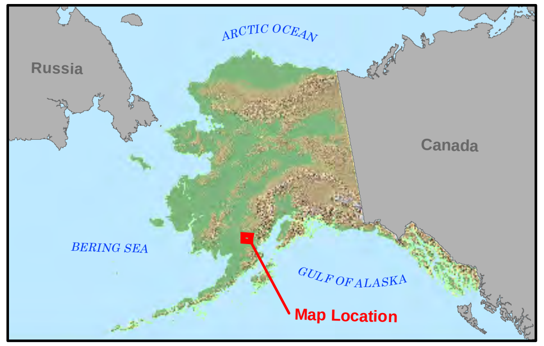
- 🟥 Transportation-corridor Mapping Area
- 🟧 Transportation-corridor Study Area
- ━ Bristol Bay/Cook Inlet Drainages Boundary
- ● Communities

Wetland Determination Plot Type (Count)

- ● Wetland (200)
- ▲ Transitional Wetland (20)
- ● Non-wetland (270)
- ▲ Transitional Non-wetland (37)

Other Plot/Photo Point Type (Count)

- ⬟ Functional Assessment (71)
- ● Stream Crossing (101)
- ● Waterbody (37)
- ■ Representative Upland (197)
- ■ Representative Wetland (192)



Scale 1:300,000
Alaska State Plane Zone 5 (units feet)
1983 North American Datum

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15. FISH AND AQUATIC INVERTEBRATES

15.1 Fish—Mine Study Area

15.1.1 Introduction

Fish studies were conducted to characterize aquatic habitat and fish assemblages and to support instream-flow modeling for the mine study area. The mine study area encompasses the North Fork Koktuli River (NFK), South Fork Koktuli River (SFK), and Upper Talarik Creek (UT) watersheds (or drainages; Figure 1-2a in Chapter 1), as well as the upper Koktuli River mainstem (KR) for a length of 29 miles (46 kilometers [km]). The NFK and SFK watersheds are relatively small and are within the Nushagak-Mulchatna River system, with the Nushagak River basin being one of eight major river basins (or regional drainages) draining southwest Alaska into Bristol Bay (Figure 15.1-1). The NFK and SFK rivers have mainstem lengths of 36 miles (58 kilometers [km]) and 40 miles (64 km), respectively. These rivers merge to form the KR, which flows for approximately 39 miles (62 km) before entering the Mulchatna River. From there, the Mulchatna River flows 44 miles (70 km) to the Nushagak River, which in turn flows approximately 109 miles (175 km) before discharging into Bristol Bay (Figure 1-1 in Chapter 1). UT flows for approximately 39 miles (62 km) before draining into Iliamna Lake, which ultimately discharges to Bristol Bay via the Kvichak River. The NFK, SFK, and UT watersheds each represent approximately 0.3 percent of the entire Bristol Bay drainage basin.

Thirteen fish resource studies were conducted in the mine study area from 2004 through 2008 (Table 15.1-1). Specific objectives of the fish resource studies were to characterize the following:

- Channel morphology and valley form in mainstem and tributary channels.
- Riverine habitat types (e.g., pools, riffles, and runs/glides) and their distribution throughout the river, as well as the amount of river and stream habitat available for fish.
- Locations of special habitat features (e.g., tributaries, springs, seeps, and possible barriers to upstream fish migration) that may influence fish distribution and abundance.
- Quality and quantity of off-channel habitat within representative off-channel habitat study areas.
- Patterns of fish distribution and relative abundance in mainstem, tributary, and off-channel habitats.
- Fish density among mainstem, tributary, and off-channel habitat types.
- Fish presence during winter months when ice conditions are present.
- Spatial and temporal distribution of adult anadromous salmon returning to and spawning in the mine study area.

- Annual abundance estimates of adult anadromous salmon.
- Relationships between streamflow and suitable fish habitat for target species at various life stages.
- The amount of fish habitat present under baseline flow conditions for target species at various life stages.
- Hydrologic relationships between mainstem channel flow conditions and off-channel habitats.
- Seasonal and longitudinal surface water-temperature regimes in mainstem channels.
- Flow-sensitive surface water-temperature models for mainstem channels.
- Fluvial geomorphic conditions in the study area, and to link potential changes in hydrology and drainage area through an evaluation of flow and channel-forming processes in mainstem channels.
- Spawning-gravel quality and other characteristics as influenced by flow and salmon-induced physical disturbance.

Aquatic-habitat data were collected primarily using survey protocols adapted from the U.S. Forest Service *Aquatic Habitat Management Handbook* (USFS, 2001). Supplemental habitat information was compiled from anecdotal field notes and remote-sensing data. The mesohabitat analysis was conducted using a combination of field surveys and remote-sensing analysis.

The fish distribution and relative abundance studies included extensive surveys to sample fish-bearing waterbodies within the mine study area, as well as several intensive studies to evaluate certain conditions (e.g., winter habitat use) or species behavioral patterns (e.g., the rainbow trout radiotelemetry study). In general, the fish distribution and abundance surveys were completed using similar sampling, species identification, and lifestage classification methods. The primary survey method for stream-dwelling fish was via direct underwater observation using snorkeling techniques. Other methods (e.g., electrofishing, minnow traps, beach seines, gill/tangle nets, angling, and dip netting) were used when sampling conditions were not conducive to snorkeling or when there was a need to physically capture certain fish for tagging and/or genetics/toxicity sampling.

Aerial helicopter surveys were used to quantify spawning salmon along the mainstem rivers and tributaries. Surveys were typically conducted from early July through October or November to capture the range of dates when adult Chinook, chum, coho, and sockeye salmon were present in the study area. The number of surveys conducted per year ranged from seven in 2004 to 26 in 2008. Annual mean index counts (Holt and Cox, 2008) were used to evaluate salmon abundance over the study period and among watersheds and to provide a first-order approximation of the relationship between counts in the NFK, SFK, and UT, and the Alaska Department of Fish and Game's Bristol Bay fisheries statistics.

Methods used for the instream-flow studies varied among the four main study components: mainstem channel flow habitat studies, off-channel flow habitat studies, water-temperature modeling, and fluvial geomorphic analysis. The mainstem channel flow habitat studies were conducted using the U.S. Fish and Wildlife Service's Instream Flow Incremental Methodology (IFIM), along with the companion suite of computer programs, Physical Habitat Simulation (PHABSIM; Bovee, 1982; Bovee et al., 1998). Selected off-channel habitats were surveyed for valley profile and water-surface elevation data to assess off-channel habitat connectivity to the mainstem channel under varying flow conditions. Continuous surface water-temperature data were collected from hydrology gaging stations and from thermistors deployed at several locations throughout the study area. These data were subsequently used to develop flow-sensitive surface water-temperature models based on the U.S. Fish and Wildlife Service's Stream Network Temperature Model (SNTEMP). Fluvial geomorphology studies included the collection of hydrologic, substrate, bank composition, and vegetation data. The fluvial geomorphology studies also included the collection of single bulk substrate samples at selected sites to assess fine sediment levels in the riverbed substrates and the monitoring of the movement of 19 radio-tagged rocks in the NFK from September 15 to 30, 2007.

In order to present the large volume of data collected in an ecologically meaningful framework, a reach analysis approach was used. The mainstem NFK, SFK, and UT were divided respectively into six, five, and seven reaches that were identified based on hydrology, geology, and channel morphology characteristics (Figure 15.1-2). Reach designations (NFK-A through NFK-F, SFK-A through SFK-E, and UT-A through UT-G) progress sequentially from downstream to upstream. Only a single reach was defined for the KR and was limited to the uppermost 29 miles (46.5 km) of the river. Because the KR reach is more than 31 miles (50 km) downstream from the Pebble Deposit, study efforts in the KR have been less intensive than those in the other three watersheds and have focused on instream-flow analysis and fish distribution. Each tributary to the mainstem NFK, SFK, or UT was assigned to a mainstem reach based on the location of the tributary's confluence with the mainstem, while off-channel habitats were assigned based on their proximity to the mainstem channel.

15.1.2 Results and Discussion

15.1.2.1 Anadromous Waters Catalog Nominations

The fish studies conducted from 2004 through 2008 resulted in the expansion of the known distribution of anadromous fish species in the mine study area and provided supporting information for existing anadromous fish streams. Using the Alaska Department of Fish and Game's 2009 anadromous waters catalog (ADF&G, 2010) as a baseline, 22 new anadromous fish streams (including eight, five, and nine streams in the NFK, SFK, and UT watersheds, respectively) were nominated to the catalog as a result of these study efforts. The known distribution of anadromous fishes was extended in an additional 14 streams, with five, two, and seven of those streams located in the NFK, SFK, and UT watersheds, respectively.

15.1.2.2 North Fork Koktuli River

Aquatic Habitat and Instream Flow

Analysis of the aquatic-habitat survey data indicates that the NFK mainstem was primarily a single-thread, gravel-bedded channel that was relatively straight in higher-gradient segments and meandered in lower-gradient segments. The three lowermost reaches (NFK-A, NFK-B, and

NFK-C) flowed through alluvial valley-bottom deposits consisting of abandoned stream terraces and deposits of reworked glacial outwash. Off-channel characteristics were indicative of past high-flow events that had overtopped the stream banks in NFK-A and extended flow into adjoining floodplains. In addition, riparian zones, wetland complexes, and off-channel habitats in NFK-A extended beyond the mainstem channel. For most of NFK-B, the channel flowed through a relatively narrow (approximately 1,525-foot long, 465-meter wide) valley bottom bordered by low hills. NFK-C flowed across glacial outwash and moraine deposits. NFK-D and NFK-E were generally lower gradient than the other reaches and flowed through a variety of different geologic types, including glacial outwash and a silt, ice-rich section. Coarse bedload from upstream did not appear to have been transported downstream of NFK-E, where the bed was composed predominantly of sand and silt. The uppermost reach, NFK-F flowed through alluvial and Brooks Lake drift deposits. The primary sources of sediment throughout the NFK were likely from undercut banks and lateral erosion that occurred during high flows and ice break-up processes. Tributaries were composed of both high- and moderate-gradient channels, as well as alluvial fan channels.

The hydrologic regime of the NFK has been dictated primarily by climate, geology, and groundwater influx, with streamflows driven by winter ice formation, runoff from spring snowmelt, and summer and fall rains. Except in losing reaches (reaches that lose water as the stream flows downstream), base flows tended to remain high because of deep soils and associated groundwater storage, as well as the large volume of water associated with lakes in the basin. Seasonal flows in the NFK had two peaks; the first peak occurred with spring snowmelt, and the second peak occurred with fall rains.

The mainstem NFK showed a pronounced interaction with groundwater. Upstream from NFK-C and in the upperstream portion of NFK-C, the river has been classified as a losing stream. In this area, the NFK flowed across unconsolidated outwash fan sediments with a high infiltration capacity, and the water generated by streamflow, precipitation, and snowmelt rapidly infiltrated into a shallow aquifer. The groundwater flowed down-valley and emerged at the downstream end of the glacial outwash deposits. The downstream third of NFK-C and a short stretch of NFK-B were gaining reaches (reaches that gain water as the stream flows downstream) that exhibited evidence of substantial groundwater upwelling. Similarly, the downstream portion of NFK-A received groundwater inflows, thus increasing the local surface water discharge at this location. There were no mainstem NFK reaches that exhibited seasonal cessation of surface water flow during the 2004 through 2008 study period. However, Tributary NFK 1.190.10, immediately upstream of its confluence with NFK 1.190, exhibited intermittent flow conditions in late summer. Such reduced flow conditions may potentially limit fish production on a local level. The hydrologic regime of the NFK has an influence on the functionality and usability of fish habitat and, in turn, the distribution and abundance of fish that use the watershed.

The annual water-temperature regime of the NFK was cold, restricting fish-rearing potential. Cold water restricts the active feeding of fish to a brief period (June through September) when water temperatures exceed 46ºF (8ºC); hence, fish productivity in the NFK may be limited as compared to watersheds where the active feeding period is longer (Campbell and Neuner, 1985). Notably, in this cold-water river, warm water temperatures documented during the summer sampling also may be limiting to fish health and productivity. The open riparian nature of most of the streams in the NFK watershed has allowed water temperatures to warm quickly during the summer months, and at a number of monitoring stations, researchers documented water temperatures that naturally exceeded state thermal criteria for spawning, incubation, migration, and rearing habitat.

The longitudinal thermal regime of the NFK was characteristic of a surface water system influenced by groundwater and cold-water tributary inflow. During the warmer summer months, water temperatures in the uppermost reaches (NFK-D and NFK-E) were warmer than those in the downstream reaches (NFK-A, NFK-B, and NFK-C). Analysis of water temperatures, combined with flow records, indicated that the NFK receives groundwater inflow in NFK-C and in portions of NFK-B and NFK-A. Tributary NFK 1.190, which is also relatively cool as a result of groundwater influences, discharges into the mainstem NFK at the upstream end of NFK-C, and thus further contributes to the observed temperature patterns in the lower NFK reaches. Generally, groundwater input in the lower NFK keeps surface water temperatures relatively cool in the summer and relatively warm in the winter.

Habitat studies indicated that the NFK overall contained mostly riffle habitat, followed by varying degrees of run/glide habitat, relatively few beaver ponds (also referred to as beaver complexes), and pools. While beaver ponds were relatively scarce among the mainstem habitat surveys, they accounted for approximately 85 percent of the 32 acres of off-channel habitat surveyed in the NFK. Beaver ponds in the NFK provided habitat for adult spawning and juvenile overwintering for Pacific salmon.

Other off-channel habitat types with comparatively few occurrences in the NFK watershed included side channels, percolation channels, beaver pond outlet channels, alcoves, and isolated ponds. The off-channel habitat instream-flow analysis indicated that many of the off-channel habitats were hydrologically connected to the mainstem channel via surface inflows at less than bankfull flows. This indicated that these habitats may have been periodically connected to the mainstem channel throughout the year.

Naturally formed lakes and ponds are prevalent in the NFK watershed, consistent with the remnants of a glacial history. Most of the lakes and ponds in this watershed occur at relatively high elevations. The largest concentration of lakes and ponds is in the vicinity of the Big Wiggly Lake complex, adjacent and connected to NFK-D (Figure 15.1-2). Surface water impoundments in the NFK watershed may be valuable for anadromous salmon rearing and/or spawning and for their ability to store water and provide surface water runoff volumes late in the summer.

The quality of spawning gravels in the NFK was good. The levels of fine sediments in bulk substrate samples collected from the NFK were lower than levels found in either the SFK or UT. Overall, the concentrations of size fractions that were documented were below those shown to be harmful to embryo survival and fry emergence.

Within the NFK, instream cover for fish was provided primarily by undercut banks, overhanging vegetation, and sporadically distributed boulders and large cobbles. However, a general scarcity of mainstem channel pool habitat and instream cover features in the NFK resulted in a lack of velocity shelter for rearing fishes. This condition suggested that juvenile rearing may be largely relegated to off-channel habitats, especially for winter refuge when water temperatures and streamflows become quite low. The lack of habitat for juvenile winter rearing in the mainstem NFK was evident in the instream-flow habitat study results.

The instream-flow habitat modeling and time series analyses were computed for various salmonid fish species within reaches. Results of the habitat and time series analyses for spawning and juvenile life stages were evaluated as the total habitat area versus river flow relationships, because this parameter provided reach-scale estimates of the total amount of habitat for a given species and life stage available under different flow conditions. The time series analysis revealed substantial variability in habitat amounts on a daily basis in response to changes in flow. This variation was most evident during flow transitional periods. For example, model predictions for the spring-summer periods when flows decline were for a general increase in juvenile habitat. Similarly, for the summer-fall periods when flows increase, the model predicted a general increase in spawning habitat.

Fish Distribution

At least 13 different fish species were documented in the NFK (Table 15.1-2). The greatest number of fish species was found in NFK-C, and there was a general tendency for the number of species to decrease in reaches farther upstream.

Anadromous salmon spawn throughout the NFK; however, most of the spawning occurs from the lower to the middle mainstem river reaches (i.e., NFK-A, NFK-B, NFK-C). An assessment of spawning distributions for individual anadromous species indicates that Chinook and sockeye salmon spawn predominantly in the large river reaches low in the drainage basin. Conversely, coho salmon spawning was ubiquitous throughout the NFK mainstem and tributary reaches. Nevertheless, the greatest abundance of coho and chum salmon spawners was found in NFK-C. The instream-flow model predictions help explain these patterns, in part, because the highest amounts of available spawning habitat for Chinook salmon were in NFK-A, while the highest amounts of available spawning habitat for coho and chum salmon were in NFK-C. No similarity of pattern was evident for sockeye salmon. When considering the in-reach spawning distributions of sockeye salmon and, to a large extent, chum salmon, a direct association was evident between spawning areas and those areas identified as gaining reaches as a result of inflow from groundwater, seeps, or springs.

The NFK thermal regime also appeared to influence fish spawning distributions. The NFK exhibits a sharp temperature decline near the top of NFK-C where cooler waters from NFK 1.190 enter the mainstem channel. NFK reaches above NFK 1.190 were warmer, and instantaneous temperature measurements exceeding optimal temperatures for spawning and incubation have been documented.

Although little spawning was observed in NFK-D over the study period, this reach contains habitat that supported a distinct life-history strategy for sockeye salmon. Big Wiggly Lake in the NFK 1.240 drainage in NFK-D supported a population of lake-spawning sockeye salmon. The results of limited sampling around the lake perimeter did not document the presence of sockeye salmon juveniles in the lake, but rearing is assumed to occur in NFK-D and reaches downstream.

Based on mean index counts (multiple counts over time in the same approximate area), the NFK supported the largest run of Chinook and chum salmon among the three watersheds in the mine study area. Coho salmon mean index counts were similar in the NFK and SFK and were substantially less in the NFK than in the UT. The sockeye salmon run in the NFK was consistent year to year, yet it was the smallest run among the three watersheds.

The distributions of river-rearing, juvenile Pacific salmon follow similar patterns as the spawning distributions. Juvenile Chinook salmon were prominent in mainstem channel, fast-water habitats that dominated the lower three reaches of the NFK. Juvenile coho salmon, on the other hand, were widely dispersed throughout the mainstem NFK and in several tributaries. Juvenile coho salmon were found in numerous habitat types. Off-channel habitat appeared particularly important to coho salmon rearing, with coho salmon at their highest densities in off-channel backwater and alcove habitats. This wide distribution and broad habitat use for juvenile coho salmon is consistent with the fact that they were the most abundant juvenile fish species documented in the NFK. In contrast, the relatively few juvenile chum salmon were found only during winter fish surveys and only in NFK-C.

Patterns evident for juvenile sockeye salmon distribution were also noteworthy. Observations of juvenile sockeye salmon in the middle NFK in April were not surprising, given that this time period corresponds to the typical out-migration period for juvenile sockeye salmon. However, juvenile sockeye salmon also were documented in lower NFK reaches during summer sampling (as late as August), an indication that some sockeye salmon were rearing for at least several months in the mainstem NFK.

At least nine non-anadromous salmonid and non-salmonid fishes were present in the NFK (Table 15.1-2). In general, these stream-dwelling fishes were distributed in low numbers throughout the lower reaches. Arctic grayling, northern pike, and stickleback species also were found upstream in NFK-D. Dolly Varden and sculpin were the most widespread of non-anadromous fishes and were documented in all reaches, as well as in several tributaries. Relative abundance of these fishes was generally low, with the exception of Dolly Varden and sculpin in NFK-C. Although juvenile Chinook and coho salmon dominated mainstem habitats, Dolly Varden exhibited the highest relative abundance among all fishes within NFK-C tributaries.

Within the watershed, NFK-C and NFK-D had the most diverse species assemblages, and NFK-C and Tributary NFK 1.190 supported the highest relative abundance of the fishes documented over the study period. The abundance and diversity of fish in NFK-C did not appear to be driven by habitat availability. As predicted by the instream-flow model, NFK-B should provide much more habitat for all juvenile salmonids except rainbow trout, and the highest estimates of available spawning habitat for four out of seven salmonids was in NFK-A. The habitat quality in NFK-C may be a factor influencing the richness of fish species. NFK-C gains inflow from NFK 1.190, as well from numerous seeps and springs located along the mainstem channel margin. Tributary 1.190, which is also largely influenced by seeps and springs, contributed cooler water to NFK-C, thus providing an enhanced thermal regime to habitats downstream compared to those upstream in NFK-D, NFK-E, and NFK-F.

The data collected during the study period reveal that the preponderance of fish spawning and rearing in the NFK occurred in areas where there was an observable influence of groundwater on the rivers surface, as evidenced by open water areas during winter. These areas of detectable groundwater influence were widespread throughout the lower three reaches, with areas of higher groundwater concentration noted in the upper portion of NFK-B, NFK-C, and NFK 1.190. In areas where groundwater influx was not prevalent, fish diversity and abundance were reduced.

15.1.2.3 South Fork Koktuli River

Aquatic Habitat and Instream Flow

Analysis of aquatic-habitat data from the SFK demonstrated that the SFK mainstem was primarily a single-thread, gravel-bedded channel with a tendency to meander throughout its floodplain. The lowermost reaches appeared to reflect adjustment to the post-glacial flow regime. Valley-bottom deposits in these reaches consisted of reworked glacial outwash material, including abandoned stream terraces and recent alluvial deposits, with the channel flanked by glacial moraine and drift deposits. High flows had overtopped the stream banks in these reaches, and large channels were bordered by floodplains and former stream terraces. Furthermore, the associated riparian zones, wetland complexes, and off-channel habitats extended well beyond the mainstem channel. SFK-C flowed through glacial lake deposits and was relatively low gradient compared to the rest of the mainstem. SFK-D flowed through primarily alluvial deposits but with a high percentage of sand-sized materials. Portions of the reach contained stratified layers of gravel and lake deposits in the banks. The uppermost reach, SFK-E, included a naturally impounded section of river that forms shallow Frying Pan Lake, which extended upstream in the mainstem SFK for 1.4 miles (2.3 km; Figure 15.1-2). Upstream of Frying Pan Lake, a riverine portion of SFK-E flowed across a former glacial lakebed, where fine sediments and organic materials were common and soils were less well drained. As a result, glacial lake deposits were prevalent in SFK-E upstream of Frying Pan Lake. The reach was represented by a palustrine channel type that typically contains more fine sediments than other channel types located elsewhere in the basin. Tributary channels that flowed from isolated mountain blocks into the middle of the SFK-E reach had high- and moderate-gradient, alluvial fan channels. Like the NFK, the primary sources of sediment in the SFK channel were from undercut banks and lateral erosion that occurs during high flows and ice break-up processes.

The hydrologic regime of the SFK has been influenced by climate, geology, and groundwater with streamflows driven by winter ice formation, runoff from spring snowmelt, and summer and fall rains. Seasonal flows in the SFK generally have shown two peaks, similar to other streams in southwestern Alaska and similar to the adjoining watersheds in the study area. The first peak occurred with spring snowmelt, while the second peak occurred with fall rains.

The mainstem SFK exhibited a pronounced interaction with groundwater aquifers. From the outlet of Frying Pan Lake downstream through SFK-C (Figure 15.1-2), the river flows generally decrease in a downstream direction as water infiltrated into permeable glacial outwash sediments. In SFK-C, a large and variable portion of the river exhibited intermittent flows during some summer and winter months and in some years. The river in this reach dried up from the upstream and downstream ends inward towards the middle, resulting in isolated pools that had the potential to strand fish and/or dewater incubating eggs. The extent and duration of low seasonal flow events varied by year. For example, according to flow records from gaging station

SK100C during 2007, there was no surface flow in SFK-C for a period of 40 days between early July and early September 2007. Conversely, the reach did not completely dry up in the summer of 2008. Ephemeral flows also were documented in three SFK tributaries: 1.260, 1.330, and 1.370. These periodically dry habitats have potentially limited fish production on a local level.

The hydrologic regime of the SFK has a substantial influence on the functionality and usability of fish habitat, and in turn, the distribution and abundance of fish that use the watershed. Streamflow in the SFK was augmented by groundwater in the lower portion of the mainstem channel, in reaches SFK-A and SFK-B. Springs, seeps, and upwelling groundwater were common, and these groundwater contributions influenced habitat conditions in this portion of the river year round. For example, the relatively warm groundwater contributed to ice-free winter conditions in these reaches. These conditions may, in turn, provide stable overwintering habitat and promote higher fish-embryo survival. Furthermore, during the summer, groundwater inputs create localized areas of more stable water supply and temperature for rearing.

The water-temperature regime of the SFK was cold and likely restrictive for fish rearing. Cold water restricts active fish feeding to a brief summer period when water temperatures exceed 46ºF (8ºC), and hence, fish productivity in the SFK is likely limited as compared to watersheds where the active feeding period is longer (Campbell and Neuner, 1985). Notably in this cold-water river, very warm water temperatures in the summer months also may be limiting to fish health and productivity. The open riparian nature of most SFK streams had allowed water temperatures to warm quickly during the summer months, and water temperatures that naturally exceeded state thermal criteria for spawning, incubation, migration, and rearing habitat were documented at several monitoring stations, especially upstream of reach SFK-B.

The longitudinal thermal regime of the SFK was characteristic of a surface water system influenced by groundwater inflow. There was a large concentration of seeps and springs in tributaries upstream of Frying Pan Lake and in the mainstem channel of the SFK throughout SFK-B. Frying Pan Lake is a large shallow lake, which may have provided some attenuation of flows to downstream reaches, but also has had a substantial warming effect on surface waters in SFK-D. In the summer months, warmer temperatures were observed in SFK-C and SFK-D than in the downstream reaches SFK-A and SFK-B. In addition to the warming that occurred in Frying Pan Lake, the river in SFK-C and SFK-D lost surface water flow to subsurface layers. As a result, the remaining shallower surface waters heated more rapidly than in stable and flow-gaining sections of the river. For example, summer water temperatures declined on the order of 41ºF (5ºC) in the mainstem between SFK-C and SFK-B, shortly downstream of the Tributary SFK1.190 confluence. Analysis of water-temperature and flow records indicated that the mainstem in SFK-B received groundwater inflow that was relatively cool in the summer and relatively warm in the winter. SFK-A and SFK-B generally remained ice-free, presumably a reflection of the warming influence of groundwater in the winter.

Habitat studies indicated that the SFK downstream of Frying Pan Lake was composed of mostly riffle and run/glide habitat with relatively few pools. Habitat mapping upstream of Frying Pan Lake demonstrated much greater heterogeneity in the mainstem channel habitat types, which included runs/glides, ponds/lakes, riffles, pools, beaver ponds, wetlands, and backwaters/sloughs.

While beaver ponds were relatively scarce in the SFK mainstem channel, there was a preponderance of beaver ponds in the off-channel habitats. Beaver ponds accounted for approximately 91 percent of the off-channel habitat surveyed. Beaver ponds in the SFK provide adult spawning and juvenile overwintering habitat for Pacific salmon.

Other representative off-channel habitat types included isolated ponds, beaver pond outlet channels, side channels, and alcoves. The off-channel habitat instream-flow analysis indicated that many of the off-channel habitats were hydrologically connected to the mainstem channel via surface inflow at less than bankfull flows.

Lakes and ponds were prevalent in the SFK watershed, consistent with the area’s glacial history. The largest named lakes in the basin were Frying Pan and Chiquita lakes. The greatest number of the lakes and ponds in this watershed were located relatively high in the watershed, upstream of Frying Pan Lake. Analysis of data indicated that the surface water impoundments in the SFK watershed provided habitat for several resident fish species and may have been valuable for their ability to store water and attenuate flow.

The quality of spawning gravels in the SFK was good. Although the levels of fine sediments in samples collected from the SFK were higher than levels found in samples from the NFK and UT, the concentrations of size fractions documented were below levels that have been shown to be harmful to embryo survival and fry emergence.

Within the SFK, instream cover for fish was largely provided by undercut banks and overhanging vegetation, along with scattered boulders and cobbles. Large woody debris was scarce because of a general lack of forest vegetation in the riparian zone. Mainstem channel pool habitat was also scarce. A general lack of winter rearing habitat for juveniles was evident from the instream-flow study results.

The instream-flow habitat modeling and time series analyses were computed for various salmonid fish species in SFK-A, SFK-B, SFK-C, and SFK 1.190. Results of the habitat and time series analyses for salmon spawning and juvenile life stages were evaluated as the total habitat area versus river flow relationships, because this parameter provided reach-scale estimates of the total amount of habitat for a given species and life stage available under different flow conditions. The time series analysis demonstrated that there can be substantial variability in habitat amounts on a daily basis, in response to changes in flow. This variation was most evident during flow transitional periods. For example, model predictions during the spring-summer periods, when flows decline, were for a general increase in juvenile habitat. Similarly, during the summer-fall period when flows increase, the prediction was for a general increase in spawning habitat. Juvenile habitat was absent in SFK-C from February through April, reflecting the ephemeral nature of this reach.

Fish Distribution

At least 14 different fish species were documented in the SFK during the 2004 through 2008 study period (Table 15.1-3), making the SFK fish assemblage the most species-rich in the mine study area. The ephemeral reach area in SFK-C marks the portion of the SFK where the habitat transitioned from supporting a Pacific salmon-dominated fish assemblage to supporting populations of stream-rearing anadromous and resident non-anadromous fishes. SFK-B had the greatest number of fish species (14) observed in the watershed. This reach also supported the greatest amount of predicted available habitat for most species and life stages present. The reaches with the fewest fish species were SFK-D (six species) and SFK-E (nine species). The fish assemblages in the headwater areas were dominated by resident fish species.

In the SFK watershed, all anadromous salmon spawning occurred downstream of Frying Pan Lake, and the majority of the spawning occurred in the lowermost reaches SFK-A and SFK-B. Analysis of the spawning-reach analysis data showed that spawning Chinook salmon were more abundant in the large river reaches of SFK-A, whereas spawning chum, coho, and sockeye salmon were more abundant in SFK-B. These patterns for spawning distributions were somewhat in contrast with the instream-flow habitat results. The model indicated that substantially more anadromous spawning habitat should be available in SFK-A compared to SFK-B and SFK-C, yet only one anadromous salmon species was found spawning in greater abundance in SFK-A. Other factors, such as hydrology and temperature, appeared to influence spawning distributions. The species distributions of adult sockeye and chum salmon in these reaches showed a direct relationship between spawning and areas with inflow from groundwater, seeps, or springs. These salmon spawned only in the vicinity of groundwater both on a localized scale within a reach and among reaches. Furthermore, summertime surface water temperatures in the SFK increased in Frying Pan Lake and were relatively high from there to the upstream end of SFK-B, where Tributary SFK 1.190 enters the mainstem channel. As a result of cool water inflows from the SFK 1.190, as well as numerous springs and seeps, water temperatures began to decline at the upper end of SFK-B and continued to decline to the middle of that reach. This cold-water upwelling area and the area immediately downstream supported the majority of salmon spawners in the SFK.

The observation that anadromous fish spawning was largely limited to the lower three reaches of SFK reflected the unreliable habitat conditions associated with the large and variable ephemeral section of river in the middle of reach SFK-C. In low-flow years, such as 2007, a large portion of this ephemeral reach went dry. However, in higher-flow years, such as 2008, the ephemeral section remained fully wetted, and anadromous salmon had access to the entire length of SFK-C. Adult chum, coho, and sockeye salmon expanded their distributions upstream in 2008 with small numbers of fish spawning in the available habitat in SFK-C. While spawning locations for chum and sockeye salmon were limited to the downstream portion of SFK-C, coho salmon spawned sporadically throughout the entire reach.

Based on mean index counts, the SFK supported the second largest run of Chinook and chum salmon among the three watersheds in the study area, following closely behind the NFK. The mean index counts of coho salmon in the SFK and NFK were similar. Both were substantially less than the UT coho salmon index counts. The mean index counts for sockeye salmon in the SFK were consistently 2 to 3 times greater than those for the NFK. Still, in most years, SFK sockeye salmon counts were an order of magnitude less than the UT sockeye salmon counts. In 2006 and 2007, however, when the UT counts dropped dramatically, the SFK sockeye salmon counts were within an order of magnitude of the UT sockeye salmon counts.

The distributions of river-rearing juvenile Pacific salmon followed similar patterns as the adult spawning distributions. The highest abundance and diversity of juvenile salmon in the SFK were found in the lower two reaches. Juvenile chum salmon were observed in low numbers and only in SFK-A and SFK-B, and very few Chinook salmon were found upstream of SFK-C; however, during high-water years, small numbers of coho and sockeye salmon were documented in SFK-C and further upstream, including in habitats above Frying Pan Lake. This expansion in juvenile distribution was, in general, consistent with spawning further upstream during high-water years, but also implied that juvenile salmon may have redistributed upstream of SFK spawning areas for rearing purposes. The environmental conditions in Frying Pan Lake were suboptimal for juvenile salmonids and, as such, may have restricted fish passage and influenced the overall distribution of salmonid fishes throughout the SFK watershed.

Juvenile Chinook salmon were prominent in mainstem channel, fast-water habitats that dominate the lower reaches of the SFK. Juvenile coho salmon were more widely dispersed and found in a variety of habitat types. Given the lack of pools and slack-water habitat features observed in the mainstem channel, off-channel habitats may have offered more suitable conditions for both summer and winter rearing of fishes. This was apparent for juvenile coho salmon, which were observed at the highest densities among all salmonids in off-channel habitats. The wide distribution and broad habitat use for juvenile coho salmon were consistent with the finding that coho salmon were the most abundant juvenile salmon documented in SFK and that four age classes of juvenile coho salmon were identified in SFK habitats. Although no adult anadromous species have been recorded spawning along the shores of Frying Pan Lake, limited observations of juvenile coho and sockeye salmon indicate that the lake has some potential for rearing.

Ten non-anadromous salmonids and non-salmonid fish species were present in the SFK. Unlike the anadromous salmonids, the stream's resident fish species were distributed in low numbers throughout the SFK. Arctic grayling and Dolly Varden were the most abundant and were broadly distributed species of the resident fishes. Frying Pan Lake provided habitat for a population of northern pike, an aggressive predator of smaller fishes including juvenile salmon and resident stream fishes. Another distinction of the SFK fish assemblage was the documentation of both burbot and lamprey species. These species were not present in any other watersheds, but were found within and downstream of SFK-C.

Overall, analysis of the data collected during the study period show that the preponderance of fish spawning and rearing in the SFK was associated with areas where there was an observable influence of groundwater on the rivers surface, as evidenced by open water areas during winter. These areas of detectable groundwater influence were widespread throughout the lower two reaches, with areas of higher groundwater influence noted in SFK-B. In areas where groundwater influx was not prevalent, fish diversity and abundance were reduced.

15.1.2.4 Upper Talarik Creek

Aquatic Habitat and Instream Flow

During baseline habitat surveys, the UT was characterized as primarily a single-thread, gravel-bedded channel that was relatively straight along much of its length, except where the river valley and floodplain widened and multiple channels had formed. The channel slopes of the UT were generally steeper than those of both the NFK and SFK and ranged from 0.1 to 2.0 percent. Alluvial transport and deposition were common in the lower UT reaches (i.e., in most of UT-B and the entire length of UT-A). Within these areas, there was evidence that high flows had overtopped the stream banks, and the channels were bordered by relatively wide floodplains. In addition, the associated riparian zones, wetland complexes, and off-channel habitats extended well into the floodplains. In the upper third of UT-B and throughout UT-C, the river channel was low gradient, contained, and flowed through a relatively narrow valley bottom, bordered by low hills to the west and carved glacial deposits to the east. UT-D, UT-E, and the lower half of UT-F were classified as alluvial floodplain channels that formed by water reworking glacial outwash deposits. Multiple former stream terraces and colluvial slopes were evident where the present stream channel had downcut through glacial outwash and lacustrine deposits. Steep side slopes represented sediment sources where the channel impinged against the valley walls. Tributaries that flowed in from the isolated mountain blocks were varied and had a variety of channel types, including high gradient, contained, moderate gradient, mixed control, and alluvial fan. In the upper half of both UT-F and UT-G, the channel flowed across deep glacial lacustrine deposits. The stream there tended to contain higher levels of fine sediment than elsewhere in the basin. The downstream limits of the lacustrine deposits were in the same area as the downstream limit of beaver dam construction in the mainstem channel (i.e., at the lower end of UT-F).

Like the NFK and SFK watersheds, the baseline hydrology of the UT mainstem was strongly influenced by climate, geology, and groundwater influx. Streamflows were driven by runoff from spring snowmelt and summer and fall rains. Analysis of available data indicated that surface water flows generally declined from October through April, were highest in late April to late May as a result of snowmelt, and then reached a secondary peak in the late summer and early fall as a result of rainfall. Base flows tended to remain high in both winter and late summer because of groundwater storage.

The UT hydrograph showed a pronounced groundwater influence, which was largely due to a cross-basin transfer of groundwater from the SFK. Approximately 25 cubic feet per second (0.7 cubic meters per second) of flow entered the UT basin through this cross-basin transfer. The groundwater flowed eastward from SFK, likely along flow paths formed by former glacial meltwater channels, and emerged in Tributary UT 1.190, which flows into the mainstem UT at the upstream end of UT-C. Flow records indicated that the downstream portion of reach UT-F and reach UT-D also received groundwater inflow and that portions of these reaches remained ice-free during winter months. No mainstem UT reaches exhibited seasonal or temporary cessation of flow during the study period.

The annual water-temperature regime in the UT was cold. Cold water restricts active fish feeding to a brief summer period when water temperatures exceed 46ºF (8ºC); hence, fish productivity in the UT is likely limited as compared to watersheds where the active feeding period is longer (Campbell and Neuner, 1985). Notably, warm water temperatures in the summer months also may be limiting to fish health and productivity. The open riparian nature of most of the streams in the UT watershed has allowed water temperatures to warm quickly during the summer months, and at several monitoring stations researchers documented temperatures that naturally exceeded state thermal criteria for spawning, incubation, migration, and rearing habitat. The maximum temperatures in the UT were less than those in the NFK and SFK, yet were still on the high end of recorded temperature maxima for other regional streams.

During the study period, the longitudinal thermal regime of the UT was characteristic of a surface water system influenced by groundwater and cold-water tributary inflow. In particular, there was a broad distribution of distinct groundwater effects in the middle reaches of the watershed and in Tributary UT 1.190. The middle mainstem reaches and UT 1.190 were relatively cool in summer and warm in the winter and may have provided thermal refuge for juvenile fish-rearing. Overall, the thermal regime of the UT was cooler than those of the Koktuli watersheds. This thermal difference may have been due, in part, to the prominent groundwater influence throughout the UT and the lack of lake-related warming effects in this watershed, in contrast to warming effects seen from Frying Pan Lake in SFK and Big Wiggly Lake in NFK. The north/south alignment in the upper UT also likely provided shade from the surrounding terrain and helped to insulate the water temperature.

The UT habitat studies indicated that the mainstem river was composed largely of riffle and run/glide habitats, similar to the SFK. Beaver ponds were present in the mainstem channel only in UT-F and accounted for 7 percent of the total habitat area in that reach. Habitat surveys indicated that riffle and run/glide habitat types dominated the morphology of the UT tributary channels as well.

While beaver ponds were relatively scarce in the mainstem UT, the off-channel habitat study revealed a preponderance of beaver ponds in the off-channel habitats. As in the SFK watershed, beaver ponds accounted for more than 90 percent of the off-channel habitat surveyed. Beaver ponds in the UT provided habitat for adult spawning and juvenile overwintering for Pacific salmon. The water temperature in beaver ponds in the UT was slightly warmer than in other habitat types and thus, beaver ponds may represent a more productive habitat as compared to other mainstem channel habitat types.

Other off-channel habitat types that were represented in very low proportions were side channels, beaver pond outlet channels, percolation channels, isolated ponds, and alcoves. The off-channel habitat instream-flow analysis indicated that many of the off-channel habitats were hydrologically connected to the mainstem channel via surface inflow at less than bankfull flows, thus indicating that these habitats were accessible to fish periodically throughout the year. However, a subsample of off-channel habitat units demonstrated that the flows at which off-channel habitats were connected to the mainstem varied within and among off-channel habitat types.

Lakes and ponds were prevalent in the UT watershed, particularly along the eastern boundary of the basin. The largest concentration was along the long unnamed ridge that separates the UT drainage from the Newhalen River to the east. A large lake was located east of the headwaters of UT 1.60 (First Creek), and a series of kettle ponds and lakes occurred east of UT-D and UT-E. Adult coho and sockeye spawning was observed in a small lake associated with Tributary UT 1.350.20, as well as in beaver ponds in the UT. In general, surface water impoundments of this nature also provide habitat for other stream-dwelling fish species and are valuable for their ability to store water and to provide extended surface water runoff volumes during low-flow periods as compared to basins without such storage.

The quality of spawning gravels in the UT was good. Overall, fine sediment levels in the UT were less than those in the SFK, but greater than those in the NFK. The concentrations of fine sediment size fractions observed were below levels that have been shown to be harmful to embryo survival and fry emergence.

There was a general lack of instream fish cover and mainstem channel pool habitat in the UT. As in the NFK and SFK, large woody debris was scarce in the upper portion of the UT because of a general lack of forest vegetation in the riparian zone. Thus, juveniles rearing in the upper UT may need to rely on off-channel habitats for rearing, especially for winter refuge when water temperatures and streamflows become low. While large woody debris was scarce throughout most of the basin, it was more prevalent in UT-A and UT-B because of large source trees from the riparian zone. The presence of large woody debris created fish cover and was responsible for creating and maintaining habitat diversity in this lower portion of the UT.

The instream-flow habitat modeling and time series analyses were computed for various salmonid fish species. Results of the habitat and time series analyses for salmon, as well as for rainbow trout spawning and juvenile life stages were evaluated as the total habitat area versus river flow relationships, because this parameter provided reach-scale estimates of the total amount of habitat for a given species and life stage available under different flow conditions. The time series analysis revealed substantial variability in habitat amounts on a daily basis in response to changes in flow. This variation was most evident during flow transitional periods. For example, the model predictions for the spring-summer period, when flows were declining, were for general increase in juvenile habitat. Similarly, predictions for the summer-fall period, when flows increased, were for a general increase in spawning habitat.

Fish Distribution

At least 12 different fish species were documented in the UT from 2004 through 2008 (Table 15.1-4). Overall, species numbers remained relatively constant in most reaches, with the greatest number of species (11) found in UT-C and UT-D. Only four species were found in the headwater reach UT-G.

Four anadromous salmon species spawned annually in habitats throughout the mainstem UT. Chinook, chum, coho, and sockeye salmon were documented spawning in reaches UT-A through UT-F, with the coho salmon spawning distribution extending into UT-G. In addition, what appeared to be exploratory runs of pink salmon were documented in the UT in 2006 and 2007. Chinook and chum salmon spawning abundance was consistently low (less than 60 spawning fish per reach) throughout their distributions. Spawning coho salmon were more abundant than Chinook and chum salmon spawners, but less abundant than spawning sockeye salmon. The abundance of spawning coho salmon was generally greatest in the middle and uppermost reaches (UT-D, UT-E, and UT-F). For sockeye salmon, the greatest abundance of spawners occurred in UT-A, with spawner abundance declining in each consecutive upstream reach.

The instream-flow habitat assessment results help to explain the spawning distribution pattern for coho salmon, as the greatest amount of available habitat was predicated in the middle spawning reaches. However, the results for sockeye salmon habitat availability do not explain the sockeye salmon distribution. It is possible that the lack of predictive capability for sockeye salmon habitat is related to a limited number of instream-flow transects located in UT-A and UT-B, the reaches with the highest abundances of spawning sockeye. It is also interesting to note that, unlike in the NFK and SFK, a direct relationship between spawning distributions of sockeye and chum salmon and groundwater inflow areas was not apparent in the UT.

Five tributaries in the UT support spawning populations of anadromous salmonids. Most tributaries support small numbers of spawning sockeye and coho salmon, but large spawning populations were observed in UT 1.60 (First Creek). The mouth of UT 1.60 is located low in the watershed, and the tributary continues upstream to the east of the mainstem UT for approximately 20 miles (32 km). Analysis of aerial survey data indicated that this creek has supported as much as 43 percent of the total UT adult sockeye salmon run and 17 percent of the total UT coho salmon run in some years. The UT 1.60 and UT 1.350 subwatersheds also support a life-history variation for coho and sockeye salmon—small populations of lake-spawning sockeye and coho salmon were documented in several small lakes and ponds in these subwatersheds.

A comparison of index counts of mean adult salmon among watersheds shows that the UT sockeye salmon run was the largest run in the study area. The mean index counts for UT coho salmon were greater by one or two orders of magnitude than those for the NFK and SFK. In contrast, the runs of UT Chinook and chum salmon were less compared to mean index counts in the other two watersheds.

The overall distribution of river-rearing juvenile Pacific salmon was driven largely by juvenile coho salmon, which were the most abundant juvenile fishes in the UT. Peak abundances of juvenile coho salmon occurred in the middle to upper UT, including reaches UT-C through UT-F. The highest abundance estimates for Chinook salmon were also located in the middle watershed. Observations during winter surveys indicated that Chinook and coho salmon were present in UT-C through UT-F in November and again the following April, thus indicating that these reaches provide overwintering habitat in addition to summer rearing habitat. Limited numbers of juvenile sockeye salmon were found up through UT-F in early summer, and they appear to rear in lower UT reaches throughout the summer. Juvenile chum salmon were observed in limited numbers and only in UT-D. The only anadromous salmon documented in UT-G were coho salmon.

Juvenile Chinook salmon were found predominantly in fast-water habitats that were present throughout the UT mainstem channel. Juvenile coho salmon were widely dispersed throughout the mainstem channel and tributaries and occupied a variety of habitat types. High relative abundances and densities of coho salmon were found in the mainstem channel glides, riffles, pools, and beaver ponds and in tributary backwaters. Off-channel habitats were used for coho salmon rearing and to a limited extent for Chinook salmon; however, juvenile Chinook and coho salmon abundances in off-channel habitats were typically less than the corresponding mainstem channel abundances. This broad habitat use was consistent with the fact the coho salmon were the most abundant juvenile fishes in this watershed.

Patterns evident for sockeye salmon distribution also were noteworthy. Although sockeye salmon typically out-migrate in their first spring after emergence, some juvenile sockeye salmon were found from April through September in the UT watershed. This information indicated that some sockeye salmon are rearing in the mainstem UT for several months.

At least seven non-anadromous salmonids and non-salmonid fish species were present in the UT. In general, these stream-dwelling fishes were distributed in low numbers throughout most of the watershed. Dolly Varden, sculpin, and one arctic grayling were the only resident fishes found in the headwater reach (UT-G). Arctic grayling and sculpin were the most widespread of the non-anadromous fishes and were documented in all reaches, as well as in several tributaries. Relative abundance of these fishes was generally low, with the exception of arctic grayling in UT-C, rainbow trout in UT-B, and sculpin in UT-C, UT-E, and UT-F. A separate rainbow trout radio-telemetry study revealed that adults using the UT for foraging and spawning left the UT to rear for extended periods in Iliamna Lake and other tributaries to Iliamna Lake.

Although some species-specific abundance patterns were evident, overall the freshwater fish assemblage in the UT was more consistent throughout the watershed and tributaries than the NFK and SFK assemblages. Large numbers of fish and similar species composition were documented from UT-B to UT-F. This distribution reflects the overall stable habitat conditions in the UT. No ephemeral areas were documented, and no warm-water lakes are present in the UT. Furthermore, areas of groundwater inflow were widely dispersed throughout the middle and upper portions of the watershed, and thus, a more stable flow regime was present. The relatively constant fish assemblage among reaches in the UT was consistent with similar levels of habitat availability in reaches UT-B through UT-F as predicted by the instream-flow model.

15.1.2.5 Koktuli River

Aquatic Habitat and Instream Flow

Although no habitat surveys were undertaken in the upper KR mainstem, instream-flow transect data provide some information on fish habitat. Similar to the NFK, SFK, and UT instream-flow analyses, the analyses for the upper KR mainstem indicated there can be substantial variability in habitat amounts on a daily and monthly basis in response to changes in flow. This variation was most evident during flow transitional periods. For example, model predictions for the spring-summer period when flows were declining were for a general increase in juvenile habitat. Similarly, the model predicted that during the late summer-fall period when flows increase there would be a general decrease in spawning habitat as a result of increased flow velocities that are slightly higher than optimal for most salmonid spawning. Conversely, for the spring spawning species, including arctic grayling and rainbow trout, the model showed a strong decrease in available spawning area when river flows decrease in the late May and June time frame.

Fish Distribution

The fish community inhabiting the upper KR mainstem consists of at least 10 different species (Table 15.1-5), including four anadromous salmonids, four non-anadromous (resident) salmonids, and two non-salmonid fishes. Anadromous salmonids represent the most abundant fish taxa surveyed. The resident salmonids were the second most abundant species group, and non-salmonid fishes were observed in very low numbers.

Observations of Chinook, chum, coho, and sockeye salmon occurred in July and August. The most abundant species of Pacific salmon in the study reach in the upper KR mainstem were Chinook and coho salmon. Field surveys identified both juvenile and adult Chinook, coho, and sockeye salmon. For chum salmon, only adults were documented. The abbreviated riverine residence time of juvenile chum salmon prior to downstream migration likely explains the absence of juvenile observations in the upper KR mainstem during summer surveys. In addition to providing spawning, incubation, and rearing habitat, the KR is a migratory corridor for adult and juvenile Pacific salmon that use upstream habitats in the NFK and SFK watersheds.

At least six non-anadromous salmonid and non-salmonid fish species were present in the upper KR mainstem: arctic grayling, whitefish, Dolly Varden, rainbow trout, sculpin, and stickleback. Among these fishes, arctic grayling, whitefish, and Dolly Varden were the most abundant species groups observed. Arctic grayling and whitefish were more abundant than Dolly Varden in pool habitat, whereas Dolly Varden were more abundant in riffle habitat. Rainbow trout were observed in both pool and riffle habitats, although in very low numbers (approximately 2 fish per 328 feet [100 meters]). Non-salmonid fishes, including sculpin and stickleback, were observed in very low numbers. Only 13 stickleback and five sculpin were documented as occurring in the upper KR mainstem.

15.1.3 References

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TABLE 15.1-1
Fish Resource Studies, by Major Study Category, Conducted in the Mine Study Area, 2004 through 2008

	Watershed				
Study Category	**2004**	**2005**	**2006**	**2007**	**2008**
Aquatic Habitat Assessments:					
Mainstem and Tributary Habitat Surveys					
USFS Modified Tier 1 Aquatic Habitat Surveys (USFS, 2001)	NFK, SFK, UT			UT	NFK, SFK, UT
USFS Modified Tier 3 Aquatic Habitat Surveys (USFS, 2001)	NFK, SFK, UT	SFK, UT		UT	NFK, SFK, UT
Fish/Habitat Associations via Anecdotal Data Collection	NFK, SFK, UT	KR, NFK, SFK, UT	KR, NFK, SFK, UT	KR, NFK, SFK, UT	
Off-Channel Habitat Surveys					
USFS Modified Tier 3 Aquatic Habitat Surveys (USFS, 2001)					NFK
Fish/Habitat Associations via Anecdotal Data Collection		SFK	SFK	SFK, UT	
Mesohabitat Mapping Field Surveys		NFK, SFK, UT		NFK, SFK, UT	
Fish Assemblage Surveys:					
Fish Distribution and Relative Abundance Surveys	KR, NFK, SFK, UT	KR, NFK, SFK, UT	KR, NFK, SFK, UT	KR, NFK, SFK, UT	KR, NFK, SFK, UT
Fish Use of Off-Channel Habitats Study		SFK	SFK	SFK, UT	NFK
Winter Fish Study	KR, NFK, SFK, UT	NFK, SFK, UT	NFK, SFK, UT	SFK, UT	
Mainstem Index Surveys	NFK, SFK, UT	NFK, SFK, UT		NFK, SFK, UT	NFK, SFK, UT
Adult Salmon Surveys	KR, NFK, SFK, UT	KR, NFK, SFK, UT	KR, NFK, SFK, UT	KR, NFK, SFK, UT	NFK, SFK, UT
Rainbow Trout Radio-telemetry Study [a]				UT	UT
Instream-flow Habitat Studies:					
Mainstem Channel Flow Habitat Studies	KR, NFK, SFK, UT	KR, NFK, SFK, UT		KR, NFK, SFK, UT	NFK, SFK, UT
Off-Channel Flow Habitat Studies		SFK	SFK	UT	NFK
Water Temperature Monitoring/Modeling	NFK, SFK, UT	NFK, SFK, UT	NFK, SFK, UT	NFK, SFK, UT	NFK, SFK, UT
Fluvial Geomorphology and Spawning Gravel Quality		SFK, UT		KR, NFK, SFK, UT	NFK, SFK, UT

Notes:

a. The rainbow trout radio-telemetry study was centered around Iliamna Lake downstream to the upper extent of tidal influence in the Kvichak River, with special emphasis on the Lower Talarik Creek and the UT.

KR = Koktuli River mainstem.

NFK = North Fork Koktuli River.

SFK = South Fork Koktuli River.

USFS = U.S. Forest Service.

UT = Upper Talarik Creek.

TABLE 15.1-2
Fish Taxa Found in the North Fork Koktuli Watershed, by Study Reach, 2004 through 2008

Common Name	Scientific Name	NFK-A	NFK-B	NFK-C	NFK-D	NFK-E	NFK-F
Chinook salmon	*Oncorhynchus tshawytscha*	X	X	X	X		X
Chum salmon	*Oncorhynchus keta*	X	X	X			
Coho salmon	*Oncorhynchus kisutch*	X	X	X	X	X	
Sockeye salmon	*Oncorhynchus nerka*	X	X	X	X		
Arctic grayling	*Thymallus arcticus*	X	X	X	X		
Dolly Varden	*Salvelinus malma*	X	X	X	X	X	X
Rainbow trout	*Oncorhynchus mykiss*	X		X			
Round whitefish	*Prosopium cylindraceum*			X			
Whitefish [a]	Coregoninae	X	X	X	X		
Sculpin [b]	*Cottus sp.*	X	X	X	X	X	X
Northern pike	*Esox lucius*			X	X		
Ninespine stickleback	*Pungitius pungitius*	X	X	X	X		
Threespine stickleback	*Gasterosteous aculeatus*	X			X		
Stickleback [c]	Gasterosteidae			X	X		

Notes:

a. Identified to subfamily; may include round whitefish, humpback whitefish, and least cisco.

b. Identified to genus; may include slimy sculpin and coastrange sculpin.

c. Identified to family; may include ninespine and threespine stickleback.

NFK = North Fork Koktuli River.

TABLE 15.1-3
Fish Taxa Found in the South Fork Koktuli Watershed, by Study Reach, 2004 through 2008

Common Name	Scientific Name	SFK-A	SFK-B	SFK-C	SFK-D	SFK-E
Chinook salmon	*Oncorhynchus tshawytscha*	X	X	X	X	
Chum salmon	*Oncorhynchus keta*	X	X	X		
Coho salmon	*Oncorhynchus kisutch*	X	X	X	X	X
Sockeye salmon	*Oncorhynchus nerka*	X	X	X		X
Arctic grayling	*Thymallus arcticus*	X	X	X	X	X
Dolly Varden	*Salvelinus malma*	X	X	X	X	X
Rainbow trout	*Oncorhynchus mykiss*	X	X			X
Whitefish [a]	Coregoninae	X	X	X		
Sculpin [b]	*Cottus sp.*	X	X	X	X	X
Northern pike	*Esox lucius*		X	X	X	X
Ninespine stickleback	*Pungitius pungitius*	X	X	X		X
Threespine stickleback	*Gasterosteous aculeatus*	X	X			X
Stickleback [c]	Gasterosteidae	X	X	X		X
Burbot	*Lota lota*		X	X		
Lamprey [d]	*Lampetra sp.*	X	X			

Notes:

a. Identified to subfamily; may include round whitefish, humpback whitefish, and least cisco.

b. Identified to genus; may include slimy sculpin and coastrange sculpin.

c. Identified to family; may include ninespine and threespine stickleback.

d. Identified to genus; may include arctic and Pacific lamprey.

SFK = South Fork Koktuli River.

TABLE 15.1-4
Fish Taxa Found in the Upper Talarik Watershed, by Study Reach, 2004 through 2008

Common Name	Scientific Name	UT-A	UT-B	UT-C	UT-D	UT-E	UT-F	UT-G
Chinook salmon	*Oncorhynchus tshawytscha*	X	X	X	X	X	X	
Chum salmon	*Oncorhynchus keta*	X	X	X	X	X	X	
Coho salmon	*Oncorhynchus kisutch*	X	X	X	X	X	X	X
Sockeye salmon	*Oncorhynchus nerka*	X	X	X	X	X	X	
Pink salmon [a]	*Oncorhynchus gorbuscha*	ND	ND	ND	ND	ND	ND	ND
Arctic grayling	*Thymallus arcticus*	X	X	X	X	X	X	X
Dolly Varden	*Salvelinus malma*		X	X	X	X	X	X
Rainbow trout	*Oncorhynchus mykiss*	X	X	X	X	X	X	
Whitefish [b]	Coregoninae	X		X	X			
Sculpin [c]	*Cottus sp.*	X	X	X	X	X	X	X
Ninespine stickleback	*Pungitius pungitius*			X	X	X	X	
Threespine stickleback	*Gasterosteus aculeatus*			X	X	X		
Stickleback [d]	Gasterosteidae	X	X	X	X	X	X	

Notes:

a. Data not available on a reach scale; however, pink salmon were observed in the UT during the study period.

b. Identified to subfamily; may include round whitefish, humpback whitefish, and least cisco.

c. Identified to genus; may include slimy sculpin and coastrange sculpin.

d. Identified to family; may include ninespine and threespine stickleback.

ND = No data.

UT = Upper Talarik Creek.

TABLE 15.1-5
Fish Species Found in the Upper Koktuli River Mainstem, 2004 through 2008

Common Name	**Scientific Name**
Chinook salmon	*Oncorhynchus tshawytscha*
Chum salmon	*Oncorhynchus keta*
Coho salmon	*Oncorhynchus kisutch*
Sockeye salmon	*Oncorhynchus nerka*
Arctic grayling	*Thymallus arcticus*
Dolly Varden	*Salvelinus malma*
Rainbow trout	*Oncorhynchus mykiss*
Whitefish [a]	Coregoninae
Sculpin [b]	*Cottus sp.*
Stickleback [c]	Gasterosteidae

Notes:

a. Identified to subfamily; may include round whitefish, humpback whitefish, and least cisco.

b Identified to genus; may include slimy sculpin and coastrange sculpin.

c. Identified to family; may include ninespine and threespine stickleback.

Snorkeling for fish presence and relative abundance.

Electrofishing to assess relative fish abundance.

Estimating amounts of wood cover during aquatic habitat surveys.

Measuring the height of a beaver dam during aquatic habitat surveys.

A snorkeler’s view of juvenile coho salmon under instream cover.

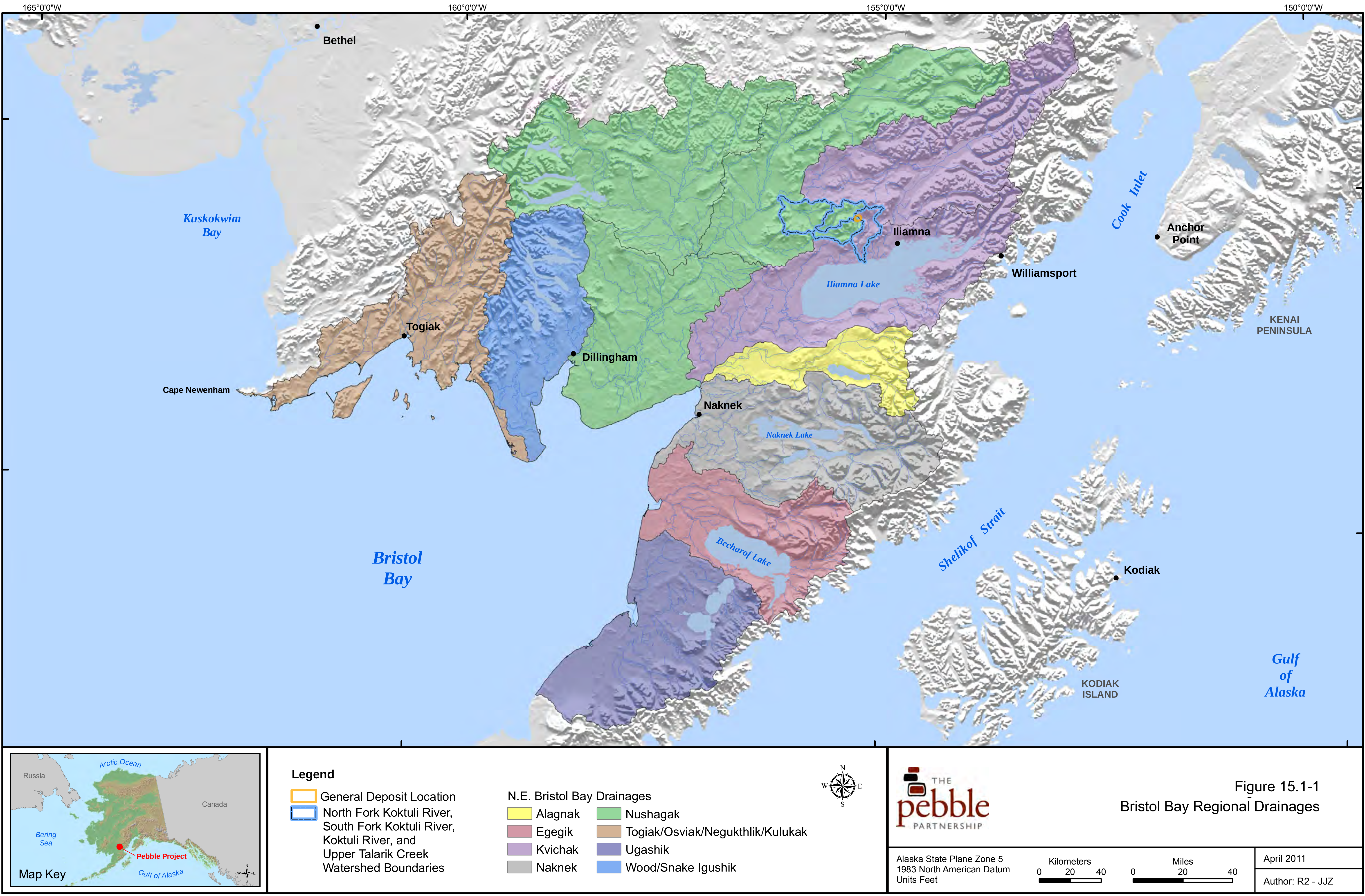
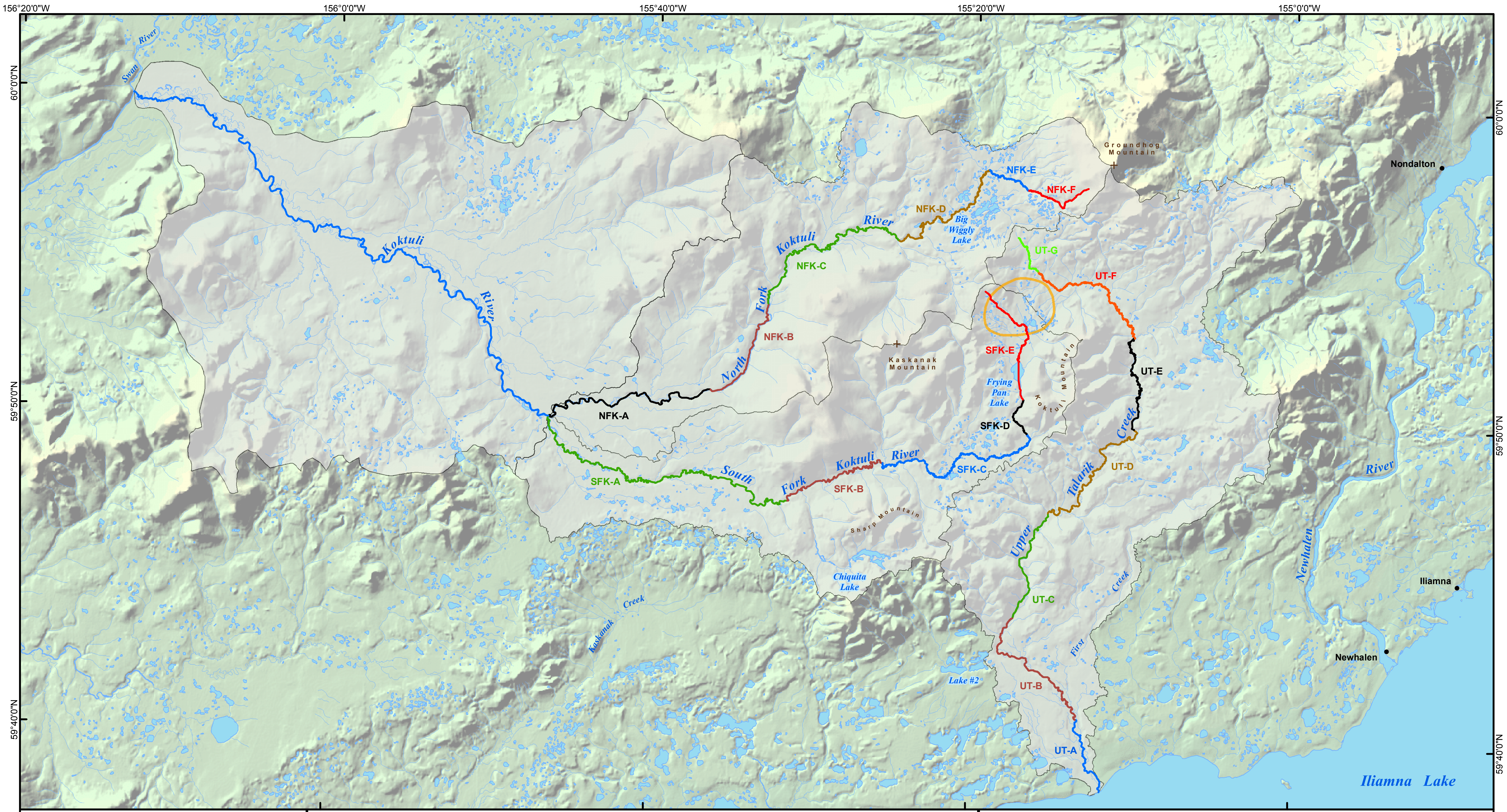


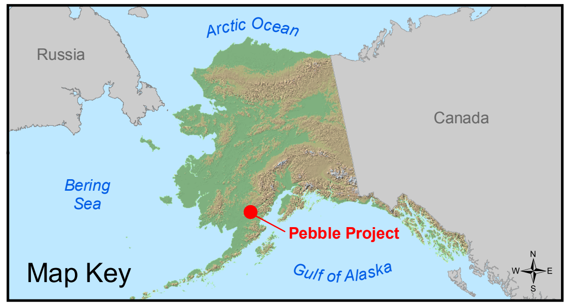
Figure 15.1-1
Bristol Bay Regional Drainages

Alaska State Plane Zone 5
1983 North American Datum
Units Feet

April 2011

Author: R2 - JJZ





Legend

UT-A Mainstem Reach Example

▭ Watershed Boundary

▭ General Deposit Location

THE pebble PARTNERSHIP

Figure 15.1-2

Fish-Mine Study Area Reaches

Alaska State Plane Zone 5
1983 North American Datum
Units Feet

Kilometers
0 1 2

Miles
0 1 2

August 2011

Author: R2 - JJZ

15.2 Aquatic Invertebrates —Mine Study Area

15.2.1 Introduction

The macroinvertebrate and periphyton studies in the vicinity of the Pebble Deposit are part of the overall program of baseline investigations to describe the current aquatic conditions in the mine study area (Figure 1-4 in Chapter 1). Baseline information on macroinvertebrate and periphyton community assemblages is valued because these creatures are essential components of the aquatic food web and their community structure, particularly with respect to the more sensitive taxa, is an indicator of habitat and water quality. The objective of the macroinvertebrate and periphyton field and laboratory program was to characterize the diversity, abundance, and density of macroinvertebrates and periphyton within freshwater habitats in the study area.

Macroinvertebrates are organisms without a backbone that are large enough to be seen without the aid of a microscope. Sampling of macroinvertebrates typically targets those organisms that live in or on the substrate of streams and lakes (usually in larval and pupal life stages). Periphyton, defined as micro-algae attached to rocks or other solid surfaces, has been sampled in order to describe the primary producers within freshwater habitats in the study area. As with macroinvertebrates, periphyton is also sensitive to changes in the aquatic environment and can be used as a monitoring tool for in situ primary productivity.

Macroinvertebrates and periphyton were sampled in the mine study area in 2004, 2005, and 2007 as part of the environmental baseline studies for the Pebble Project. In 2004, 20 sites in the mine study area were sampled for macroinvertebrates and periphyton. Of these, eight sites (five in the immediate vicinity of the deposit) were selected for continued sampling in 2005, and 10 were sampled in 2007.

A range of macroinvertebrate and periphyton sample-collection methods was employed during the beginning stages of this project to determine which methods would work best in these systems. Methods used to sample macroinvertebrates and periphyton differed slightly between 2004 and the subsequent sampling years of 2005 and 2007. Beginning in 2005, Surber sampling for macroinvertebrates replaced drift-net sampling in streams, and collection of periphyton samples for analysis of chlorophyll-*a* concentrations replaced sampling by the modified Environmental Protection Agency’s Rapid Bioassessment Protocol method. Alaska Stream Condition Index sampling was consistent throughout all 2004, 2005, and 2007 events. The variety of methods used contributes greatly to the robustness of the baseline data-collection program and offers a detailed set of project information for refinement of future sampling methods.

15.2.2 Results and Discussion

Macroinvertebrate and periphyton baseline studies were conducted in the mine study area in 2004, 2005 and 2007.

Two hundred thirty-five macroinvertebrate taxa, including 64 chironomid taxa, have been identified in the Bristol Bay drainages study areas (the Bristol Bay drainages study areas include both the mine and transportation-corridor study areas, the latter of which is discussed in Section 15.4.). During the course of the program, 132 primary macroinvertebrate samples, plus duplicates on a minimum frequency of 10 percent, were collected at the established biological monitoring sites in the mine study area. Analysis of data from 2004 indicated that benthic sampling using a kick net (Alaska Stream Condition Index method) was generally more successful at collecting a variety of macroinvertebrates than the drift-net method of sampling the water column. Macroinvertebrate metrics were calculated based on the 2004, 2005, and 2007 data for Alaska Stream Condition Index and Surber samples. Diptera, including the family Chironomidae, was generally the dominant taxon, and Ephemeroptera typically made up the bulk of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa (sensitive taxa). Total taxa richness was lower in 2005 than in 2007. Average percent EPT was generally higher for samples collected using the Surber method (riffle/cobble habitat sampling) than percent EPT in Alaska Stream Condition Index-method samples (multi-habitat sampling) in the mine study area, despite the fact that riffle/cobble habitat composed the largest portion of habitats sampled by the Alaska Stream Condition Index method.

The results for measurements of habitat parameters at each site fell within ranges considered good to optimal for aquatic habitat. The sites sampled in this study are located in a pristine area with few to no human-caused effects. Water-quality results were comparable to typical results for Alaskan cold-water streams. Analysis of results for percent dissolved oxygen indicated frequent supersaturated conditions. In general, at the time of sampling, all three drainages in the study area provided good to optimal levels of dissolved oxygen, temperature, dissolved constituents (electrical conductivity), and pH, which are water-quality parameters that are important to diverse macroinvertebrate communities.

Thirty-six diatom genera and 188 diatom species were present in the 20 samples collected in 2004 in the Bristol Bay drainages study areas. During the course of the study, 115 primary periphyton samples were collected from the mine study area. Taxa richness and percent dominant taxon were calculated for periphyton collected in 2004. The metrics using the 2004 data were calculated from identifications of periphyton genera. Taxa richness was relatively uniform across the seasons among the sites sampled in 2004, with seasonal differences of four or fewer taxa at each site, except at one site in the South Fork Koktuli River (SK100B), which had a difference of seven taxa. The percent dominant taxon in periphyton samples in some instances equaled more than 50 percent. Periphyton samples collected in 2005 and 2007 were analyzed for chlorophyll-*a* concentration as a quantifiable measure of productivity. In 2005, samples were collected from six sites, and in 2007, samples were collected from 10 sites; 10 samples were collected from each site in each year. Average chlorophyll-*a* concentrations from samples collected in 2005 ranged from a low of 2.1 ±0.82 milligrams per square meter in a sample from Upper Talarik Creek (at UT100D) to a high of 17.0 milligrams per square meter in a sample from the South Fork Koktuli River (at SK100B). Variability among the five samples collected at each site was relatively high and was particularly notable at SK100B and at two sites on Upper Talarik Creek— UT100B and UT138A. Chlorophyll-*a* concentrations from samples collected in 2007 ranged from 2.3 milligrams per square meter at UT119A on Upper

Talarik Creek to a high of 30.2 milligrams per square meter at UT100D (also Upper Talarik Creek).

15.3 Fish—Transportation-corridor Study Area

15.3.1 Introduction

The transportation-corridor study area in the Bristol Bay drainages traverses multiple rivers, streams, and channels that eventually drain into Iliamna Lake (Figure 1-4 in Chapter 1). Fish and aquatic habitat surveys were conducted in the study area from July through October in 2004, 2005, 2007, and 2008 to characterize channel conditions, water quality, fish assemblages, and habitat use at possible stream-crossing locations along a representative road alignment. Fifty-five primary survey sites (stream-crossing sites on the representative road alignment) and 42 support survey sites (located upstream or downstream of primary survey sites or on nearby tributaries) were surveyed during the study period. To facilitate the characterization of the survey sites, sites were grouped into the following eight watershed groups:

- Upper Talarik Creek.
- Newhalen River.
- Isolated Watersheds.
- Roadhouse/Northeast Bay/Eagle Bay.
- Young/Chekok/Canyon Creeks.
- Knutson Bay/Pedro Bay.
- Pile Bay/Lonesome Bay.
- Iliamna River.

15.3.2 Results and Discussion

During fish and habitat surveys along the representative road alignment, a variety of stream channels were encountered. These channels ranged from small shallow channels of headwater reaches and tributaries to wider and deeper mainstem channels of Canyon Creek, Knutson Creek, and the Iliamna River. Channel-bed widths ranged from 2 to 51 meters. Stream gradients were also variable, ranging from 1 to 6 percent, and tended to be steepest in the Eagle Bay, Chekok Creek, and Pedro Bay watersheds.

Approximately 51 percent of primary survey sites were dry or had intermittent flow at the time of initial sampling. A second visit to dry channels showed that a few of these sites had flowing water after the fall rains had commenced. Forty-five percent of primary survey sites were never observed to have flowing water in the channel. All but two of these dry sites were located between Roadhouse Mountain and the Iliamna River, with a majority of them located in the Knutson Bay/Pedro Bay watershed group.

Where the channels contained flowing water, the sites consisted of predominantly fast-water riffle and/or glide habitats (greater than 70 percent), with cobble and gravel as the most prevalent substrates. Pools were present less frequently and accounted for approximately 10 to

30 percent of the habitat surveyed. Cascade habitat was encountered only at one primary survey site, at Chinkelyes Creek.

Water quality was generally good at all sites, with seasonally appropriate water temperatures and levels of saturated dissolved oxygen. High water-temperature measurements that exceeded the state water quality criteria for salmon were noted at four primary survey sites in late summer 2004. Overall, the pH was neutral, but there were many spot estimates that exceeded state criteria for pH. Measurements at nine sites indicated that the pH exceeded the state maximum criteria. These sites were located in Upper Talarik Creek (4 sites), the Newhalen River (3 sites), a tributary to Eagle Bay (1 site), and Chinkelyes Creek (1 site). Additionally, there were 17 sites where the spot measurement of pH was below the state minimum criteria. Low pH was documented in all eight watershed groups and in most streams surveyed. Specific conductivity was consistently low across all sites.

Ten fish species were documented in the study area. Dolly Varden and sculpin were the most common and were found at sites in seven watershed groups. Chinook salmon were documented only in primary survey sites in Upper Talarik Creek, but are known to be present in the Newhalen River based on the Alaska Department of Fish and Game's 2009 anadromous waters catalog (ADF&G, 2010). Coho salmon were found at primary and support survey sites in the Upper Talarik Creek and Newhalen River watershed groups. In addition, the 2009 anadromous waters catalog indicates that coho salmon have a presence in Youngs, Chekok, and Canyon creeks. Adult sockeye salmon were documented at primary survey sites in Chekok, Canyon, and Knutson creeks and the Iliamna River, and at support survey sites in the Iliamna and Newhalen rivers watershed groups. Although not evident during these surveys, sockeye salmon have been observed spawning in Upper Talarik Creek in the vicinity of the farthest-downstream primary survey sites. According to the 2009 anadromous waters catalog, additional streams that support spawning sockeye include the Pile River and tributaries to Knutson and Pedro bays. No fish were observed at sites in the Isolated Watershed Group.

15.3.3 References

Alaska Department of Fish and Game (ADF&G). 2010. Catalog of Waters Important for the Spawning, Rearing or Migration of Anadromous Fishes. http://www.adfg.alaska.gov/sf/SARR/AWC/

15.4 Aquatic Invertebrates—Transportation-corridor Study Area

15.4.1 Introduction

As noted in Section 15.2 for the mine study area, the macroinvertebrate and periphyton studies in the transportation-corridor study area (Figure 1-4 in Chapter 1) are part of the overall program of baseline investigations to describe current aquatic conditions. Baseline information on macroinvertebrate and periphyton community assemblages is valued because these creatures are essential components of the aquatic food web and their community structure, particularly with respect to the more sensitive taxa, is an indicator of habitat and water quality.

Macroinvertebrates and periphyton were sampled at three sites in the transportation-corridor study area in 2004 and 2005. The objective and methods for the study of macroinvertebrates and periphyton in the transportation-corridor study area are the same as those described for the mine study area (Section 15.2.1).

15.4.2 Results and Discussion

During the 2004 and 2005 sampling events six composite drift samples, nine composite Alaska Stream Condition Index samples, and 15 Surber samples were collected in the transportation-corridor study area. As noted in Section 15.2.2, 235 macroinvertebrate taxa, including 64 Chironomidae taxa, have been identified in the Bristol Bay drainages study areas (which includes both the mine and the transportation-corridor study areas). Three of the non-Chironomidae macroinvertebrate taxa and three of the Chironomidae taxa were identified only in the transportation-corridor study area samples. Of the non-Chironomidae taxa identified only in the transportation-corridor study area samples, one taxon was identified only in 2004. One of the Chironomidae taxa identified only in transportation-corridor study area samples was identified only in samples collected in 2004, and two were identified only in samples from 2005. Metrics that describe the macroinvertebrate population at each sample site were calculated. Slightly more taxa per site were collected in 2004 using the Alaska Stream Condition Index method than in 2005 Alaska Stream Condition Index samples, indicating possible interannual variability. The number of taxa collected at each site in 2005 from riffle/cobble areas by Surber sampler generally was less than the in Alaska Stream Condition Index samples, which were collected in more diverse habitats. Habitat data collected at the time of sampling indicated that riffle/cobble areas comprised a large component of the habitats in streams in the transportation-corridor study area. Differences in numbers of taxa collected in 2004 compared to 2005 could be the result of changes in the sampling program. However, the difference in taxa richness between 2004 and 2005 at transportation-corridor study area sites was not as great as the difference in the mine study area. The same number of sites was sampled in the transportation-corridor study area in both years (three total), which could account for the smaller difference in taxa richness as compared to the mine study area where the number of sites was reduced in 2005 from 20 to eight (offering less opportunity for collecting organisms).

Unlike the mine study area, Diptera, including the family Chironomidae, was not the clearly dominant taxa at sampling sites in the transportation-corridor study area. In 2005, Diptera comprised a higher percentage than EPT in Alaska Stream Condition Index samples from all the sites, while EPT taxa comprised a higher percentage than Diptera in Surber samples from all the sites. This difference may indicate that there were more Diptera taxa in the varied habitats sampled using Alaska Stream Condition Index methods.

The results for measurements of water-quality and habitat-quality parameters at each site fall within ranges considered good to optimal for aquatic and riparian habitat. The concentration of dissolved oxygen was consistently high at all sites, and supersaturation (dissolved oxygen higher than 100 percent) was found at some sites. Water temperature ranged from 5.5 to 13.2°C and was much lower in 2005 than in 2004, except at Ursa 100B on Ursa Creek.

Periphyton was collected successfully from all three sites in the transportation-corridor study area during the 2004 and 2005 sampling events. Among the three sites sampled in the transportation-corridor study area in 2004, periphyton taxa richness ranged from 13 to 22 and percent dominant taxon ranged from 52 to 68 percent. In 2005, chlorophyll-*a* concentrations were highest at Bear Den Creek and lowest at Ursa Creek. All three sampling sites were largely dominated by Chironomidae (more than 60 percent), of which some genera feed heavily on periphyton.

Collecting macroinvertebrate samples.

Collecting periphyton samples.

Identification of Chironomidae larvae using a dissecting microscope.

16. WILDLIFE AND HABITAT

16.1 Habitat Mapping and Habitat-value Assessments—Mine Study Area

16.1.1 Introduction

Wildlife habitats in the mine study area (Figure 1-4 in Chapter 1) were mapped to provide a baseline inventory of the availability of wildlife habitats and evaluated for use by wildlife to assess the value of those mapped habitats to a selected set of bird and mammal species of concern.

Field surveys to collect information on vegetation, physiography, landforms, and surface forms in the mine study area were conducted in August 2004 and August and September 2005. Physiography was mapped by photo-interpretation of true-color aerial photographs acquired for the mine study area in July 2004. Multivariate wildlife habitats were derived by adding physiographic information (and landform and surface-form information, as needed) to the vegetation mapping polygons prepared for the study area by Three Parameters Plus, Inc., and HDR Alaska, Inc.

To assess the use of the mapped habitat types by important species of wildlife, 38 bird and mammal species of concern (25 bird species and 13 mammal species) that are known or have the potential to occur in the mine study area were selected for their conservation, cultural, and/or ecological importance. Habitat use for each species in each mapped habitat type was qualitatively categorized into one of four value classes (high, moderate, low, or negligible value) based primarily on wildlife survey data specific to the mine study area and habitat-use information from scientific literature.

16.1.2 Results and Discussion

Twenty-five types of wildlife habitat were mapped in the mine study area. Two habitat types (Upland Moist Dwarf Scrub and Alpine Moist Dwarf Scrub[1]) account for 52 percent of the study area. Barren habitats in upland and alpine areas cover another 7 percent of the area. Willow- and alder-scrub habitats in both low and tall forms are common (21 percent of the study area) and occur primarily in protected upland and riverine areas. Wetter low and tall willow-scrub habitats are more rare (2 percent of the study area) and occur in poorly drained lowland areas often adjacent to inactive riverine features. As is typical of other mountainous areas in southwestern Alaska, only small patches of forest habitats occur. Lacustrine waterbodies, wet graminoid-dominated meadows, and shrub-dominated bog habitats occur primarily in lowland and riverine physiographic settings (8 percent of the study area). Marsh habitats are rare and occur along the margins of lakes and ponds. Three prominent riverine corridors (the north and

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[1] The names of habitat types that were mapped in this study are capitalized, while the names of general habitat types that were not mapped, such as forest, scrub, meadow, etc., are not capitalized.

south forks of the Koktuli River and Upper Talarik Creek) traverse the study area and support numerous stream channels and associated riverine meadow and scrub vegetation. Many of the streams support anadromous fish populations and provide foraging opportunities for wildlife.

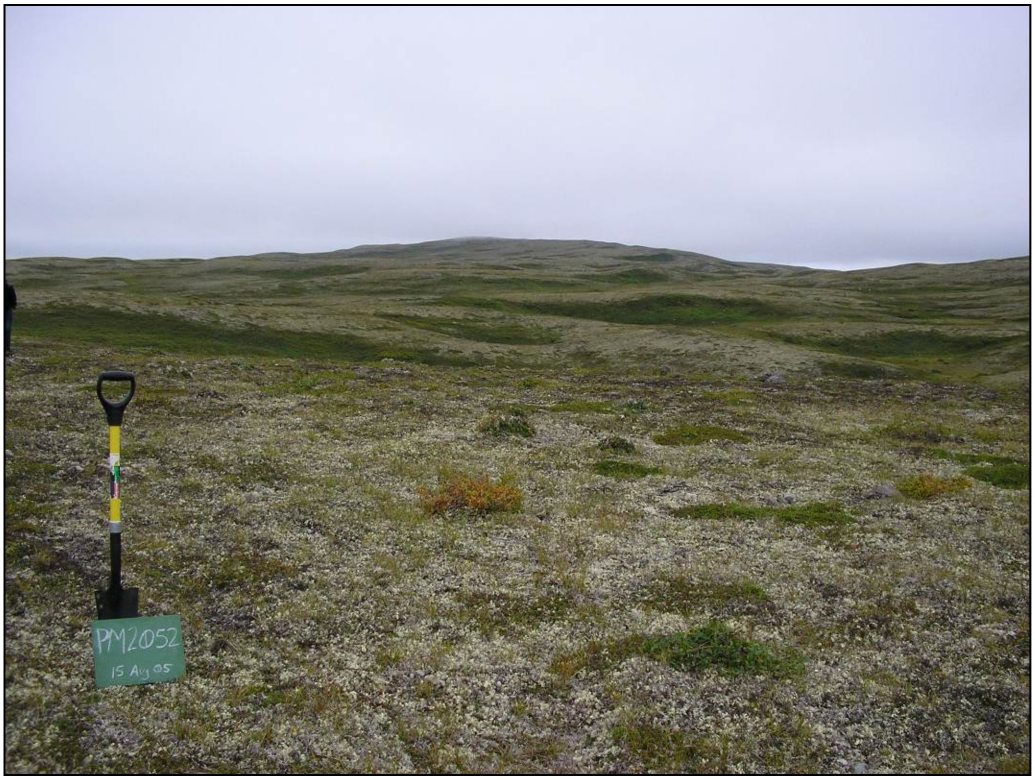
The results of the wildlife habitat-value assessments indicate that the most species-rich habitats are the open and poorly drained types. Three habitats (Lowland Ericaceous Scrub Bog, Lowland Wet Graminoid-Shrub Meadow, and Riverine Wet Graminoid-Shrub Meadow) had the greatest numbers (19 to 20 species) of bird and mammal species of concern that were given moderate- or high-value habitat rankings based on study specific criteria. Concentrations of these habitat types occur directly north of Frying Pan Lake, in the headwaters of Upper Talarik Creek, in the complex of waterbodies in the north-central portion of the study area, and along the north and south forks of the Koktuli River.

The mine study area provides at least some suitable habitat (moderate- and/or high-value habitat rankings) for 13 mammal species of concern—wolf, red fox, river otter, wolverine, brown bear, moose, caribou, arctic ground squirrel, red squirrel, beaver, northern red-backed vole, tundra vole, and snowshoe hare.

Brown bears are known to use a wide variety of habitats depending on the season, and 20 habitat types were considered to be of moderate value for brown bears; these types are common and widespread in the study area. One habitat type (Rivers and Streams [Anadromous]) was considered to be of high value for brown bears because salmon streams are heavily used by foraging bears in late summer. For moose, willow-scrub habitats, riverine forests, and lacustrine waterbodies were considered to be of high value, although moose have been recorded only infrequently. Moderate- and high-value moose habitats are concentrated in the stream drainage systems. Caribou pass through in midsummer after calving elsewhere, and they are not known to winter in the area. Because of this, no habitats were considered to be of high value for caribou. However, a set of 14 (primarily open) habitats was considered to be of moderate value for caribou; these habitats are common and widespread in the study area.

For birds, the mine study area provides at least some suitable habitat (moderate- and/or high-value habitat rankings) for 25 species of concern: seven raptor species (Bald Eagle, Northern Goshawk, Golden Eagle, Merlin, Gyrfalcon, Peregrine Falcon, Great Horned Owl), eight waterbird species (Tundra Swan, Harlequin Duck, Surf Scoter, American Scoter, Long-tailed Duck, Red-throated Loon, Common Loon, Arctic Tern), six shorebird species (American Golden-Plover, Lesser Yellowlegs, Whimbrel, Hudsonian Godwit, Surfbird, Short-billed Dowitcher), and four landbird species (Willow Ptarmigan, Rock Ptarmigan, Gray-cheeked Thrush, Blackpoll Warbler).

Habitats considered suitable for nesting and/or foraging tree-nesting raptors (forests, lacustrine and riverine waterbodies, and some barren habitats) are of limited occurrence in the study area. In contrast, the study area provides abundant (mostly open) habitat for cliff-nesting raptors. Thirteen barren, scrub, forest, meadow, scrub-bog, marsh, riverine, and lacustrine habitats suitable for nesting and/or foraging cliff-nesting raptors are common and widespread. For breeding and migrant waterbirds, suitable habitats in the study area include lacustrine waterbodies and stream drainages and associated wetland habitats, low and dwarf scrub, riverine forests, marshes, scrub-bogs, and meadows. These habitats are concentrated in the lower-elevation headwaters areas of the three primary riverine corridors. Suitable habitats for breeding shorebirds include wet, lowland meadows, scrub-bogs, and marshes, especially when adjacent to lacustrine or riverine waterbodies. Concentrations of these habitats occur directly north of Frying Pan Lake, in the headwaters of Upper Talarik Creek, and in the complex of waterbodies in the north-central portion of the study area. Well-drained upland and alpine habitats also are used for breeding by other shorebird species, and these habitats are widely distributed in the study area. Habitats suitable for breeding landbirds include tall willow and alder scrub in upland, lowland, and riverine areas. In general, these habitats are widely distributed across the study area, although concentrations tend to occur in stream drainage systems. Landbirds also use low- and dwarf-scrub habitats, barrens, scrub-bogs, and forests in a variety of physiographic settings. These landbird habitats occur commonly across the study area.



Upland Dry Dwarf Shrub-Lichen Scrub, mine study area, August 2005

Rivers and Streams (Anadromous) with Riverine Low and Tall Willow Scrub, mine study area, August 2005

Lowland Low and Tall Willow Scrub, mine study area, August 2005

Lowland Sedge-Forb Marsh, mine study area, August 2005

16.2 Terrestrial Mammals—Mine Study Area

16.2.1 Introduction

Forty species of mammals are known (or are strongly suspected) to occur in the geographic region of the Bristol Bay drainages in which the mine study area (Figure 1-4 in Chapter 1) is located.

The caribou is one of the most abundant large mammals in the region and is important to both subsistence and sport hunters. The mine study area is located within the annual range of the Mulchatna Caribou Herd (MCH), one of the larger herds in the state. Other species of large mammals also are ecologically and economically important inhabitants of the region. Brown bears are abundant in southwestern Alaska, whereas black bears occur only in the northern portion of the region in lower densities. Moose occur throughout the region in low densities, and winter concentrations have been noted previously in the Upper Talarik Creek drainage on the east side of the mine study area. These species were of primary interest for Pebble Project surveys, but all mammal species encountered incidentally, such as gray wolf and other species of large furbearers, were recorded. Mammal observations also were recorded incidentally during bird surveys (waterfowl, raptors, and breeding birds).

Field surveys were conducted periodically from April through November 2004, March through December 2005, May through July and in December 2006, June and July 2007, May 2009, and April 2010. Specific work elements included the following tasks:

- Collection and review of relevant literature on all species of mammals inhabiting the region around the Pebble Deposit.
- Acquisition and analysis of radio-telemetry data on the MCH collected by the interagency MCH Technical Working Group.
- Aerial strip-transect surveys within the mine study area during various seasons.
- Aerial line-transect survey to estimate the population density of bears in the Iliamna Lake region.
- Aerial quadrat survey to estimate the population density of moose in the mine and transportation-corridor study areas.
- Aerial survey of brown bears along salmon-spawning streams and examination of dens of brown bears and gray wolves in and near the mine study area.
- Aerial survey of beaver colonies throughout the mine study area.
- Collection of wildlife observations by other Pebble Project personnel.

16.2.2 Results and Discussion

Analysis of 29 years of telemetry data from radio-collared animals in the MCH documented seasonal patterns and changes in range use as the herd grew and expanded its range during the 1980s and 1990s. According to telemetry data locations, over all years, the greater mine study area has experienced moderate- to high-density use during spring, low-density use during calving, high-density use during summer and winter, and moderate-density use during autumn.

Brown bears were common in the mine study area, whereas black bears were recorded only rarely. Brown bears were recorded consistently during mammal surveys conducted during the nondenning season (May-October) in 2004 through 2007. Incidental sightings during other wildlife surveys in and near the mine study area produced additional sightings. The bear population survey conducted in collaboration with the Alaska Department of Fish and Game during May 2009 in the region surrounding Iliamna Lake produced density estimates of 47.7 to 58.3 brown bears per 1,000 square kilometers.

A moose population survey in the mine study area in April 2010 estimated 33 moose in the 1,178-square-kilometer survey area, an estimated density of 0.03 moose per square kilometer. The population density of moose may be higher in the fall and early winter when moose use habitats at higher elevations than they frequent later in the winter.

Wolves and wolverines were seen during aerial surveys for mammals and as incidental observations during surveys for other species. The mine study area generally hosts low densities of brown bears, moose, wolves, and wolverines throughout the year.

Because most of these species are highly mobile and cover relatively large home ranges, the numbers of animals using the area vary seasonally and even daily; in addition, the detectability of animals in shrub and forest cover is low. Therefore, the numbers observed and densities calculated from these surveys are low estimates of the use of the mine study area by large mammals throughout the year.

A family of river otters observed during a waterbird brood survey in the deposit area, July 2005.

A wolverine encountered in the mine study area during a waterbird brood survey in July 2005.

Part of a large aggregation of caribou finds relief from insect harassment on a remnant snowfield, Koktuli Mountain, late June 2007.

A group of caribou finds relief from insect harassment on a remnant snow bank, Koktuli Mountain, July 2007.

A family group of brown bears feeds on fresh spring vegetation, May 2009.

Two moose observed during the moose population survey in April 2010.

16.3 Raptors—Mine Study Area

16.3.1 Introduction

Studies were undertaken in 2004 and 2005 to collect baseline data on the distribution, abundance, and nesting status and habitat use of large tree- and cliff-nesting birds of prey (raptors) in the mine study area (Figure 1-4 in Chapter 1). Information on all raptors and Common Ravens was recorded, but special emphasis was placed on species of conservation concern, protected species, and species potentially sensitive to disturbance (Bald and Golden eagles, Gyrfalcon, Peregrine Falcon, Rough-legged Hawk, Northern Goshawk, Osprey, and Great Horned Owl). In addition, fall and winter surveys were undertaken in 2005 and 2006 to gather information on wintering Bald Eagles. Also, researchers developed aircraft guidelines to avoid disturbance of wildlife, including nesting raptors.

Field work was conducted primarily during April and May 2004, May through August 2005, and late fall and mid-winter 2005 and 2006. Aerial surveys were conducted by helicopter for all nest occupancy and productivity surveys and for most winter Bald Eagle surveys.

16.3.2 Results and Discussion

During aerial surveys, researchers recorded ten raptor species and Common Ravens in the mine study area, but at least 19 species of raptors may occur in the general region. Seventy-three nests of seven raptor species (Bald and Golden eagles, Osprey, Gyrfalcon, Merlin, Rough-legged Hawk, and Great Horned Owl) and the Common Raven were recorded in the mine study area. The greatest densities of woodland nest sites were located along Upper Talarik Creek, while the greatest densities of nest sites on cliffs were found on small canyons along Upper Talarik Creek and uplands between and including Groundhog Mountain and mountains east of Frying Pan Lake.

Bald Eagles were the most abundant nesting raptor (21 nests or 30 percent of all raptor nests in 2005), followed by Golden Eagle (20 percent), Rough-legged Hawk (14 percent), and Gyrfalcon (13 percent). Merlin, Osprey, and Great Horned Owl also were recorded nesting in the mine study area. No Peregrine Falcons or Northern Goshawks were recorded, but some suitable habitat occurs for these species in the mine study area. Common Ravens were found nesting in the mine study area where they regularly use both cliff and tree substrates and “improve” habitats for some raptor species that do not build their own nests (e.g., Gyrfalcon, Peregrine Falcon).

Information on nesting success and productivity was determined for five species of raptors, including Bald and Golden eagles, Gyrfalcon, and Rough-legged Hawk. Nesting success ranged from 67 percent for Rough-legged Hawk and Golden Eagle to 71 and 80 percent for Bald Eagle and Gyrfalcon, respectively. Productivity (young per successful nest) for each of these species generally fell within the ranges of productivity determined for studies conducted elsewhere in Alaska and/or North America. Bald Eagle nests were found along the lower north and south forks of the Koktuli River, Upper Talarik Creek, and Lower Talarik Creek. Golden Eagle, Gyrfalcon, and Rough-legged Hawk, which are primary cliff-nesting raptors, were found in uplands and on cliffs along the Upper Talarik and Koktuli drainages and the uplands between them.

Although open water was present in small sections of the Koktuli and Talarik drainages in winter, no Bald Eagles were recorded on the aerial surveys designed to record wintering eagles in the mine study area. Wintering Bald Eagles have been recorded in the region, but probably occur uncommonly, particularly by mid-winter (November through February).

View from Golden Eagle Nest GE015 (looking north) on Talarik Creek, August 2005.

Cliff-nesting habitat for Gyrfalcons, Rough-legged Hawks, and Golden Eagles in the UpperTalarik-Groundhog Mountain area, August 2005.

Riparian forest stands used by Bald Eagles for nesting, Upper Talarik Creek, April 2004.

Bald Eagle nest in cottonwood tree, Upper Talarik drainage, April 2004.

Cliff used by Gyrfalcons in the upper Koktuli drainage, 2004.

16.4 Waterbirds—Mine Study Area

16.4.1 Introduction

The waterbird studies were conducted in the mine study area (Figure 1-4 in Chapter 1) to collect baseline data on the distribution, abundance, species composition, and habitat use of waterbird species during the breeding season and during spring and fall migration. Waterbirds observed included geese, swans, ducks, loons, grebes, cormorants, cranes, shorebirds, gulls, terns, and jaegers. Species-specific surveys were conducted during the breeding season for Tundra Swan and Harlequin Duck because they are key indicator species of the environmental health of lakes and rivers, respectively. Additionally, studies determined the productivity of waterfowl based on brood-rearing surveys.

Field work was conducted during April through October 2004 and 2005 and in September 2006. Surveys were conducted using helicopter or fixed-wing aircraft and followed standard survey techniques.

16.4.2 Results and Discussion

Ponds, lakes, rivers, and wetlands in the mine study area support a diverse assemblage of waterbirds during breeding and during spring and fall migration. Thirty-seven species were observed. Twenty-one of these species, including swans, ducks, loons, shorebirds, and gulls, were recorded as confirmed breeders.

Waterbirds use lakes and rivers throughout the mine study area for staging during spring and fall migration. Swans and dabbling ducks arrived in late April to early May and fed in mixed-species flocks on rivers and on lakes in open water created by stream runoff. Many of these birds probably nested in the area. Diving ducks arrived in mid- to late May and staged on rivers and lakes. Some of these diving ducks probably nested in the area, while others, in small flocks (approximately 60 birds), rested and fed on lakes before continuing their migration. During fall migration, both dabbling and diving ducks staged in flocks of 60 to 120 birds, using primarily large lakes. Concentrations of birds occurred in both seasons in the northern half of the mine study area from Frying Pan Lake north to the lakes in the North Fork Koktuli River basin. Upper Talarik Creek was the creek most heavily used by dabbling and diving ducks. Some small flocks of dabbling and diving ducks stayed in the mine study area to molt during late summer. Scaup, in flocks of 35 to 60 birds, were the most common duck observed during summer and were found on Big Wiggly Lake, Frying Pan Lake, and other large lakes adjacent to the north and south forks of Koktuli River.

Nikabuna and Long lakes, and the outlets of Upper and Lower Talarik creeks at Iliamna Lake, are important stopover sites for large flocks of waterfowl and are within 20 kilometers of the Pebble Deposit. The outlet of Upper Talarik Creek is an important staging location for swans, ducks, and gulls during spring. Lower Talarik Creek, particularly the area of lakes and wetlands near the outlet, supports large flocks of ducks, gulls, and terns during both spring and fall. Nikabuna and Long lakes are important staging areas for swans, geese, and ducks during spring and fall. In late April 2005, hundreds of swans, Greater White-fronted and Canada geese, and dabbling and diving ducks staged at the lakes. From August to mid-October 2005, thousands of ducks were counted on the lakes and hundreds of swans congregated on the lakes starting in early October.

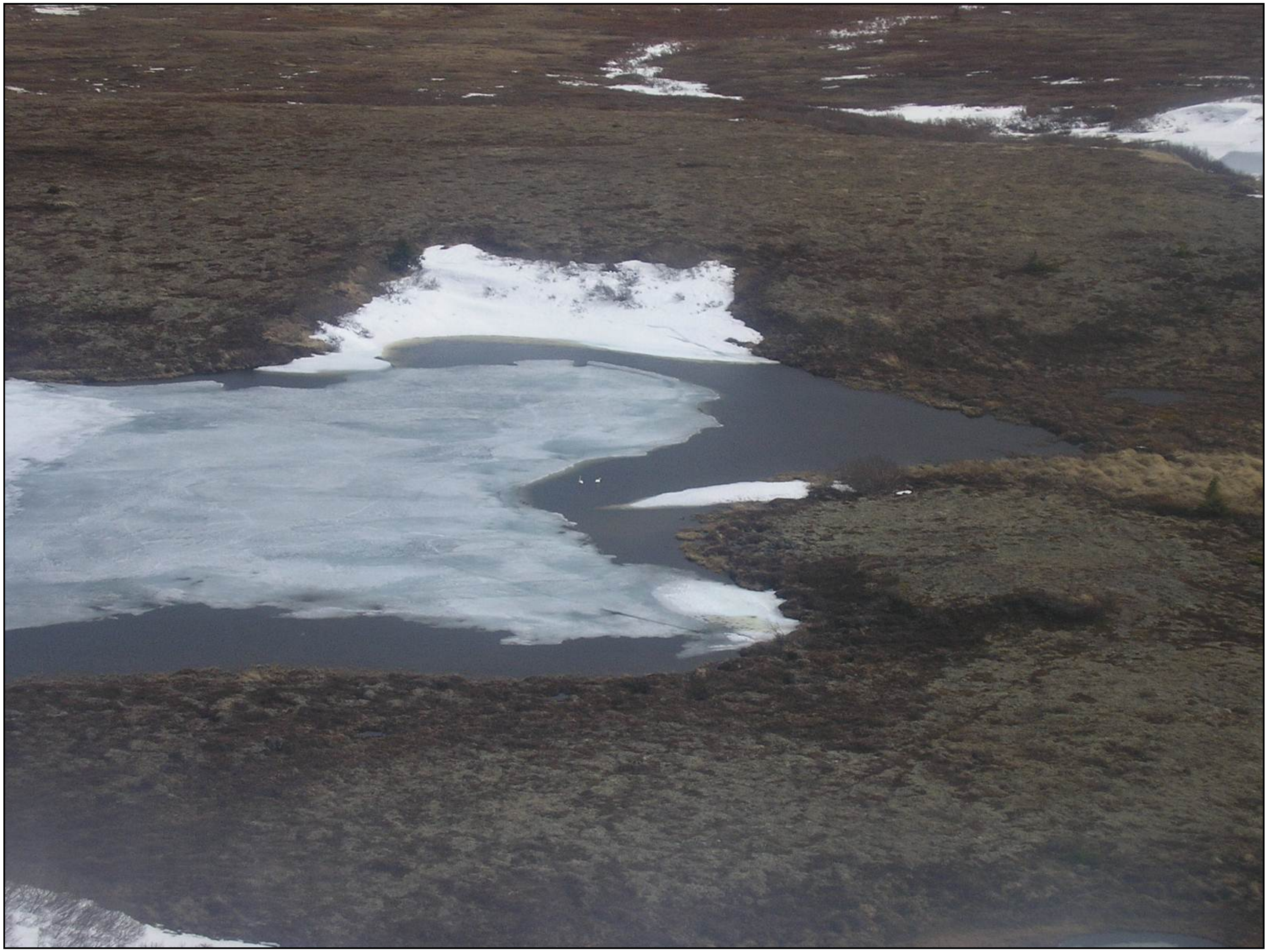
Tundra Swans were a common breeding bird in the mine study area, where over half the nests found in 2004 and 2005 occurred near lakes and wetlands in the North Fork Koktuli River drainage. Many swans returned to the same territories in 2005 and some to the same nest sites used in 2004. Harlequin Ducks were common and were found breeding in all three river drainages in the mine study area. During pre-nesting and brood-rearing surveys, Harlequin Ducks were most numerous on Upper Talarik Creek, followed by North Fork Koktuli River and South Fork Koktuli River. Common Loons nested and raised young on large lakes in the mine study area. Three lakes (including Big Wiggly Lake) were confirmed as breeding lakes by the presence of a Common Loon nest or brood, and another three lakes were suspected to be breeding lakes because of the repeated presence of loons. Two small colonies of nesting Mew Gulls were found, both north of Frying Pan Lake, and a breeding pair was observed in the North Fork Koktuli River drainage.

Eighteen species of waterbird broods were recorded in the mine study area. Brood-rearing groups were found on 33 percent of the lakes sampled in 2004 and 25 percent of the lakes sampled in 2005. In the same years, respectively, 75 and 88 percent of broods were ducks. American Wigeon, Northern Pintail, and scaup were the most common broods seen on lakes, while Red-breasted Merganser, Green-winged Teal, and Mallard broods were more common on rivers. Brood distribution was patchy, with most broods found on lowland lakes in the central part of the North Fork Koktuli River drainage, in upland and lowland lakes north of Frying Pan Lake in the South Fork Koktuli River drainage, in Frying Pan Lake, and in lakes in the floodplain of the lower South Fork Koktuli River drainage.

American Wigeon brood observed during waterbird brood-rearing survey, mine study area, July 2005.

A researcher counts waterbird broods on a lake during the waterbird brood-rearing survey, mine study area, July 2005.

Greater Scaup nest found during the waterbird brood-rearing survey, mine study area, May 2005.



Pair of Tundra Swans observed on lake during a spring migration survey, mine study area, May 2005.

16.5 Breeding Landbirds and Shorebirds—Mine Study Area

16.5.1 Introduction

Field surveys for breeding landbirds and shorebirds were conducted to collect baseline data on the distribution, abundance, and habitat use of these species during the nesting season in the mine study area (Figure 1-4 in Chapter 1). Landbirds recorded in the mine study area included ptarmigan and passerines (songbirds), and shorebirds included plovers and sandpipers. Researchers recorded all bird species observed in the field, paying special attention to species of conservation concern. Only landbirds and shorebirds are discussed in this section, however. Raptors and waterbirds are discussed separately (Sections 16.3 and 16.4, respectively).

The ground-based field work for this study was conducted during late May and June 2004 and 2005, using standard point-count survey methods. All birds seen or heard were recorded and, as is typical in point-count surveys, most observations were made by sound (songs and calls of breeding birds).

16.5.2 Results and Discussion

Including observations recorded outside the point-count periods, researchers identified 28 landbird species and 14 shorebird species in the mine study area. In addition to there being a greater number of landbird species, landbirds also were numerically more abundant than shorebirds.

Nine of the 28 landbird species (Savannah Sparrow, Golden-crowned Sparrow, Wilson’s Warbler, Orange-crowned Warbler, Common Redpoll, American Tree Sparrow, Gray-cheeked Thrush, Fox Sparrow, and Yellow Warbler) were considered to be abundant breeders in the mine study area. Three species (Savannah Sparrow, Golden-crowned Sparrow, and Wilson’s Warbler) were especially abundant and comprised 37 percent of the point-count observations in both years combined. Eight other landbird species (Northern Waterthrush, Lapland Longspur, American Robin, American Pipit, Blackpoll Warbler, Hermit Thrush, Horned Lark, and Snow Bunting) occurred less frequently, but were considered to be common in the mine study area. Of the 14 shorebird species observed in the mine study area, six species (Greater Yellowlegs, Wilson’s Snipe, Least Sandpiper, Black-bellied Plover, Whimbrel, and American Golden-Plover) were considered common breeders. Of the various landbird and shorebird species-groups observed, sparrows were by far the most abundant, while warblers, thrushes, and finches also were common. Larks, pipits, and swallows were less common, and ptarmigan, flycatchers, corvids, and kinglets were rarely recorded. Sandpipers and plovers were the only shorebird species-groups recorded.

Landbirds were recorded in 15 of the 19 wildlife habitat types sampled in the study area, and shorebirds were recorded in 12. Eight scrub, bog, or meadow habitats (Riverine Tall Alder or Willow Scrub, Riverine Low Willow Scrub, Lowland Low and Tall Willow Scrub, Lowland Ericaceous Scrub Bog, Lowland Wet Graminoid-Shrub Meadow, Upland Moist Tall Alder Scrub, Upland Moist Tall Willow Scrub, and Upland Moist Low Willow Scrub) had the greatest numbers of breeding landbird and shorebird species (with both bird groups considered together). The most productive breeding habitats, in terms of bird abundance, were Lowland Low and Tall Willow Scrub, Riverine Tall Alder or Willow Scrub, and Upland Moist Tall Willow Scrub. In these three habitats, more than nine birds were observed per point-count. Most landbirds regularly used tall- and low-scrub habitats, but some landbird species favor more open habitats (bogs, meadows, dwarf-scrub types, and barrens). Shorebirds were found most commonly in these same open habitats.

Point-count sampling in Lowland Low and Tall Willow Scrub, mine study area, June 2005.

Point-count sampling in Upland Moist Tall Willow Scrub, mine study area, June 2005.

Point-count sampling in Alpine Wet Dwarf Shrub-Sedge Scrub Meadow, mine study area, June 2005.

Point-count sampling in Alpine Dry Barrens, mine study area, June 2005.

16.6 Habitat Mapping and Habitat-value Assessments—Transportation-corridor Study Area

16.6.1 Introduction

Wildlife habitats in the Bristol Bay transportation-corridor study area (Figure 1-4 in Chapter 1) were mapped to provide a baseline inventory of the availability of wildlife habitats and were evaluated for use by wildlife to assess the value of those mapped habitats to a selected set of bird and mammal species of concern.

Field surveys to collect information on vegetation, physiography, landforms, and surface forms were conducted in August 2004 and August and September 2005. Physiography was mapped by photo-interpretation of true-color aerial photography acquired for the study area in July and October 2004 and September 2008. Multivariate wildlife habitats were derived by adding physiographic information (and landform and surface-form information, as needed) to the vegetation mapping polygons prepared for the study area by Three Parameters Plus, Inc., and HDR Alaska, Inc.

To assess use of the mapped habitat types by important species of wildlife, 45 bird and mammal species of concern (32 bird species and 13 mammal species) that are known or have the potential to occur in the transportation-corridor study area were selected for their conservation, cultural, and/or ecological importance. Habitat use for each species in each mapped habitat type was qualitatively categorized into one of four value classes (high, moderate, low, or negligible value) based primarily on wildlife survey data specific to the area and habitat-use information from scientific literature.

16.6.2 Results and Discussion

Twenty-five wildlife habitat types were mapped in the transportation-corridor study area. Forest habitats strongly dominate in the area. Four forest types in upland, lowland, and riverine settings (Upland and Lowland Spruce Forest, Upland and Lowland Moist Mixed Forest, Riverine Moist White Spruce Forest, and Riverine Moist Mixed Forest) cover 65 percent of the study area. Low- and tall-scrub habitats dominated by willow and alder, also occurring in upland, lowland, and riverine areas, are relatively common and comprise 15 percent of the study area. Open dwarf-scrub and barren habitats in upland and alpine areas are less common and cover 11 percent of the study area. Lacustrine waterbodies, wet graminoid-dominated meadows, and shrub-dominated bog habitats are relatively uncommon (7 percent of the study area) and occur primarily in lowland and riverine physiographic settings. Marsh habitats are rare and occur along the margins of lakes and ponds. A large number of riverine corridors occur in the area and support numerous stream channels and associated riverine forest, scrub, and meadow vegetation. Prominent streams in the study area, all of which drain into Iliamna Lake, include, from east to west, Chinkelyes Creek; Iliamna and Pile rivers; Knutson, Canyon, and Chekok creeks; and the Newhalen River (Figures 1-3c and 1-3b in Chapter 1). Many of the streams support anadromous fish populations and provide foraging opportunities for wildlife.

Results of the wildlife habitat-value assessments indicate that four forested habitats (Upland and Lowland Moist Mixed Forest, Upland and Lowland Spruce Forest, Riverine Moist Mixed Forest, and Riverine Moist White Spruce Forest) and one open wetland habitat (Lowland Ericaceous Scrub Bog) had the greatest numbers (20 to 24 species) of bird and mammal species of concern that were given moderate- or high-value habitat rankings based on study-specific criteria. The species-rich forest habitats are concentrated in the westernmost portion of the study area to the west of the Newhalen River and also from the base of Roadhouse Mountain east to where the transportation-corridor study area runs along Chinkelyes Creek to Summit Lakes. The species-rich lowland-bog habitats are scattered throughout the study area, occurring in small patches in poorly drained areas.

The study area provides at least some suitable habitat (moderate- and/or high-value habitat rankings) for 13 mammal species of concern—wolf, red fox, river otter, wolverine, black bear, brown bear, moose, arctic ground squirrel, red squirrel, beaver, northern red-backed vole, tundra vole, and snowshoe hare.

Black bears favor habitats that provide cover, and most forest and tall-scrub habitats were considered to be of high value for black bears. Other forest, scrub, scrub-bog, meadow, marsh, and lacustrine habitats, and those rivers and streams supporting anadromous fishes were considered to be of moderate value for black bears. In contrast, brown bears are known to use a broader array of habitats, and 20 habitats in the study area were considered to be of moderate value for brown bears. One habitat type (Rivers and Streams [Anadromous]) was considered to be of high value for brown bears because salmon streams are heavily used by foraging brown bears in late summer. Habitats suitable for both black and brown bears are common and widespread in the study area. For moose, low and/or tall willow-scrub habitats, riverine forests, and lakes and ponds were considered to be of high value, primarily for forage. The high-value moose habitats in the study area tend to be concentrated in stream drainage systems. Other scrub, scrub-bog, forest, meadow, marsh, and lacustrine habitats were considered to be of moderate value for moose, again for forage.

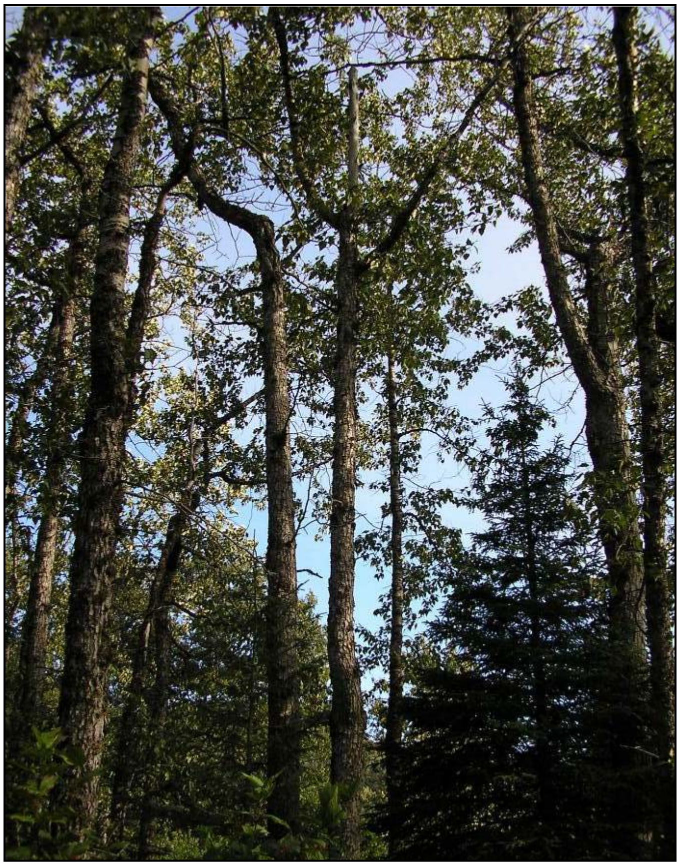
For birds, the study area provides at least some suitable habitat (moderate- and/or high-value habitat rankings) for 29 species of concern: seven raptors (Bald Eagle, Northern Goshawk, Golden Eagle, Merlin, Gyrfalcon, Peregrine Falcon, Great Horned Owl), nine waterbirds (Trumpeter Swan, Tundra Swan, Harlequin Duck, Surf Scoter, American Scoter, Long-tailed Duck, Red-throated Loon, Common Loon, Arctic Tern), four shorebirds (American Golden-Plover, Solitary Sandpiper, Lesser Yellowlegs, Surfbird), and nine landbirds (Spruce Grouse, Willow Ptarmigan, Rock Ptarmigan, Black-backed Woodpecker, Olive-sided Flycatcher, Gray-cheeked Thrush, Varied Thrush, Blackpoll Warbler, Rusty Blackbird). Habitats considered suitable for nesting and/or foraging tree-nesting raptors (forests, some scrub and barren habitats, meadows, lacustrine and riverine waterbodies) are common and widespread. For cliff-nesting raptors, a set of higher-elevation, open dwarf-scrub and barren habitats and some forest, scrub, scrub-bog, meadow, marsh, and aquatic habitats were considered suitable for nesting and/or foraging. The habitats preferred for foraging by cliff-nesting raptors in the study area are relatively common and widespread, but nesting habitats (cliffs) are uncommon. For breeding and migrant waterbirds, lacustrine waterbodies and associated wet meadow habitats were considered to be of high value. Scrub-bogs, marshes, anadromous fish streams, and some forest and dwarf-, low-, and tall-scrub habitats were considered to be of moderate value.

Suitable habitats for breeding and migrant waterbirds are relatively common and widespread in the study area, but these habitats have a higher likelihood of use when adjacent to aquatic habitats, especially lacustrine waterbodies. Suitable habitats for breeding shorebirds include open wetland types such as Lowland Ericaceous Scrub Bog and a diverse set of nine other habitats including well-drained barrens, dwarf-scrub, tall-scrub, some forests, streams (both anadromous and non-anadromous types), meadows, marshes, and the shorelines of lacustrine waterbodies. The suitable habitats for breeding shorebirds are widely scattered throughout the transportation-corridor study area. Habitats suitable for breeding landbirds include forests, tall-scrub and scrub-bog, low-scrub, dwarf-scrub, and barren types in a variety of physiographic settings. Suitable habitats for breeding landbirds are common and widespread across the study area.

Upland and Lowland Spruce Forest (in an upland, open woodland form), transportation-corridor study area, August 2005.

Upland Moist Tall Alder Scrub (foreground), and Rivers and Streams (Anadromous, below), transportation-corridor study area, August 2005.

Upland and Lowland Moist Mixed Forest, transportation-corridor study area, August 2005.



Riverine Moist Mixed Forest, transportation-corridor study area, August 2005.

16.7 Terrestrial Mammals—Transportation-corridor Study Area

16.7.1 Introduction

Forty species of mammals are known (or are strongly suspected) to occur in the geographic region of the Bristol Bay drainages in which the transportation-corridor study area for the Pebble Project is located.

Although caribou are one of the most abundant large mammals in the Bristol Bay drainages, the transportation-corridor study area is at the eastern edge of the annual range of the Mulchatna Caribou Herd, and few caribou occur in the study area. Other species of large mammals are ecologically and economically important inhabitants of the region. Brown bears are common, occurring at moderate densities, whereas black bears are present in low densities. Moose occur throughout the study area in low densities. These species were of primary interest for the surveys, but all mammal species encountered incidentally, such as gray wolf and other species of large furbearers, were recorded. Another source of mammal observations was incidental sightings during other wildlife surveys conducted for the Pebble Project (notably waterfowl, raptor, and breeding-bird surveys) and field delineation of wildlife habitats.

Field surveys were conducted periodically from April through November 2004, March through December 2005, December 2006, May 2009, and April 2010. Specific work elements included the following tasks:

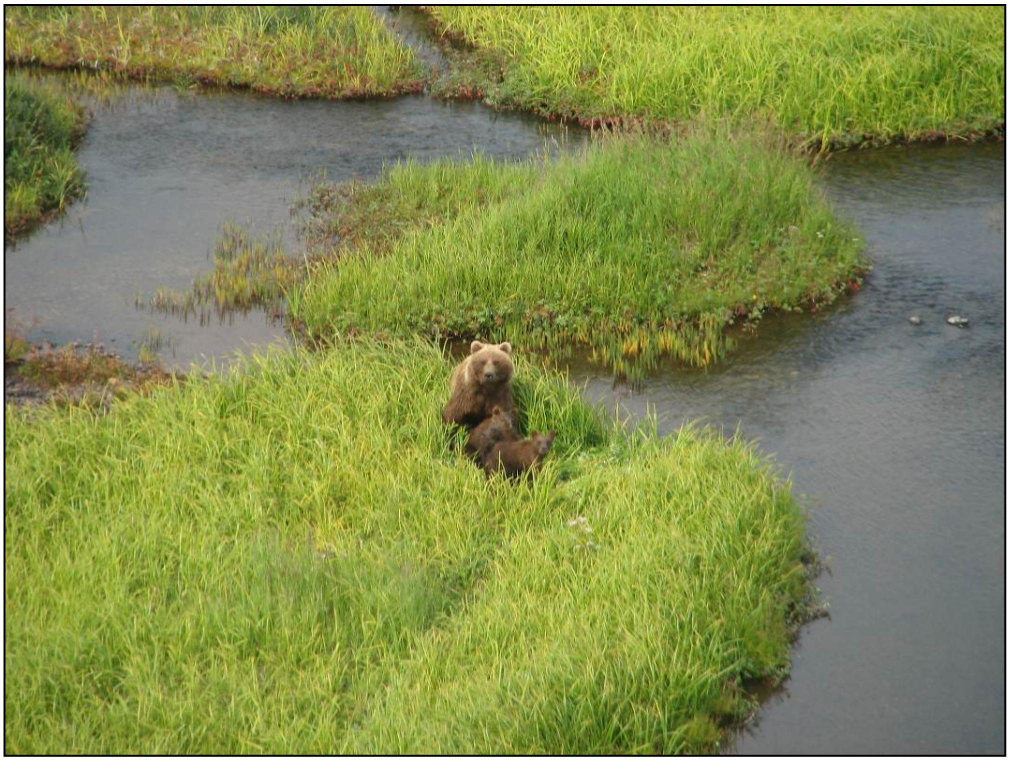
- Collection and review of relevant literature on all species of mammals inhabiting the region.
- Five aerial reconnaissance surveys of the study area during various seasons.
- Aerial line-transect survey to estimate the population density of bears in and near the study area.
- Aerial quadrat survey to estimate the population density of moose in and near the study area.
- Aerial survey of brown bears along salmon-spawning streams and examination of reported dens of brown bears and gray wolves.
- Aerial survey of beaver colonies.
- Acquisition and analysis of radio-telemetry data for the MCH.
- Collection of wildlife observations by other Pebble Project personnel.

16.7.2 Results and Discussion

The study area contained moderate densities of brown bears and low densities of black bears, moose, coyotes, wolves, river otters, and wolverines. Judging from telemetry data collected during 1981 through 2008, caribou from the MCH were found in the area only rarely; their principal range is located farther west. Because of the low densities of large mammals and the thick vegetation in the survey area, accurate calculation of density was difficult, requiring calculation of a sightability correction factor.

Small numbers of brown bears and black bears were observed on fixed-wing and helicopter surveys during 2004 and 2005. Incidental observations during other wildlife surveys produced sightings of both species. The bear population survey conducted in collaboration with the Alaska Department of Fish and Game in May 2009 in the region surrounding Iliamna Lake produced density estimates of 47.7 to 58.3 brown bears per 1,000 square kilometers. Although the numbers of black bears seen on that survey were insufficient to calculate a density estimate, all but one of the 18 black bear sightings occurred in the northeastern quadrant of the bear survey area, east of Nondalton and north of Iliamna Lake.

Pebble researchers recorded small numbers of moose throughout the study area during the aerial reconnaissance surveys in 2004 through 2006; the largest number seen on a single survey was 27 moose during the transect survey in December 2006. Incidental observations during bird surveys consistently produced moose sightings. Among all surveys in 2005, the estimated mean density of moose in the study area was 0.03 moose per square kilometer, incorporating a sightability correction estimated by simultaneous double-count surveys. The moose population survey in April 2010 estimated 63 moose in the 1,219-square-kilometer portion of the survey area in the transportation-corridor study area, for an estimated density of 0.05 moose per square kilometer.



A female brown bear with three spring cubs rests beside a salmon-spawning stream, July 2005.

Bull moose with antlers in velvet, July 2005.

16.8 Iliamna Lake Harbor Seals

16.8.1 Introduction

Harbor seals typically inhabit marine waters, but they also enter freshwater rivers and lakes. Iliamna Lake supports one of the few freshwater populations of harbor seals in the world, but relatively little is known about the population size, movements, and behavior of seals in the lake. This population of seals provides a source of food for local subsistence hunters.

Multiple aerial surveys of known and potential haulout sites in the eastern and central portions of Iliamna Lake were flown in 2005, 2007, and 2008 to examine the seasonal occurrence and abundance of the species. The study had four objectives:

- Review existing information on the population of harbor seals inhabiting the lake.
- Enumerate harbor seals hauled out at known and newly discovered sites in Iliamna Lake during spring, summer, and fall.
- Search for new haulout sites.
- Examine factors affecting haulout use.

16.8.2 Results and Discussion

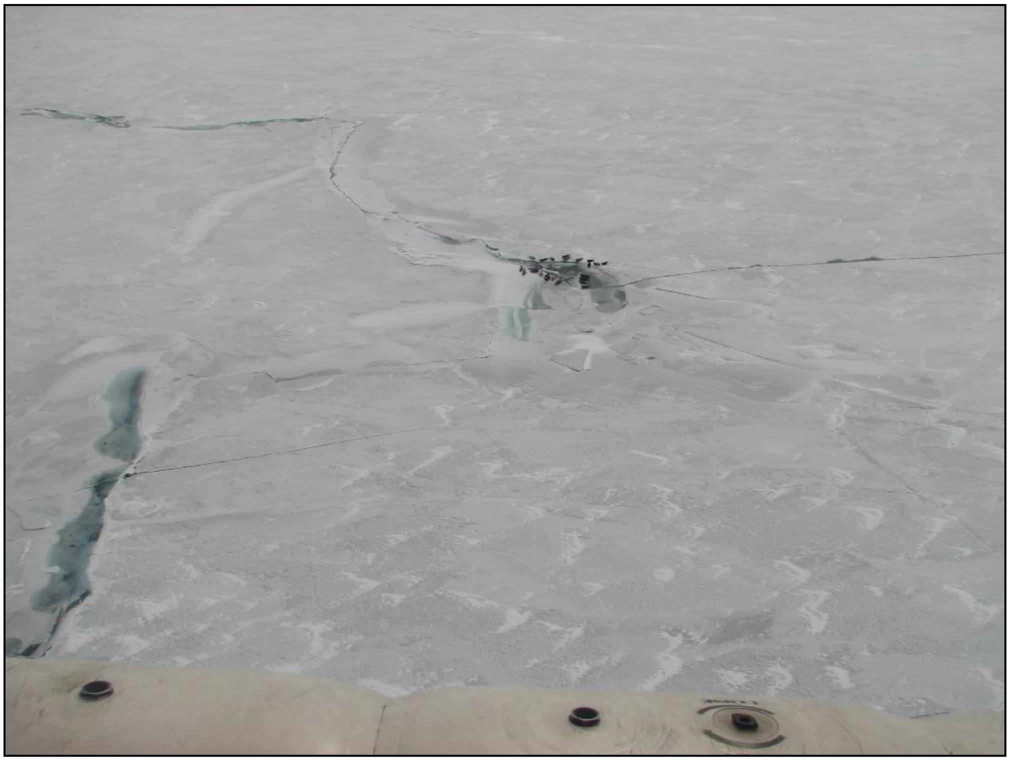
Freshwater populations of harbor seals are rare; the best known such populations of this species occur in the Hudson Bay in Canada. Harbor seals have been documented inhabiting Iliamna Lake since at least the late 19th century. The Iliamna Lake seals are considered to be year-round residents, but there are no geographic barriers to the movement of seals between the lake and Bristol Bay. Observations and harvests of seals in the Kvichak River near Igiugig and experience in the Canadian Arctic suggest that, despite the fact that seals are present year round, the Iliamna Lake population may not be as isolated as it might appear. Current evidence is insufficient to evaluate the degree of ecological or genetic isolation of the lake population from the marine population in Bristol Bay.

Surveys conducted for the Pebble Project examined previously described haulout locations in Iliamna Lake and also searched for additional haulout sites. Twenty aerial surveys were flown in a small fixed-wing airplane between March and December 2005, nine surveys were flown between May and October 2007, and seven surveys were flown in August 2008. During each survey, seals were counted as the aircraft circled each potential haulout location; photographs were taken if more than about 20 seals were present.

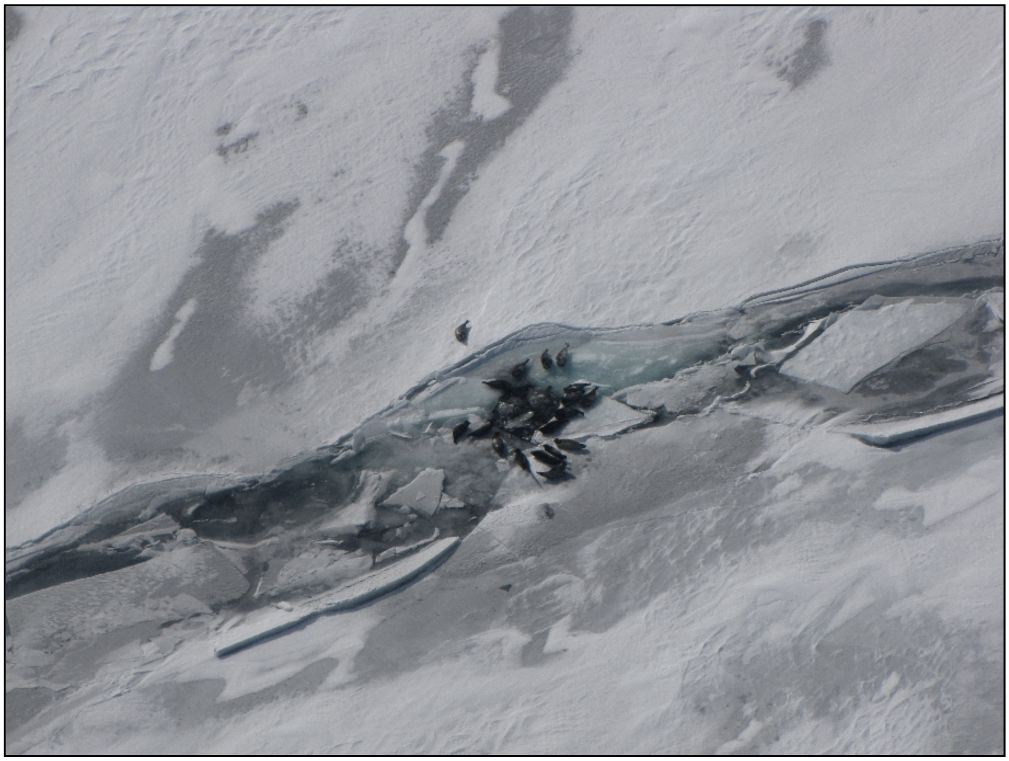
Most of the haulout sites documented in this study were identified from existing literature and consultation with agency researchers, but five more sites were added in 2005, two were added in 2007, and one was added in 2008. Seals were observed using 15 different haulout sites at various times during the three study years; seals were never observed at several other potential haulout sites.

Total counts among all surveys ranged from zero to 276 harbor seals in 2005, zero to 313 seals in 2007, and 205 to 357 seals in 2008. The number of seals hauled out varied substantially among seasons and was highest in summer, peaking in August during the molting period. Annual peak counts were obtained on August 17, 2005, August 15, 2007, and August 18, 2008. The largest number observed during a single survey was 357 seals. That count represents a minimum population estimate because not all seals in the lake would have been hauled out at one time and because there may have been additional, undiscovered haulout sites. The peak number counted during the 2008 surveys (357 seals) was greater than the peak numbers counted by other researchers in 1991 (137 seals), 1998 (321 seals), 1999 (225 seals), and 2003 (171 seals), suggesting that the population is stable or possibly increasing. Comparisons among years are confounded, however, by an increase in the number of known haulout locations and by seasonal differences in survey timing.

The highest level of use was at haulouts in the Flat/Seal Island group (southwest of Pedro Bay) and the Thompson Island group (north of Kokhanok). Despite substantial variability among surveys, two haulout locations (LI-05 on Seal Island and LI-07 east of Thompson Island) accounted for two-thirds of all the seals observed. Haulout use by harbor seals in Iliamna Lake is influenced by substrate conditions, seasonal variations in the water level of the lake, and by annual variation in the extent and duration of winter ice cover. The timing and location of spawning activity by sockeye salmon in summer and early fall also appear to influence haulout use.



A group of 23 harbor seals rests beside a hole in the ice cover of Iliamna Lake, March 17, 2008.



A group of 18 harbor seals rests beside a hole in the ice cover of Iliamna Lake, March 28, 2010.

Harbor seals resting at Site LI-07, a regularly used haulout east of Thompson Island in the southern portion of Iliamna Lake, August 11, 2005.

Harbor seals hauled out on Seal Island in Iliamna Lake during light rain, August 14, 2007.

Harbor seals resting on small islet in Iliamna Lake, August 29, 2007. Note sockeye salmon (live and carcasses) near left end of islet.

16.9 Raptors—Transportation-corridor Study Area

16.9.1 Introduction

Studies were undertaken in 2004 and 2005 to collect baseline data on the distribution, abundance, and nesting status and habitat use of large tree- and cliff-nesting birds of prey (raptors) in the transportation-corridor study area (Figure 1-4 in Chapter 1). Information on all raptors and Common Ravens was recorded, but special emphasis was placed on species of conservation concern, protected species, and species potentially sensitivity to disturbance (Bald and Golden eagles, Gyrfalcon, Peregrine Falcon, Rough-legged Hawk, Northern Goshawk, Osprey, and Great Horned Owl). In addition, fall and winter surveys were undertaken in 2005 and 2006 to gather information on wintering Bald Eagles. Also, researchers developed aircraft guidelines to avoid disturbance of wildlife, including nesting raptors.

Field work was conducted primarily during April and May 2004, May through August 2005, and late fall and mid-winter 2005 and 2006. Aerial surveys were conducted by helicopter for all nest occupancy and productivity surveys and for most winter Bald Eagle surveys.

16.9.2 Results and Discussion

Twelve raptor species and Common Ravens were recorded in the transportation-corridor study area during aerial surveys, but at least 19 species of raptors probably occur at least occasionally in the vicinity. Researchers located 125 nests of eight of these raptor species (Rough-legged Hawk, Red-tailed Hawk, Golden Eagle, Bald Eagle, Osprey, Gyrfalcon, Peregrine Falcon, and Great Horned Owl) and Common Ravens. A few sightings of Merlin suggested nesting by this species. Only a single Northern Goshawk was observed, although surveys were undertaken to find their nests. The greatest densities of tree-nesting raptor sites were located along the Newhalen River and sections of the shoreline of Iliamna Lake. The greatest densities of cliff-nesting raptor sites were found on Canyon Creek and along the southern edge of the Alaska Range north of Iliamna Lake.

Only Bald and Golden eagle nests were common, representing 43 and 19 percent, respectively, of nests found in 2005. Nests of Osprey were the next most abundant (5 percent of the nests found). Other species—Peregrine Falcon, Gyrfalcon, Rough-legged Hawk, Great Horned Owl, and Red-tailed Hawk—had three or fewer nests located in the study area. Common Raven regularly nested in the study area (13 percent of nests). Common Ravens regularly use both cliff and tree substrates and “improve” habitats for some raptor species that do not build their own nests (e.g., Gyrfalcon, Peregrine Falcon).

Nesting success and productivity were determined for five raptor species in the study area in 2005. Ospreys and Golden Eagles, although represented by only a few nests, had high nesting success and productivity compared to other populations in Alaska and North America. Bald Eagles, on the other hand, had lower nesting success (33 percent) than comparative subpopulations in southern Alaska (range 53 to 88 percent); however, productivity (young per successful nest) was similar to values for these other populations. A single Red-tailed Hawk nest, probably at the southwestern extent of it breeding range, was successful. Finally, one of three occupied Peregrine Falcon nests produced young.

Habitats for tree-nesting raptors are abundant in the study area, particularly east of and including the Newhalen River and below 400 meters in elevation. The best habitats for large tree-nesting species, like Bald Eagles, occur in cottonwood stands most closely associated with the floodplains of major rivers like the Newhalen and Iliamna rivers. Suitable and high-value habitats for cliff-nesting species are found along the southern front of the Alaska Range. Good to excellent habitats occur in the hills between Upper Talarik Creek and the Newhalen River, along Canyon Creek and Knutson Mountain, and along the upper Iliamna River (including a few cliffs on Chinkelyes Creek). A few cliffs along the shoreline of Iliamna Lake are suitable, including those on islands in the eastern extent of the lake and those on some lakes between the Pile and Iliamna rivers.

Bald Eagles were recorded on aerial surveys conducted during winter, and observations ranged from a single bird (February) to 120 birds (early November). Roughly two thirds of sightings were of adult plumaged eagles. Most were associated with open water along the Iliamna River, but eagles also were recorded along the Newhalen River, the north shore of Iliamna Lake, and the Knutson River. Wintering Bald Eagles may gather in numbers in fall, but occur uncommonly in the study area, particularly by mid-winter (mid-December through February). Bald Eagles are probably more common along the coast throughout the winter.

Eagle nest (BE058A), New Halen River, August 2005.

Osprey nest, Pile River area, August 2005.

Lower Canyon Creek cliff-nesting raptor habitat (Peregrine Falcons and Golden Eagles), August 2005.

Gyrfalcon nesting in old Golden Eagle nest (GYF060), Upper New Halen River drainage, May 2004.

16.10 Waterbirds—Transportation-corridor Study Area

16.10.1 Introduction

The waterbird studies were conducted in the transportation-corridor study area (Figure 1-4 in Chapter 1) to collect baseline data on distribution, abundance, species composition, and habitat use during the breeding season and during spring and fall migration. Waterbirds observed included geese, swans, ducks, loons, grebes, cormorants, cranes, shorebirds, gulls, terns, and jaegers. Observations of all waterbird species were recorded during breeding and migration surveys. Species-specific surveys were conducted during the breeding season for Tundra Swan and Harlequin Duck because they are key indicator species of the environmental health of lakes and rivers, respectively.

Field work was conducted during April through October 2004 and 2005 and in September 2006. Most surveys were conducted using helicopter or fixed-wing aircraft and followed standard survey techniques.

16.10.2 Results and Discussion

Ponds, lakes, rivers, and wetlands in the study area support a diverse assemblage of waterbirds during breeding and during spring and fall migration. Thirty-four species were observed in the transportation-corridor study area, and 14 of those, including swans, ducks, loons, cranes, and gulls, were recorded as breeders.

Waterbirds used lakes and rivers for staging throughout the study area during spring and fall migration. Swans, geese, and dabbling ducks arrived in late April to early May and fed in mixed-species flocks on rivers and on lakes and the bays of Iliamna Lake in open water created by river runoff. The highest concentrations of swans, geese, and dabbling ducks were found in an area of the Newhalen River known as Three-mile Lake and at Goose Cove, a small cove off Chekok Bay in Iliamna Lake. During spring, dabbling ducks also were concentrated at river outlets in the bays of Iliamna Lake and in adjacent flooded lake and wetland habitats. Diving ducks arrived in mid- to late May and staged in large flocks at protected bays of Iliamna Lake, at a large inland lake 15 kilometers north of Iliamna, and on the Iliamna and Newhalen rivers. During fall migration, concentrations of waterbirds occurred at many of the same locations where they were found in spring. No groups of swans or geese staged in the study area during fall; only brood-rearing groups and adult swans as singles or pairs were observed. Thousands of ducks and gulls were recorded during fall surveys, with duck abundance remaining high during the entire period from mid-August to mid-October and gull abundance peaking in mid- to late September.

Swans were common breeding birds. All nests, except for one, were found in the western half of the study area between Upper Talarik and Chekok creeks. Swans within this area were identified as Tundra Swans. A pair of breeding Trumpeter Swans was found each year near the Pile River. Many swans returned to the same territories in 2005 and some to the same nest sites used in 2004. Harlequin Ducks were found during the breeding season on seven different rivers in the study area. Pairs of ducks during the pre-nesting season and females with broods during the brood-rearing season were most numerous on the Newhalen and Iliamna rivers. Additionally, broods were observed on the Pile River and on Stonehouse Lake, a creek-fed lake 15 kilometers east of Iliamna. Common Loons were found on large, deep lakes between Upper Talarik Creek and the Iliamna River from early May to late September in 2004 and 2005. Five broods were recorded in each year; these 10 broods were found on eight different lakes, most of which were near the Newhalen or Iliamna rivers.

Goose Cove, a small cove off Chekok Bay in Iliamna Lake, where hundreds of swans, geese, and dabbling ducks stage during spring and fall migration, April 2005.

Tundra Swan identified during species delineation survey, September 2006.

Surveying the Iliamna River for Harlequin Duck broods, April 2005.

16.11 Breeding Landbirds and Shorebirds—Transportation-corridor Study Area

16.11.1 Introduction

Field surveys for breeding landbirds and shorebirds were conducted to collect baseline data on the distribution, abundance, and habitat use of these species during the nesting season in the transportation-corridor study area (Figure 1-4 in Chapter 1). Landbirds recorded in the study area included grouse, ptarmigan, cranes, kingfishers, woodpeckers, and passerines (songbirds), and shorebirds included plovers and sandpipers. Researchers recorded all bird species observed in the field, paying special attention to species of conservation concern. Only observations of landbirds and shorebirds, however, are discussed in this summary. Only landbirds and shorebirds are discussed in this section, however. Raptors and waterbirds are discussed separately (Sections 16.9 and 16.10, respectively).

The ground-based field work was conducted during June 2005, using standard point-count survey methods. All birds seen or heard were recorded and, as is typical in point-count surveys, most observations were made by sound (songs and calls of breeding birds).

16.11.2 Results and Discussion

Including observations recorded outside the point-count periods, researchers identified 46 landbird species and seven shorebird species in the study area. In addition to there being a greater number of landbird species, landbirds also were numerically more abundant than shorebirds.

Ten of the 46 landbird species (Wilson’s Warbler, Orange-crowned Warbler, Swainson’s Thrush, Yellow-rumped Warbler, Golden-crowned Sparrow, Dark-eyed Junco, Ruby-crowned Kinglet, American Robin, Varied Thrush, and Hermit Thrush) were considered to be abundant breeders in the study area. Three of these species (Wilson’s Warbler, Orange-crowned Warbler, and Swainson’s Thrush) were especially abundant and comprised 33 percent of all point-count observations. Sixteen additional landbird species (Blackpoll Warbler, White-crowned Sparrow, Common Redpoll, Yellow Warbler, Fox Sparrow, Gray-cheeked Thrush, Savannah Sparrow, Olive-sided Flycatcher, White-winged Crossbill, Northern Waterthrush, Tree Swallow, Gray Jay, Boreal Chickadee, American Tree Sparrow, Alder Flycatcher, and Lincoln’s Sparrow) occurred less frequently, but were considered to be common in the study area. The two most frequently observed shorebird species were Greater Yellowlegs and Wilson’s Snipe, and they were considered common breeders. These two species accounted for 92 percent of all point-count observations of shorebirds. Of the landbird and shorebird species-groups observed, warblers were by far the most abundant. Thrushes were the second most abundant group, and sparrows and allies (including juncos) also were common. Kinglets and finches were less common, and the rest of the landbird and shorebirds species-groups were much less common in the study area.

Landbirds were recorded in all 12 of the wildlife habitat types sampled, and shorebirds were recorded in four of the 12. The three sampled forest habitats in the study area (Upland and Lowland Moist Mixed Forest, Upland and Lowland Spruce Forest, and Riverine Moist Mixed Forest) had the greatest numbers of breeding landbird and shorebird species (with both bird groups considered together). In terms of bird abundance, six forest and scrub habitats (Riverine Moist Mixed Forest, Riverine Low Willow Scrub, Upland and Lowland Moist Mixed Forest, Upland and Lowland Spruce Forest, Upland Moist Tall Alder Scrub, and Upland Moist Low Willow Scrub) were the most productive and supported five or more birds per point-count. Individual landbird species often used a range of different forest, scrub, bog, and meadow habitats, with the more common species using a larger set of habitats than the uncommon species. Shorebirds, however, were found primarily in four relatively open habitat types: Lowland Wet Graminoid-Shrub Meadow, Lowland Ericaceous Scrub Bog, Upland Moist Dwarf Scrub, and Upland and Lowland Spruce Forest (when in an open forest form).

Point-count sampling in Lowland Ericaceous Scrub Bog, June 2005.

Moving between point-count locations, Riverine Moist Mixed forest, June 2005.

Checking data in the field, Lowland Wet Graminoid-Shrub Meadow, June 2005.

Point-count sampling in Upland and Lowland Spruce Forest, June 2005.

16.12 Wood Frogs—Mine Study Area

16.12.1 Introduction

The wood frog study was undertaken to collect baseline data on the occupancy rate of breeding wood frogs and the distribution of occupied waterbodies in the mine study area (Figure 1-4 in Chapter 1) and to evaluate habitat characteristics of waterbodies used by breeding wood frogs.

Researchers conducted ground-based surveys of randomly chosen waterbodies in the mine study area during mid-May 2007. An occupancy estimation modeling technique, using a repeated survey design with pseudo double-blind observers, was used to accurately estimate the population probability of wood frogs using waterbodies in the study area.

Researchers conducted ground-based surveys for breeding wood frogs at 119 waterbodies randomly selected from the set of 1,668 mapped waterbodies in the mine study area. Of these 119 waterbodies, 86 were surveyed a second time following the repeated survey protocol. Data from the surveys were used to map the general distribution of wood frog occurrence and to estimate the occupancy rate of wood frogs breeding in waterbodies in the mine study area.

16.12.2 Results and Discussion

Wood frogs were detected at waterbodies throughout the mine study area, and their distribution did not indicate any obvious spatial pattern of occupancy within the study area. An occupancy estimate, corrected for the calculated detectability (27 percent) of wood frogs, indicated wood frogs likely bred in 50 percent of the mapped waterbodies in the mine study area during 2007.

Several waterbody habitat characteristics also were evaluated for their influence on wood frog occupancy of waterbodies. The habitat characteristics chosen as potentially important in influencing breeding wood frog occupancy were as follows:

- Percent hibernation habitat within 50 meters of the waterbody shoreline.
- Waterbody size.
- Depth of the waterbody.
- Presence of emergent and/or aquatic vegetation within the waterbody.
- Whether or not the waterbody was a beaver pond.

(Although the presence of fish likely is an important characteristic influencing amphibian occupancy of waterbodies, researchers were unable to adequately determine fish presence in the waterbodies studied. Thus, a variable representing the presence of fish was not used in the analyses.)

Although not statistically conclusive, modeling of the habitat covariates indicated that various independent characteristics had varying degrees of influence on wood frog occupancy of waterbodies in the mine study area. Depth of the waterbody had a stronger magnitude of effect than the presence of emergent/aquatic vegetation and whether or not the waterbody was a beaver pond. Deep waterbodies (greater than 1.5 meters deep) were 10.1 times more likely to be occupied by wood frogs than shallow waterbodies (less than 1.5 meters deep). As the percent of hibernation habitat surrounding waterbodies increased, wood frog occupancy increased in a near linear manner (the influence of percent of hibernation habitat on occupancy was most pronounced for shallow waterbodies). Waterbodies with more than 1 percent cover of emergent or aquatic vegetation were 2.9 times more likely to be used by wood frogs than waterbodies without emergent/aquatic vegetation. The size of a waterbody was only marginally important, but the model results suggested a moderate increase in wood frog occupancy as waterbody size increased, and the magnitude of influence was fairly linear and most pronounced in shallow waterbodies. Finally, whether a waterbody was a beaver pond or not was not a strong factor affecting wood frog occupancy.

Overall, model results suggested that depth of the waterbody and percent of hibernation habitat were the most important factors influencing wood frog occupancy and that the presence of emergent/aquatic vegetation also may have increased occupation of waterbodies by wood frogs in the mine study area. The size of a waterbody and whether it was a beaver pond had only minimal influence and little magnitude of effect on wood frog occupancy rates in the study area. Therefore, study results suggested that if a waterbody in the mine study area was more than 1.5 meters deep, that if herbaceous, low shrub, and tall shrub vegetation were present within 50 meters of its shoreline, and if the waterbody contained even a small amount (greater than 1 percent) of emergent/aquatic vegetation, it was more likely to be occupied by wood frogs.

An example of an ice-free waterbody that was surveyed for wood frog occupancy in the mine study area, May 2007.

An example of a partially ice-covered waterbody that was surveyed for wood frog occupancy in the mine study area, May 2007.

An example of a beaver-occupied waterbody that was surveyed for wood frog occupancy in the mine study area, May 2007.

17. THREATENED AND ENDANGERED SPECIES AND SPECIES OF CONSERVATION CONCERN

17.1 Introduction

A review of existing information was conducted to determine whether any threatened or endangered bird and mammal species occur in Pebble Project study areas in the Bristol Bay drainages (Figure 1-4 in Chapter 1), to derive a list of the vertebrate species of conservation concern that have been found in the region, and to summarize what is currently known about the conservation status of those species. This work focused on bird and mammal species of conservation concern and did not address other high-profile wildlife species (e.g., caribou, bears, moose) that are of concern for subsistence, sport hunting, or ecological reasons, but are not of conservation concern in this part of Alaska. Similarly, another high-profile and federally protected species (Bald Eagle) was not addressed because in Alaska Bald Eagles are abundant and are not considered of conservation concern. In addition to the work on vertebrate species, an analysis of the potential for a set of rare vascular plant species to occur in the Bristol Bay drainages was conducted.

Researchers conducted two activities: a review of data from field surveys and a literature review. Field survey data from 2004 through 2008 (the surveys are summarized in Chapter 16) were reviewed for species-occurrence information. The literature review was used to assess which species are currently listed as threatened or endangered or of conservation concern and to summarize information on why each of those species is of concern.

To determine which rare vascular plant taxa could potentially occur in the Bristol Bay drainages, researchers requested information from the Alaska Natural Heritage Program on those species that have state rankings that indicate rarity (S1, S2, S1S2, or S2S3) and that have been collected in the region. The potential for these species to actually occur in the region was assessed by evaluating the known ranges of the plants, their habitat associations, and the habitats available in the Pebble Project study areas in the Bristol Bay drainages.

17.2 Results and Discussion

No threatened or endangered species listed under the Endangered Species Act or any candidate or proposed species for the Endangered Species Act, is known to occur in the Bristol Bay drainages study areas. Similarly, no species listed as endangered by the State of Alaska is known to occur in the study areas.

Twenty-two bird species that were recorded in one or both of the Bristol Bay drainages study areas are considered of conservation concern for Alaska. These species were listed as being of concern by at least two of 10 statewide or national-level management agencies or nongovernmental organizations that address bird conservation issues in the state. These species are Trumpeter Swan, Surf Scoter, Black Scoter, Long-tailed Duck, Red-throated Loon, Golden Eagle, Gyrfalcon, Peregrine Falcon, American Golden-Plover, Lesser Yellowlegs, Whimbrel, Hudsonian Godwit, Solitary Sandpiper, Surfbird, Short-billed Dowitcher, Arctic Tern, Black-backed Woodpecker, Olive-sided Flycatcher, Gray-cheeked Thrush, Varied Thrush, Blackpoll Warbler, and Rusty Blackbird. Of these 22 species, 21 are of concern primarily because population declines have been documented or are strongly suspected, either in Alaska or in breeding or wintering areas outside the state. These species also are of concern for a variety of additional reasons, which, depending on the species, can include the following issues:

- Sensitivity to disturbance and contaminants.
- Vulnerability to habitat loss and alteration during the breeding, migration, and wintering periods, but especially during migration and on the wintering grounds, which are often outside Alaska.
- Susceptibility to hunting pressure, fisheries bycatch, or heavy natural mortality during migration.
- Naturally small population sizes.
- Restricted breeding and/or wintering ranges.

Two mammals species recorded or expected to occur in the Bristol Bay drainages study areas are of conservation concern for Alaska. One of these, a marine mammal species—the harbor seal, is resident year-round in Iliamna Lake. Harbor seals typically are found in marine waters, but they have also been known to enter freshwater rivers and lakes occasionally (Chapter 16, Section 16.8). The presence of the species in freshwater in Iliamna Lake has been known since the late 19th century (Nelson and True, 1887). Harbor seals are not listed by the National Marine Fisheries Service under the Endangered Species Act and populations in Alaska are not considered to be depleted (NMFS, 2010), but like all marine mammals, they are protected under the Marine Mammal Protection Act. Suspected declines in the Bering Sea population of harbor seals (Angliss and Outlaw, 2007) presumably influenced the decisions of two management agencies to designate the harbor seal as a species of conservation concern (ADF&G, 1998; BLM, 2005).

The other mammal species of conservation concern is a terrestrial small mammal, the Alaska tiny shrew, which may occur in the Bristol Bay drainages study areas. The occurrence of this recently described species in the study areas has not been confirmed. The tiny shrew is listed as of conservation concern by the Alaska Natural Heritage Program (AKNHP, 2008). The Alaska Natural Heritage Program classified this shrew as vulnerable in the state (ranking S3), presumably because of its apparent rarity and uncertain conservation status. This ranking warrants further scrutiny, however, as more information becomes available, especially in view of the species' cryptic nature, the possibility of misidentification, the difficulty of capture, and the shrew's widespread distribution, as documented by inventory work in various parts of the state in the decade since the species was described.

The wood frog, which has been has been recorded in the mine study area (Chapter 16, Section 16.12) and may occur in the transportation-corridor study area as well, is considered of conservation concern in Alaska (ADF&G, 2006). The wood frog is the only species of amphibian that occurs in Alaska north of the southeastern panhandle of the state (Hodge, 1976). In developed areas in eastern Cook Inlet, the species was found to be abundant and widespread (Gotthardt, 2004). Nevertheless, the species is considered of conservation concern in Alaska, as are amphibians worldwide, because of widespread population declines in all groups of amphibians (McCallum, 2007).

Based on data compiled through 2006 (AKNHP, 2006), 16 rare vascular plant taxa with state rankings that indicate rarity (S1, S2, S1S2, or S2S3) were determined to have some potential to occur in the Bristol Bay drainages study areas. These species are: *Arabis lemmonii*, *Botrychium alaskense*, *Botrychium multifidum*, *Botrycium virginianum*, *Carex heleonastes*, *Catabrosa aquatica*, *Ceratophyllum demersum*, *Draba lonchocarpa* var. *vestita*, *Eleocharis quinqueflora*, *Eriophorum viridicarinatum*, *Geum aleppicum* var. *strictum*, *Myriophyllum farwellii*, *Potentilla drummondii*, *Primula tschuktschorum*, *Saxifraga adscendens* ssp. *oregonensis*, and *Smelowskia pyriformis*. The conclusion that these species could potentially occur in the Bristol Bay drainages region is based on the existence of known collections of these taxa within a broad region surrounding and including the Pebble Project study areas and the availability of suitable habitats in those study areas. Of these 16 rare taxa, six are listed as critically imperiled in Alaska (S1 or S1S2 ranks). These six taxa, however, are ranked as secure globally; they are considered S1 or S1S2 primarily because there are few collection records and/or small populations of these species in Alaska. The remaining 10 taxa are listed as imperiled in Alaska (S2 or S2S3 ranks). Among these 10 taxa, three species (*Botrychium alaskense*, *Primula tschuktschorum*, and *Smelowskia pyriformis*) also are listed as globally imperiled (G2 or G2G3 ranks), primarily because there are few collection records and/or small populations of these species worldwide. All three of these species are endemic to Alaska.

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18. LAND AND WATER USE

18.1 Introduction

The land use study describes and maps the existing ownership, use, and management status of public and private lands and surface waters in the Bristol Bay drainages study areas (except subsistence uses, which are addressed in Chapter 23). The study objectives include description and mapping of these uses, as well as a description of federal and state land-management regimes and applicable local governmental regulatory powers and plans for land use and coastal management.

The Bristol Bay drainages regional study area for land use encompasses territory in the northern part of the Lake and Peninsula Borough, the Bristol Bay Borough, the Dillingham Census Division, and an area east of the Mulchatna and Nushagak rivers. This regional study area includes the communities of Igiugig, Iliamna, Kokhanok, Levelock, Newhalen, Nondalton, Pedro Bay, and Port Alsworth. Within the regional study area is the central study area, which includes the local drainage areas surrounding the general deposit location and the transportation-corridor study area (the central study area coincides with the mine and transportation-corridor study areas depicted on Figure 1-4 in Chapter 1).

The method of study was to review and analyze relevant existing land use studies, plans, management documents, and land records developed by state, federal, and local governments.

18.2 Results and Discussion

The regional study area encompasses approximately 14.4 million acres. The prevalent land uses are wilderness and natural habitat, low-intensity recreational activities, and subsistence. The major landowners are the state and federal governments, and Alaska Native Claims Settlement Act village and regional corporations. Other landowners include borough and city governments, the state Municipal Land Trustee Program, Alaska Native allotment owners, and various other private landowners. The pattern of land ownership and management is complex and multifaceted, with intermingled land ownership, still-pending land transfers, and overlapping federal, state, local, and private management regimes and activities.

All the state-owned and state-selected lands in the study area are covered by the Bristol Bay Area Plan and are subject to its land use designations and management regimes, except for some management units designated for recreational uses that are also subject to the Nushagak and Mulchatna Rivers Recreation Management Plan. Over three-quarters of state lands in the regional study area, about 4 million acres, are designated for general use. General use areas contain a variety of resources or allow a variety of uses provided they are consistent with the specific management intent of the unit. They may also lack adequate information or sufficient demand for a more specific designation. The remaining lands are designated for dispersed recreation and tourism, settlement, habitat, mineral development, public use sites for recreation and tourism, public facilities to be retained in state ownership, waterfront development, materials sites, or multiple uses. The Pebble Deposit is on lands designated for mineral development.

Most federal lands in the regional study area are part of the Lake Clark National Park and Preserve, Katmai National Park and Preserve, and the Alagnak Wild River, all of which are managed by the National Park Service and are regarded as recreational lands. The Bureau of Land Management manages the balance of unencumbered federal lands in the study area. In accordance with the resource management plan for this region, the Bureau of Land Management manages these federal lands for multiple uses consistent with applicable protection measures. In the Kvichak, Iliamna West, and Alagnak planning blocks, lands managed by the Bureau of Land Management are open to exploration for and development of leasable and locatable mineral resources. The Bureau of Land Management also manages several unconveyed state and/or Native corporation selections in the central study area, pending the outcome of the selection process.

Most private landholdings, including Native village corporation holdings and Alaska Native Claims Settlement Act Section 14(c)(3) conveyances, are located in or around settlements. The Lake and Peninsula Borough has limited holdings in the area.

Non-federal and non-state lands in the regional study area may be subject to local governmental planning jurisdiction. The Lake and Peninsula Borough has not adopted zoning authority, but it administers subdivision regulations and development permits. It has an ordinance that requires large projects that meet certain conditions to complete a socioeconomic and fiscal assessment prior to permit approval. The borough does not have a land use plan, but it had an approved coastal management program, which provided an avenue for participation in federal and state decisions that affected coastal resources at the time these studies were conducted (the program has since been discontinued). The borough levies a severance tax on extraction of metal ores, coal, timber, and gravel.

The Dillingham Census Area does not have a borough government, but at the time these studies were conducted, it also had an approved coastal management program through the Bristol Bay Coastal Resource Service Area. The western part of the regional study area including the Koktuli, Mulchatna, and Nushagak drainages, downstream of the Pebble Deposit, was within the service area. The coastal management program had adopted enforceable policies that designated “all non-federal lands and waters within the coastal zone of the Nushagak and Mulchatna watershed” as subsistence and recreational use areas.

The state and the Alaska Native village corporations are the main landowners in the central study area. Under the Bristol Bay Area Plan, the management units on which the Pebble Deposit and other nearby state mining claims are located are designated as appropriate for minerals use.

In the years after the positive results of Northern Dynasty Mines Inc.’s initial mineral exploration activities (2002-2007), the vicinity of Pebble Project saw new mining claims. Some of these claims were filed by Northern Dynasty, but most were filed by other mining-exploration firms. Some of the claims have since been relinquished, although many remain active.

19. REGIONAL TRANSPORTATION

19.1 Introduction

The study described existing and planned inter- and intra-regional overland, water, and air transportation facilities and services for the Lake and Peninsula Borough communities in the Bristol Bay drainages regional study area. The study objective was to document these facilities and services.

The regional study area for the transportation study encompassed an area from Naknek and King Salmon in the south to the northern boundaries of the Lake Clark National Park and Preserve, with an emphasis on the communities of Igiugig, Iliamna, Kokhanok, Levelock, Newhalen, Nondalton, Pedro Bay, and Port Alsworth (Figure 1-1 in Chapter 1). Within the regional study area is the central study area, which is composed of the mine study area and the transportation-corridor study area (Figure 1-4 in Chapter 1).

The study methods relied on a review of existing transportation studies, plans, and documents for relevant information. This information was supplemented with interviews of several transportation services providers.

19.2 Results and Discussion

The region is characterized by small, remote, inland settlements; limited and circuitous water access; and rugged, environmentally sensitive terrain. The existing overland and water transportation infrastructure is spotty and is restricted to a few situations where special local circumstances have warranted development. Air transportation is the primary mode for moving people and goods to, from, and within the regional study area.

The eight study area communities are not connected by interregional roads to other areas of southwest or southcentral Alaska. The state-owned, 15.03-mile-long, unpaved Williamsport-Pile Bay Road is the only publicly maintained road in the transportation-corridor study area. This road is also partially in the Cook Inlet drainages study area (Chapter 47). It is open for use only seasonally, between June and November. It is used mainly to transport commercial fishing vessels and small freight overland between Cook Inlet and Iliamna Lake and its surrounding communities. In the regional study area, the Iliamna/Newhalen area has the most extensive local road system (including the Iliamna and Newhalen village roads and the Iliamna-Nondalton Road) and the highest rate of vehicle ownership and use. Elsewhere, local roads and vehicle traffic are very limited. There are no roads to or at the Pebble Deposit area.

Except for Nondalton and Port Alsworth, the eight study area communities are accessible by water via Iliamna Lake, which is accessed from the Kvichak River on the west or the Williamsport-Pile Bay Road on the east. Traditionally, most waterborne cargo was shipped to Naknek and then barged up the Kvichak River. In recent years, low water levels and river shoals made this service infeasible. In 2009, a new shipper, Iliamna Development Corporation, began shipping freight via the Williamsport-Pile Bay Road. Waterborne cargo consists mainly of bulk fuels and other freight too bulky or heavy to ship by air. Local dock and cargo-handling facilities are limited and typically are in poor repair. The shipping season is generally from late July to the end of September. The Alaska Marine Highway System does not serve any of the eight communities.

These communities rely heavily on air transportation for movement of people and goods to, from, and within the region. Each community has a state-owned airport, except Port Alsworth, which has two private landing strips. Iliamna Airport is the primary regional air-transportation hub through which most inter- and intra-regional air traffic travels. For most of the year, air cargo is the only means of transporting goods (including foodstuffs, consumer goods, building materials, and in some cases, bulk fuels) to these communities. At present, exploration activities at the Pebble Deposit area are supported by helicopter service based at Iliamna Airport.

The State of Alaska's *Southwest Alaska Transportation Plan* (PB Consult Inc., 2004) identifies three regional surface corridors for future transportation improvements: a Cook Inlet to Bristol Bay Corridor, a Dillingham/Bristol Bay Area Corridor, and an Alaska Peninsula Corridor. The plan's top-priority is the Williamsport-Pile Bay Road and associated navigation and dock improvements. The plan's next two priorities are the Iliamna-Nondalton and the Naknek-South Naknek improvements. All of these projects are part of the Cook Inlet to Bristol Bay Corridor. As part of its Industrial Roads Program, the state is evaluating the feasibility of a new deepwater port in the Williamsport vicinity, with a new road link to the Pebble Deposit area. This road would likely generally follow the Cook Inlet to Bristol Bay Corridor identified by the *Southwest Alaska Transportation Plan*.

The state is proposing airport improvements in Igiugig, Iliamna, and Kokhanok after fiscal year 2012. The ongoing airport master plan for the Port Alsworth Airport may result in the construction of a new state-owned airport.

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20. POWER

20.1 Introduction

The existing energy infrastructure in the regional study area in the Bristol Bay drainages was documented. The objective was to describe existing facilities for supply of electrical power and petroleum fuels in the communities nearest the Pebble Deposit area. The eight communities included in the study area are Port Alsworth, Nondalton, Pedro Bay, Iliamna, Newhalen, Kokhanok, Igiugig, and Levelock (Figure 20-1). Information was compiled from various publications and online information resources, supplemented by telephone interviews with staff of public agencies, local electrical utilities and fuel retailers, and fuel shippers.

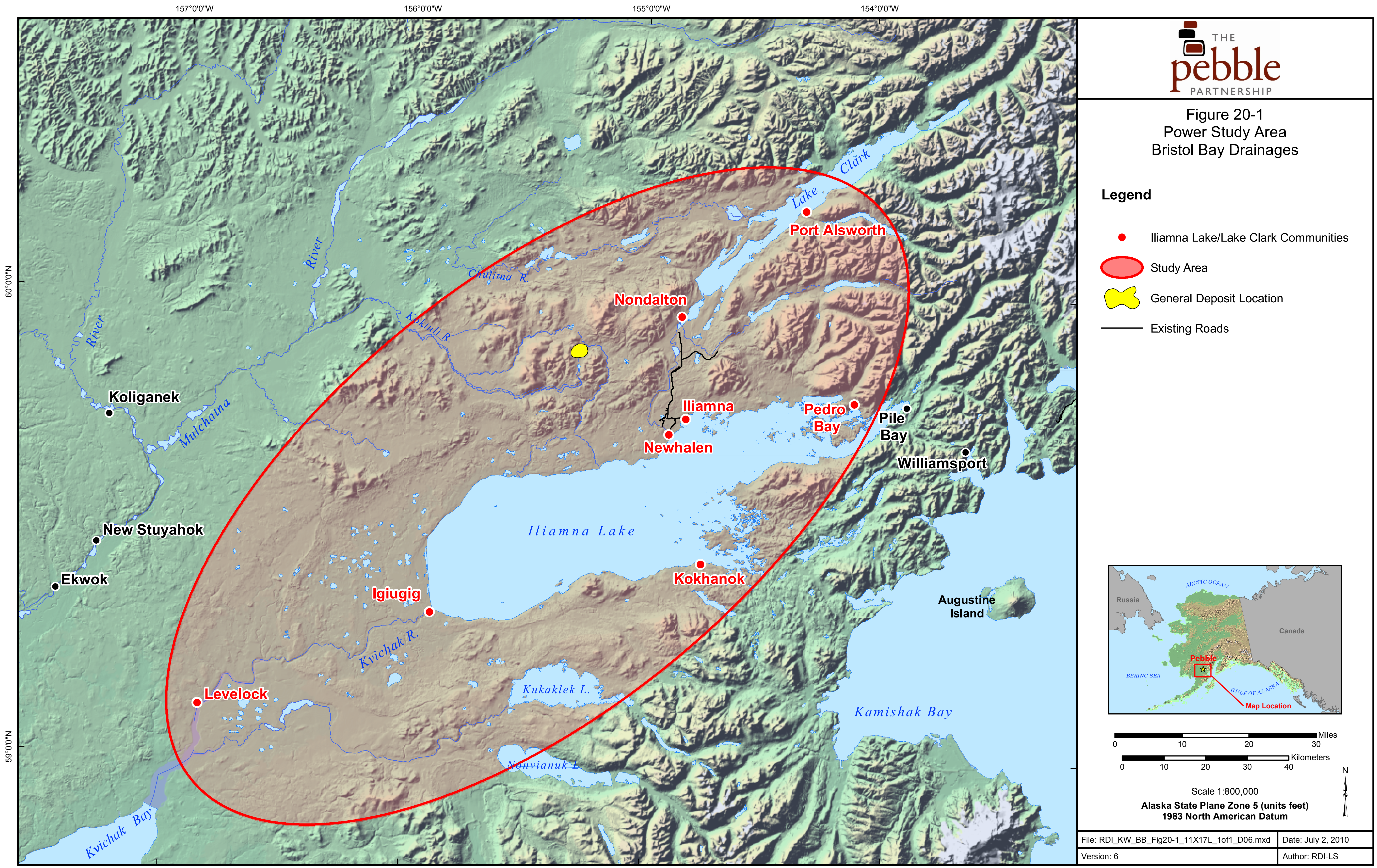
20.2 Results and Discussion

Six local electrical utilities generate and distribute electrical power to the eight communities in the study area. The cost of diesel fuel for power generation is a major operating expense for the six utilities. Overall, the weighted average cost of fuel almost tripled from $1.89 per gallon in 2002 to $5.54 per gallon in 2009, a rise of 193 percent. Electrical power rates in the study area partly reflect the cost of fuel and other operating expenses.

The most important factor in rates for residential customers and local community facilities, however, is the subsidy provided by the State of Alaska’s Power Cost Equalization Program and other programs that help defray the capital cost of power facilities. Apart from Power Cost Equalization payments, governmental grants and low-interest loans may help defray capital costs for small rural utilities. Between fiscal year (FY) 2002 and FY 2005, residential rates in the study-area communities were approximately triple the rates prevailing in Anchorage and Homer.

All the communities import all the petroleum products used locally for power generation, space heating, and transportation, including aviation fuels. Thus, the cost and reliability of fuels delivery and storage are critical to the local economies and to the security of community life. In recent years, the Denali Commission has put high priority on installation of modern, environmentally safe bulk-fuel storage facilities throughout rural Alaska.

Almost all households in the study area depend on heating oil for home space heating. Thus, local heating-oil prices and price increases are of vital importance for household economies throughout the area. Likewise, the price of gasoline affects all consumers who purchase it to operate motor vehicles, snow machines, boats, or other gas-powered equipment. As of May 2010, the average price in the study-area communities for heating oil was $5.85 per gallon, and gasoline was $6.36 per gallon.



THE pebble PARTNERSHIP

Figure 20-1
Power Study Area
Bristol Bay Drainages

Legend

● Iliamna Lake/Lake Clark Communities

🟥 Study Area

🟨 General Deposit Location

─ Existing Roads

Scale 1:800,000

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

File: RDI_KW_BB_Fig20-1_11X17L_1of1_D06.mxd	Date: July 2, 2010
Version: 6	Author: RDI-LS

21. SOCIOECONOMICS

21.1 Introduction

The socioeconomic baseline studies were undertaken to collect local- and borough-level demographic and economic information for the Bristol Bay Drainages study area. The Iliamna Lake/Lake Clark study area consists of eight communities in the Lake and Peninsula Borough: Nondalton, Newhalen, Kokhanok, Port Alsworth, Iliamna, Pedro Bay, Levelock, and Igiugig. Jurisdictions also included in the study were Lake and Peninsula Borough, the Bristol Bay Borough, and the Dillingham Census Area. Demographics include population size, age, gender, race, language, and household characteristics. The discussion of economies includes information on employment, labor force status, key employers, basic industries, income, occupational information, and other data. The discussion of community infrastructure provides information on utilities, housing, education, healthcare, and public safety.

This socioeconomic baseline description includes the most recent demographic and economic data available at the time of writing, from publically available sources. Long-term historical trend analysis relies on 1990 and 2000 U.S. census data.

21.2 Results and Discussion

Selected demographic and economic information for each of the eight communities in the Iliamna Lake/Lake Clark study area, Lake and Peninsula Borough, the Bristol Bay Borough, and the Dillingham Census Area are provided in the Table 21-1.

The eight communities in the study area ranged in population from a low of 48 in Pedro Bay and Igiugig to a high of 186 in Nondalton. The percent of population who are Alaska Natives living in these communities ranged from 22 percent in Port Alsworth to 95 percent in Levelock. Alaska Native groups are mainly comprised of Central Yup/ik Eskimos, Alutiiq speakers (Aleut or Suspiaq) and Dena'ina. Per capita income (2000) ranged from $7,732 in Kokhanok to $21,716 in Port Alsworth. Median household income (2000) ranged from $18,750 in Levelock to $60,625 in Iliamna.

Overall trends in demographics and economic status are evident upon review of the data. A review of the Lake and Peninsula data provides a regional view and indicates:

- An overall decline in population in the Lake and Peninsula Borough. While some communities are exceptions (e.g. Port Alsworth's population increased 20 percent between 2000 and 2009), there was an overall decrease in population of 15 percent from 2000 – 2009. Likewise school enrollment dropped 36 percent from 1997 to 2010.
- A substantial percentage of the population is living below the poverty level. This statistic is only available for 1999; at that time, 19 percent of individuals were living below the

> poverty level and it is likely that percentage had increased by 2009. This was attributed to the economy being dependent primarily on the Bristol Bay salmon fishery as discussed below.

There are three industries that drive the economy in the study area: commercial fishing/seafood processing, the visitor industry, and government. Though the mining industry does not currently play a major role in the region's economy, a brief overview of mining-industry activity in the region is included.

21.2.1 Commercial Fishing/Seafood Processing

Commercial fishing, dominated by sockeye salmon, has a long history in the Bristol Bay region which dates back to Russian ownership of Alaska, but began in earnest in the last two decades of the 19th century. Variable fishery management practices resulted in periods of decline mixed with rebuilding of the sockeye stocks. Throughout this history, there have been periods of foreign interest; Alaskan were alternately involved in or effectively excluded from the commercial fishery throughout its history. The State of Alaska initiated a "limited entry program" in 1973. Limited entry permits could only be issued to "natural persons" to maintain a high level of resident Alaskan participation within the fishery, but they could be sold to non-residents. Distribution of the permits among Alaskans has changed significantly over the years, although the proportion of non-residents has remained about the same. Local Alaskans consistently have the smallest average earnings and non-residents the highest. Despite progressive management and the resulting sustainability of Bristol Bay salmon stocks in more recent periods, the rise of farmed salmon into the previous dominance of commercial fisheries on a world-wide scale has profoundly affected Bristol Bay fishery economics. The value of the harvest has fallen precipitously, along with the value of the permits, and the number of fisherman participating in the harvest since 1990 has fallen nearly 40 percent.

The study of current fishing participation, success and economics focuses first on the Bristol Bay area as a whole, and then focuses specifically on the Naknek-Kvichak district, the Nushagak district, and the rivers in those districts most relevant to the study area. In 2009, 2,287 Bristol Bay gillnet permits were fished (driftnet and setnet permits combined). The total harvest in 2009 of 192 million pounds was worth $130 million. Roughly 32 million salmon were harvested in the Bristol Bay region with sockeye accounting for 31 million of this harvest.

Salmon processing in Bristol Bay is handled by both shore-based and floating facilities during the harvest season. In 2008, sockeye salmon processors in Bristol Bay produced just over 99 million pounds of finished product with a total first wholesale value of $268 million. In 2008, seafood-processing employment in the Bristol Bay Borough was 2,943 employees (total annual count), 459 employees in the Dillingham Census Area, and 565 employees in the Lake and Peninsula Borough.

The Naknek-Kvichak District includes the Kvichak, Alagnak (Branch), and Naknek rivers. During the 2009 salmon season, 8.5 million sockeye salmon with an estimated ex-vessel value of $35.2 million were harvested in this district. During the 2008 season, fishermen from the Kvichak River harvested 2.9 million sockeye with an estimated ex-vessel value of $11.5 million. Subsistence fishermen harvested a total of 48,797 sockeye in 2008.

The Nushagak District is located northwest of the Naknek-Kvichak District. In 2008, Nushagak District fishermen harvested 9 million fish with an estimated ex-vessel value of $28 million. Nushagak/Mulchatna river drainage fishermen harvested 1.1 million sockeye with an estimated ex-vessel value of $4.6 million in 2008. In 2008, an estimated 46,171 sockeye were harvested for subsistence use.

In fiscal year 2009, the Bristol Bay Borough received $1,542,615 in shared fisheries business taxes; Lake and Peninsula Borough received $151,743; and Dillingham received $187,259. In FY 2009, Bristol Bay regional development tax receipts totaled $1,066,270. Boroughs also can impose taxes on operators within their boundaries. In the Bristol Bay Borough in FY 2009, $1,441,628 was collected from the three percent raw fish tax, and the Lake and Peninsula Borough collected $1,260,995 from a two percent raw fish tax in FY 2009.

21.2.2 Visitor Industry

Tourism in the Lake and Peninsula Borough primarily involves sportfishing, hunting, and bear viewing. Secondary activities include hiking, camping, boating, and rafting. The borough contains a number of attractions, including a world-famous bear-viewing destination (Brooks Falls), , three national wildlife refuges, and numerous wild and scenic rivers, state critical habitat areas and three national parks and preserves. In 2009, 43,035 people visited Katmai National Park, 9,711 people visited Lake Clark National Park, and 14 people visited Aniakchak National Monument and Preserve. The Lake and Peninsula Borough *Comprehensive Economic Development Strategies* identified tourism as the third largest industry in the borough, after commercial fishing and government services.

21.2.3 Government

Government is by far the largest source of year-round employment in the Lake and Peninsula Borough. In 2008, federal, state, and local government (including tribal government) accounted for a monthly average of 424 jobs and nearly $11.5 million in annual payroll. Local government accounted for 373 jobs in the borough in 2008, while there were 42 jobs in the federal government, and nine jobs in state government. Government is a stabilizing influence in the borough’s otherwise highly seasonal economy. Private-sector employment in 2008 ranged from a low of 135 jobs in January to a high of 827 in July. In the same year, government employment ranged from a low of 276 jobs in July to a high of 483 in May. As reported in the Consolidated Federal Funds Report, total federal funds flowing into the borough are variable from year to year and totaled $16.6 million in FY 2008.

21.2.4 Mining Industry

Mineral resources in the area around the Pebble Deposit include metallic base, precious, platinum-group, rare earth, and industrial rocks and minerals. The area, in general, has large quantities of sand, gravel, and quarry materials. Almost all State land within the study area is open to mining. Historical mineral exploration dates back to the gold rush of 1898. Historical mineral exploration noted in this study included Kasna Creek and Crevice Creek. Detailed profiles of recent explorations included Big Chunk Super Project, Bonanza Hills, Iliamna Project, Kamishak Prospect, Pebble South, and other smaller claim activity including Chilikat East and Chilikat West Properties, Kolossus Property, Fog Lake, Kemuk, Koksetna, KUY, and Samuelson Property . Pebble deposit exploration dates back to Cominco American Exploration which began its investigation in 1986 and continued working in the area through 1997 before selling the claims to Northern Dynasty Minerals Ltd in 2001.

TABLE 21-1
Selected Demographic and Economic Overview of the Iliamna Lake/Lake Clark Communities, Lake and Peninsula Borough, Bristol Bay Borough, and Dillingham Census Area, Various Years

	Nondalton	Kokhanok	Newhalen	Port Alsworth	Iliamna	Levelock	Pedro Bay	Igiugig	Lake and Peninsula Borough	Bristol Bay Borough	Dillingham Census Area
Population, 2009	186	184	162	118	91	88	48	48	1,547	967	4,729
% Male Population, 2000	55%	59%	50%	46%	53%	59%	44%	43%	51%	55%	51%
% Female Population, 2000	45%	41%	50%	54%	47%	41%	56%	57%	49%	45%	49%
Median Age, 2000	28.5	29.5	20.5	25.5	31.5	27.5	35.0	36.3	29.2	36.0	28.9
Alaska Native or American Indian (alone or in conjunction with another race), 2000	90%	91%	91%	22%	58%	95%	64%	83%	80%	45%	76%
# of Households, 2000	68	52	39	34	35	45	17	16	588	490	1,529
Subsistence resources harvested (pounds per capita)[a]	358	680	692	133	469	527	306	542	N/A	N/A	N/A
Per capita income, 2000	$8,411	$7,732	$9,447	$21,716	$19,741	$12,199	$18,419	$13,172	N/A	N/A	N/A
Per capita income, 2007	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$32,231	$48,747	$33,380
# local employers, 2007	7	3	2	11	18	3	4	7	N/A	N/A	N/A
Commercial fishing permits fished, 2009	2	9	8	2	15	5	3	1	120	146	378
Crew-member licenses, 2009	11	15	3	3	33	8	1	2	224	149	587
Median household income, 2000	$19,583	$19,583	$36,250	$58,750	$60,625	$18,750	$36,750	$21,750	N/A	N/A	N/A
Student enrollment, FY2010	33	35	75	41	N/A	19	12	12	344	158	1,127

Notes:

a. Figures for Nondalton, Newhalen, Port Alsworth, Iliamna, and Pedro Bay are for 2004. Figures for Kokhanok, Levelock, and Igiugig are for 2005.

N/A = not available.

22. CULTURAL RESOURCES

22.1 Introduction

The purpose of the cultural resources study was to characterize the existing cultural resources on lands in the mine and transportation-corridor study areas in the Bristol Bay drainages (Figure 1-4 in Chapter 1).Cultural resources may include historic buildings, structures, and landscapes; prehistoric and historic surface and subsurface sites; and traditional- and religious-use areas. The objectives of the cultural resources field surveys in the Bristol Bay drainages were to locate, identify, and describe documented and previously undocumented archaeological, historic, and ethnographic cultural resources in the vicinity of the Pebble Deposit and at exploratory drilling locations for the Pebble Project.

Cultural resources research and field work were conducted during 2004, 2005, 2006, 2007, and 2008. In order to characterize the cultural resources in the mine and transportation-corridor study areas, researchers reviewed the Alaska Heritage Resources Survey database, literature, and archival data; conducted cultural resource interviews and consultations; and conducted field surveys. The review of existing data regarding cultural resources in the study areas and the effort to identify previously undocumented cultural resources through interviews, consultations, and field surveys helped to inform researchers as to where and what manner of cultural resources were likely to be found in the study areas.

During the 2004 through 2008 field seasons cultural resource field surveys, subsurface testing, and monitoring of ground-disturbing activities were conducted primarily within the Pebble mining claims boundary on locations that might be considered for installation and operation of mine infrastructure or for geological investigations. Because of the extent of the area to be surveyed, survey efforts were focused on areas deemed to have a high or moderate probability for discovery of previously undocumented cultural resources. The only surveys conducted in the transportation-corridor study area were in the vicinity of the Newhalen River and at a drilling-core storage area in Iliamna and were both in October 2006.

22.2 Results and Discussion

Previous cultural resources surveys in or near the study areas have resulted in the identification of a prehistoric cultural sequence from some time after the retreat of glaciers covering the area through the first, presumably proto-Dena’ina (Athabascan), users of the area. Sites of Dena’ina origin were contemporary with or were replaced by Yup’ik Eskimo-style structures and materials in some locations, such as Newhalen and Pedro Bay. This indicates the likelihood that both Athabascan and Eskimo types of material culture and sites may be present in the study areas. Cultural resources from late 18th century Russian and later American exploration and development in the region also are present in the study areas.

The relative remoteness of the Pebble Deposit likely limits the number of cultural resource sites and the extent of cultural deposits in the claim boundary area. The transportation-corridor study area, however, traverses areas where possibly both Yup'ik and Dena'ina people have lived for several thousand years, increasing the likelihood that archaeological or culturally significant sites may be found in this area. Areas with a higher likelihood of having archaeological or culturally significant sites include the Newhalen River corridor and other stream corridors, lakes, and mountain passes, as well as the shores of Iliamna Lake and its tributary streams. All these areas have high subsistence-food productivity. As of 2008, there were 20 cultural resource sites and no documented place names within the claim boundary compared to 62 cultural resource sites and 103 place names in the transportation-corridor study area.

Based on information from the Alaska Heritage Resources Survey database, 85 documented cultural resource sites are located in the mine and transportation-corridor study areas. Of these 85 documented sites, two (Russian Orthodox churches in Pedro Bay and Nondalton) are listed on the National Register of Historic Places, five (all northeast of Iliamna Lake) have been determined eligible for the National Register of Historic Places, 17 have been determined not eligible, and the remaining 61 have had no determinations of eligibility.

The compilation of place-name data for the Bristol Bay region resulted in the identification of 119 place names in the Bristol Bay drainages study areas. Sixteen place names are associated with locations in the mine study area, and 103 place names are associated with locations in the transportation-corridor study area. Cultural resources interviews, as well as subsistence and traditional knowledge interviews, in communities in the study areas resulted in identification of 565 features in the study areas. The cultural resources consultations and the collection of place names provided additional cultural context for the area and assisted researchers in determining the possible location and manner of cultural resources in the area.

Cultural resource discoveries that resulted from the 2004 through 2008 field surveys in the claim boundary area include the following:

- Two prehistoric lithic (stone tools) sites (Alaska Heritage Resource Survey codes ILI-00193 and ILI-00194) along the South Fork Koktuli River.
- One rock circle and nearby rock stack (ILI-00212) on a large glacial rubble pile south of the Cone.
- Two possible tent rings (ILI-00203 and ILI-00204) on a south-facing ridge of Kaskanak Mountain.
- Several isolated lithic finds (ILI-00196, ILI-00201, ILI-00202, ILI-00205, ILI-00207, ILI-00208, ILI-00209, ILI-00218, and ILI-00219).

Evidence of more recent use also was discovered during the surveys. These discoveries include the following:

- Subsistence camps and hunting sites along the South Fork Koktuli River, around Big Wiggly Lake (ILI-00213 through ILI-00217), and on the high ridges and benches of Kaskanak Mountain.

- Isolated modern objects (e.g., cartridge scatters, a fragmentary teacup, and metal cans and wires [ILI-00220]) observed throughout the mining claims boundary.

Archaeologists documenting an ancestral site near the northeast tributary of Upper Talarik Creek.

An ancestral stone tool found on the surface by a bear guard/cultural advisor accompanying the archaeologists.

Archaeologist and bear guard/cultural advisor documenting a historic subsistence camp among cottonwoods.

23. SUBSISTENCE USES AND TRADITIONAL KNOWLEDGE

23.1 Introduction

The purpose of the subsistence uses and traditional knowledge study is to establish a description of subsistence uses and knowledge of local resources. The subsistence uses and traditional knowledge study includes a literature review and field research conducted from 2005 to 2010. The objectives of the subsistence uses and traditional knowledge study are as follows:

- Describe the role of subsistence in the study communities.
- Describe current and historic subsistence harvests.
- Describe current (10 years prior to each interview) and historic subsistence use areas.
- Describe local perceptions of areas important to the health and abundance of subsistence species.
- Describe local issues and concerns related to subsistence.
- Document traditional knowledge as a context for understanding current subsistence patterns and environmental conditions, including recent (10 years prior to each interview) changes in resources.
- Establish and describe subsistence baseline indicators for the study communities that can be measured over time.

The study area for the Bristol Bay drainages comprises 20 communities whose residents harvest subsistence resources in the vicinity of the Pebble Deposit and possible mine infrastructure or who harvest resources that migrate through or use this area. The study communities are Aleknagik, Clarks Point, Dillingham, Ekwok, Igiugig, Iliamna, King Salmon, Kokhanok, Koliganek, Levelock, Lime Village, Manokotak, Naknek, New Stuyahok, Newhalen, Nondalton, Pedro Bay, Port Alsworth, Portage Creek, and South Naknek (Figure 1-1 in Chapter 1). Field work includes household harvest surveys conducted by the Alaska Department of Fish and Game (ADF&G) and subsistence mapping and traditional knowledge interviews conducted by Stephen R. Braund & Associates (SRB&A).

Before developing the field plan, the study team established baseline indicators of subsistence use that could be measured over time. These indicators include changes in subsistence use areas, harvest participation, harvest amounts, harvest diversity, harvest sharing, resources, harvest success, frequency of harvest trips, timing of harvest activities, and harvest effort. The ADF&G and SRB&A field efforts collect data pertinent to these baseline indicators.

ADF&G field work was conducted in phases: Phase I (2005), Phase II (2006), Phase III (2008), and Phase IV (2009). For each phase, data were collected for the previous calendar year (e.g., harvest surveys conducted in 2005 collected data for the 2004 calendar year). ADF&G's 2005 through 2009 field work supplements findings from earlier ADF&G harvest surveys and mapping studies. Three types of interviews were conducted as part of the ADF&G field work: a harvest survey, a mapping survey, and key respondent interviews. ADF&G used its standard household harvest survey instrument, which is used in its other baseline harvest research, and gathered data for all subsistence resources. The mapping survey gathered data on the areas where households conducted hunting, fishing, and gathering activities during the study year, as well as locations of successful harvests. Key respondent interviews included questions about changes in the environment; changes in hunting and harvesting patterns; changes in resource availability and local responses to resource scarcity; important hunting, fishing, and camping sites; human effects on subsistence resources; and effects of regulations on hunting and fishing.

Upon completion of household surveys in each community, ADF&G edited subsistence maps and entered the collected data. SRB&A digitized mapped features and prepared harvest-area maps. Once data analyses and map production were complete, ADF&G traveled to each community to present the preliminary survey findings at community meetings and prepared a draft technical paper for review.

SRB&A field work consisted of a four-part interview that focused on: subsistence mapping; observed changes in subsistence resources and traditional knowledge related to those changes; traditional knowledge about the physical, biological, and social environment; and issues and concerns, including those related to the Pebble Project.

For the mapping portion of the interviews, study team members mapped subsistence use areas used during the 10 years prior to each interview, recording information on an acetate sheet (referred to as an overlay) positioned over a 1:250,000 U.S. Geological Survey map (Photo 23-1). Mapping interviews addressed the following resource categories: caribou, moose, other large land mammals, seals, other marine mammals, salmon, non-salmon fish, waterfowl, upland birds, eggs, berries, plants, and marine invertebrates. In addition to subsistence use areas, researchers mapped habitat areas, travel routes, and camps and cabins. For each subsistence use area recorded on the map, study team members recorded the following baseline information: months of use, harvest success, times visited per year, duration of trip (added in 2008), and travel method.

After or during the mapping portion of the interviews, researchers asked respondents for their observations about changes in the use, abundance, quality, distribution, and migration of each resource category. Respondents were also asked to share their knowledge about the causes of observed changes. During the next part of the interviews, the questions concerned the biological, physical, and social environment. In the last portion of the interviews, residents were asked about issues and concerns related to subsistence, including concerns about the proposed Pebble Project.

Upon completion of field work in each community, study team members edited the map overlays and notes for each interview, entered the features from each overlay and related data into an Access database, coded and organized traditional knowledge derived from the field notes, and digitized the geographic features recorded in the interviews using ArcGIS ArcEdit software. The study team exported data from the Access database into the Statistical Package for the Social

Sciences and used this program to create tables and figures summarizing baseline indicators, including harvest success, frequency of use, and months of use. Furthermore, the Access database is linked to a geographic information system (GIS) database so that GIS staff can develop maps by querying specific feature information. The study team represents subsistence use areas for each resource category using an overlapping polygon method. In this method, SRB&A converts polygons (use areas) to a grid with each pixel being assigned a value of one. Then, the number of overlapping pixels are summed and assigned a color, with the darkest color representing the highest density (or number) of overlapping pixels.

SRB&A uses the tables, figures, and maps derived from the subsistence use area and traditional knowledge interviews to create a community report for each study community. SRB&A also incorporates data from the two available ADF&G technical papers prepared for this project, as well as earlier subsistence research, into each community report.

23.2 Results and Discussion

The ADF&G Division of Subsistence has conducted household interviews in 17 of the 20 study communities—Aleknagik, Clark’s Point, Igiugig, Iliamna, King Salmon, Kokhanok, Koliganek, Levelock, Lime Village, Manokotak, Naknek, New Stuyahok, Newhalen, Nondalton, Pedro Bay, Port Alsworth, and South Naknek. Field work is pending for one community—Dillingham. The remaining two communities—Ekwok and Portage Creek—are not included in ADF&G’s harvest survey efforts. The Ekwok Village Council chose not to participate in the study. Only one permanent household was living in Portage Creek in 2005 at the time of ADF&G’s planned field work, which was below ADF&G’s threshold for adequately depicting community harvest patterns. ADF&G field work was conducted by ADF&G personnel with the assistance of SRB&A staff members and locally hired research assistants. ADF&G conducted household surveys with 254 households in the first 10 study communities (Phases I and II), accounting for 71 percent of year-round resident households in those communities. Data from field work conducted in 2008 and 2009 (Phases III and IV) will be forthcoming. The final results of Phase I (2005) and Phase II (2006) of the field work are available in ADF&G technical paper No. 302 (Fall et al., 2006) and ADF&G technical paper No. 322 (Krieg et al., 2009), respectively.

In 2005, 2006, 2008, and 2010, SRB&A conducted subsistence mapping and traditional knowledge interviews in 17 of the 20 study communities—Aleknagik, Ekwok, Igiugig, Iliamna, King Salmon, Kokhanok, Koliganek, Levelock, Lime Village, Naknek, New Stuyahok, Newhalen, Nondalton, Pedro Bay, Port Alsworth, Portage Creek, and South Naknek. Field work is pending for the remaining three communities—Clarks Point, Dillingham, and Manokotak. Analyses are complete for 12 communities—Ekwok, Igiugig, Iliamna, Kokhanok, Koliganek, Levelock, New Stuyahok, Newhalen, Nondalton, Pedro Bay, Port Alsworth, and Portage Creek. SRB&A conducted interviews with a total of 288 residents in these 12 communities. Analysis of the data for the remaining five communities where SRB&A has conducted interviews will be forthcoming.

After completing community reports for the first 12 study communities, the study team provided each community with three copies of the draft report for their community and offered an opportunity to request a community review meeting. Community review meetings were requested and conducted in three communities. The reports were revised based on community input provided either at community review meetings or through telephone or email contacts and then were finalized. The study team sent a second letter and extended the comment period for communities who did not respond to the original request for comments. If no comments were received from a community after the extended comment period ended, then the report was finalized without community input. The community reports for the study communities are being provided as Appendices 23A through 23T to Chapter 23 of the environmental baseline document.

As indicated by SRB&A field work conducted in the first 12 study communities, subsistence uses in the study communities occur over an extensive area, with communities' total subsistence use areas ranging from 1,481 square miles to 26,764 square miles. Subsistence use areas documented in these communities extend west as far Kulukak Bay and Round Island, east into Cook Inlet, north to the Swift and Kuskokwim rivers, and south to the Naknek River area. Residents of the study communities rely on a wide diversity of subsistence species and so far during the SRB&A mapping and traditional knowledge interviews have reported harvesting approximately 150 individual species, including species of large land mammals, small land mammals, marine mammals, fish, waterfowl, upland birds, marine invertebrates, berries, and plants. Respondents in all 12 study communities reported year-round subsistence activities, with peaks in activities generally occurring in the summer/early fall and late winter/spring months.

For the 10 communities involved in Phase I and Phase II of ADF&G's field work, per capita harvests ranged from 132.8 pounds (Port Alsworth) to 977.3 pounds (Koliganek) during the communities' study years. Households reported harvesting an average of between 6.7 and 15.8 subsistence species and sharing an average of between 3.4 and 10.5 species. On average, 91 percent of Phase I community households and 86 percent of Phase II community households reported participating in subsistence activities during their respective study years.

Primary concerns reported by local residents during ADF&G and SRB&A field efforts were related to the Pebble Project. In particular, residents cited concerns about possible contamination of the watershed, disturbance of wildlife from project-related disruptions (e.g., noise from helicopters and blasting), contamination of wildlife, and social effects related to impacts on subsistence and an influx of outsiders to the region. While respondents' comments generally focused on concerns related to the project, there were respondents from most study communities that voiced support for the project, citing the potential economic benefits to the region.

Chapter 23 of the environmental baseline document includes a discussion of the definitions of subsistence (including regulatory definitions), an overview of each of the 20 study communities, and a discussion of the cultural values of subsistence. A synthesis and comparative analysis of subsistence uses and traditional knowledge in the Bristol Bay drainages study area is awaiting completion of field work, analysis, and report preparation for all 20 study communities.

23.3 References

Fall, J.A., D.L. Holen, B. Davis, T. Krieg, and D. Koster. 2006. Subsistence Harvests and Uses of Wild Resources in Iliamna, Newhalen, Nondalton, Pedro Bay, and Port Alsworth, Alaska, 2004. Alaska Department of Fish and Game, Division of Subsistence Technical Paper No. 302. Juneau, Alaska.

Krieg, T.M., D.L. Holen, and D. Koster. 2009. Subsistence Harvests and Uses of Wild Resources in Igiugig, Kokhanok, Koliganek, Levelock, and New Stuyahok, Alaska, 2005. Alaska Department of Fish and Game, Division of Subsistence Technical Paper No. 322. Juneau, Alaska.

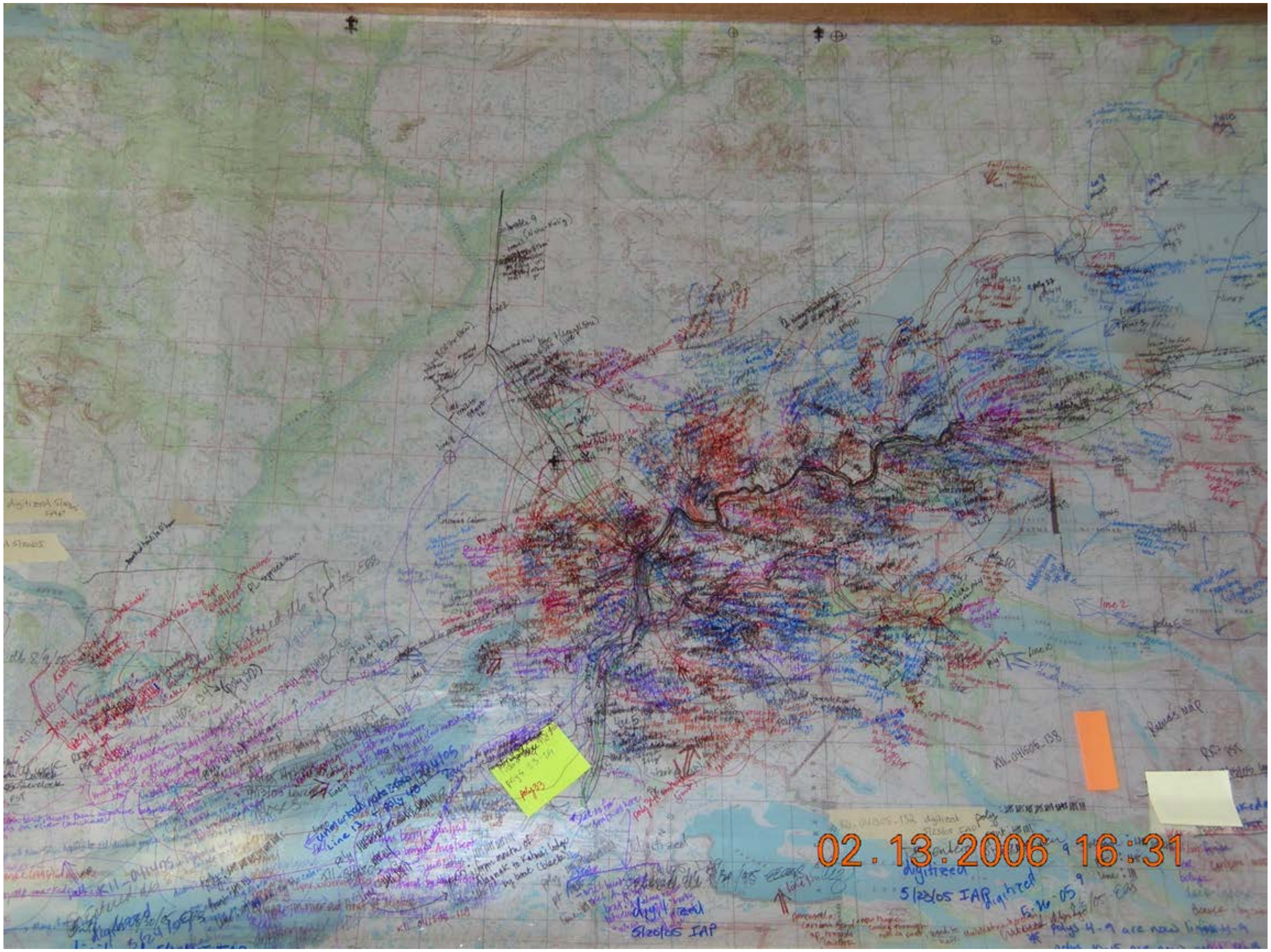


PHOTO 23-1. Example of a map with multiple acetate overlays on which information gathered during interviews has been recorded.

24. VISUAL RESOURCES

24.1 Introduction

The visual analysis was performed to evaluate the existing landscape character and quality in the Pebble Project mine and transportation-corridor study areas in the Bristol Bay drainages (Figure 1-4 in Chapter 1).

Five landscape analysis units were identified for these study areas: Talarik Creeks, Groundhog and Sharp Mountains, Iliamna, Pedro Bay, and the Chigmit Mountains. Each unit represents a unique set of landscape characteristics and components with respect to its scenic attractiveness and scenic integrity. The landscape analysis units were divided into subunits based on variations in scenic class, scenic attractiveness, distance zones, concern levels, and scenic integrity.

Landscape visibility and scenic attractiveness, and their derivative scenic classes, are used to assess the existing visual condition. Mapping for the scenic inventory takes into account the landscape visibility, the concern levels of users/residents, scenic attractiveness, scenic class, and scenic integrity. Scenic attractiveness measures the scenic importance of a landscape based on human perceptions, and scenic integrity is a measure of the completeness of a landscape.

The research was done in summer 2004 following the methodology outlined in the U.S. Forest Service document *Landscape Aesthetics, A Handbook for Scenery Management* (USFS, 1995). Researchers traveled by helicopter to document landscape character and views.

24.2 Results and Discussion

The study areas are a mix of contrasting landscapes, some of striking visual quality, others quite muted. Of particular note is that much of the landscape is undisturbed and much is little used or seen by people. The landscape in the mine study area located near and west of Sharp and Groundhog mountains is characterized by low landforms with heavily patterned vegetation that ranges from low shrubs and lichen to sparse stands of spruce. This is in marked contrast to the transportation-corridor study area, which extends eastward to the drainage boundary between the Bristol Bay drainages and Cook Inlet drainages and which is characterized by incised valleys and complex serrated peaks, as well as rounded valley bottoms with winding clear-water streams.

Viewers of the landscapes comprise residents of the communities in the study areas and tourists and recreationists that visit Lake Clark National Park and Preserve or fish camps, lodges, or hunting camps located in the area. The area is also used for subsistence purposes; thus, hunters and gatherers are also a constituent group. Aircraft fly over the study areas, and aircraft passengers are a user group as well. Portions of the study areas are visible to motor-vehicle traffic on the Williamsport-Pile Bay Road and in the vicinity of Iliamna and Newhalen, and to boats and floatplanes on Iliamna Lake. All of these viewers have a high level of concern about changes to the existing landscape.

Scenic attractiveness is categorized into three classes: Class A—distinctive, Class B—common, and Class C—indistinctive. The landscape in the study areas covers a range of classes for scenic attractiveness. The landscape varies from the common (Class B) landscape of muted hills among tundra that extends for hundreds of miles to the west to the distinctive (Class A) peaks, valleys, and water forms in the eastern portion of the study areas.

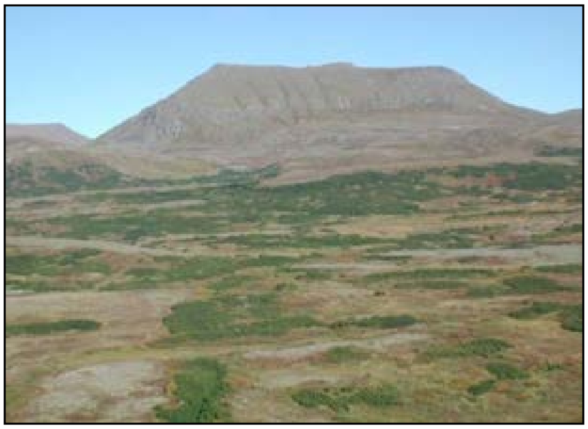
Almost all units in the study areas have a very high rating of scenic integrity where the landscape is intact and whole. Exceptions include the areas of the communities of Iliamna, Newhalen, Nondalton, and Pedro Bay and some camps in remote locations along creeks and the Iliamna Lake shoreline. Also, the Newhalen River Road and the Williamsport-Pile Bay Road are existing intrusions into what is otherwise a fully intact landscape.

Scenic class is a measure of the value of scenery using a scale of 1 to 7, with 1 being the highest value. Scenic class considers scenic attractiveness, landscape visibility, and public concern level. The ratings in the study areas are either Class 1 or Class 2.

24.3 References

U.S. Forest Service (USFS). 1995. Landscape Aesthetics: A Handbook for Scenery Management.

Unit 1, Talarik Creeks: View of Lower Talarik Creek.



Unit 2, Groundhog and Sharp Mountains: View of Pig Mountain.

Unit 3, Iliamna: View of the Newhalen River.

Unit 4, Pedro Bay: View of Community of Pedro Bay.

Unit 5, Chigmit Mountains: View of Summit Lakes.

25. RECREATION

25.1 Introduction

The recreation study inventoried, described, quantified, and mapped the outdoor recreational resources and activities in the Bristol Bay drainages study areas (Figure 25-1). The study objectives were as follows:

- Describe the location, use, and management status of important recreational resources in the study areas.
- Describe, quantify, and map the location of recreational activities.
- Estimate the economic contribution of recreation to the economy in the study areas.

A regional study area and a central study area were defined in the Bristol Bay drainages for the recreation baseline study (Figure 25-1). The regional study area comprises three overlapping study areas: land use, big game hunting, and sportfishing. The regional study area was flexibly defined to fit the geographic databases for different recreational resources, activities, and management regimes. The central study area encompasses the local drainage areas in the immediate vicinity of the Pebble Deposit and along the northeastern extent of Iliamna Lake (the central study area coincides with the mine study area, transportation-corridor study area, and Iliamna Lake study area depicted on Figure 1-4 in Chapter 1). The study area boundaries for land use, big game hunting, and sportfishing were defined as follows:

- The land use study area encompasses about 22,526 square miles. Its boundary is based on the State of Alaska’s 2005 *Bristol Bay Area Plan for State Lands* (ADNR, 2005a) and *Nushagak and Mulchatna Rivers Recreation Management Plan* (ADNR, 2005b), and the boundaries of the Katmai and Lake Clark national parks and preserves.
- The sportfishing study area encompasses an estimated 26,233 square miles. Its boundary is based on the Alaska Department of Fish and Game’s fishery management areas.
- The big game hunting study area encompasses an estimated 23,283 square miles. Its boundary is based on sub-units of the Alaska Department of Fish and Game’s game management units 9 and 17.

The baseline description draws on state and federal land use plans and resource management documents, published and online reports, and documents and unpublished data records, with additional information from extensive Internet searches and other unpublished sources. The National Park Service does not have detailed management plans for the national parks and preserves in the regional study area; much information on the parks and preserves came from National Park Service websites and publications. Because some recreational uses of state and federal lands do not require registration or permits, such uses are not systematically counted and may go unnoticed. Routine outdoor recreation of local residents goes mostly undocumented. Unless otherwise noted, sportfishing data are from 1999 through 2005 and hunting data are from 2000 through 2005.

25.2 Results and Discussion

The regional study area is sparsely populated and mostly wilderness or near-wilderness. The state and federal governments are the largest landowners. Principal uses of the region's resources are subsistence and recreation. Approximately 57 percent of the land use study area is managed primarily for recreation, including three national park units (totaling 11,697 square miles) and 1,248 square miles of state lands. Residents use the area for recreation, but recreational visitors are more numerous. Recreation and related services are important contributors to some local economies.

The Bristol Bay Area Plan (ADNR, 2005a) identifies state lands with high public recreational value based on a comparative analysis of recreational resources and uses. The most common recreational uses in the plan are sportfishing, big game hunting, camping, river and water sports, wildlife viewing, and nature photography. Noteworthy wildlife includes caribou, moose, and brown bears. Five planning regions are within the land use study area. The *Nushagak and Mulchatna Rivers Recreation Management Plan* (ADNR, 2005b) complements and elaborates on the Bristol Bay Area Plan. It identifies 29 public-use sites on state lands in the land use study area; all are remote campsites or small aircraft landing areas. The Pebble Deposit and transportation-corridor study area are not designated for recreation. The state has designated a Lower Talarik Creek Special Use Area for recreation and preservation of the rainbow trout fishery in Lower Talarik Creek.

The National Park Service units in the regional study area are the Lake Clark and Katmai national parks and preserves and the Alagnak Wild River. The national parks and preserves include substantial areas designated as federal wilderness. The parks are closed to hunting; the preserves and the Alagnak Wild River are open to hunting. Sportfishing is allowed throughout.

Lake Clark National Park and Preserve encompasses about 4 million acres; Native corporations own portions of the land within the boundaries. Small planes, floatplanes, or boats are the main means of access. Backpacking trips, hiking, rafting trips, and wildlife viewing are popular. In 2006, the National Park Service reported 5,320 recreational visits and 3,939 recreational visitor days (of 12 hours or more). In the years 2000 through 2006, the numbers of visitors averaged 5,051 visitors per year, mostly from June through September.

Katmai National Park and Preserve encompasses about 4.1 million acres; approximately 72,000 of those acres are not federally owned. Visitor access is by floatplane or small plane. There is one improved camping area in the park, near Brooks Camp (with 18 campsites), and only a few short improved trails. Three lodges are operated under National Park Services concession, and there are four remote lodges on private inholdings. Recreational attractions include wildlife viewing, sportfishing, sightseeing, flight-seeing, nature photography, canoeing, five active volcanoes, and remote wilderness land and waters. Brooks Camp, for brown bear viewing, and the overlook for the Valley of Ten Thousand Smokes are by far the most popular visitor destinations in the park. Data report 68,630 recreational visits in 2006, with 7,430 overnight stays. Data show a decline in recreational visits from 2000 through 2005, but an increase in 2006. Ninety-eight percent of all visits occurred during June through September.

The Alagnak Wild River is a 67-mile-long river corridor that encompasses 30,665 acres. Primary access is by floatplane. Five remote, private recreational lodges are situated along the corridor. The Alagnak River is the most productive fly-in sport fishery in southwest Alaska, and the Alagnak Wild River corridor is one of the region's most popular destinations. Other recreational activities include river rafting, wildlife viewing, and backcountry camping. There are no published visitor statistics for the Alagnak Wild River and, therefore, no estimates of economic impacts.

The National Park Service requires commercial operators in park units to obtain a commercial use authorization for each type of service offered in the parks. The most common commercial use authorizations in the parks in the regional study area are for sportfishing (133), bear viewing (120), air taxis (81), and photography guides (68).

It is estimated that nonlocal visitors to Lake Clark National Park and Preserve spent $352,000 in 2006, generating an estimated seven jobs and $141,000 in personal income. The National Park Service payroll at Lake Clark National Park and Preserve supported an additional 37 jobs and $2,202,000 in personal income. Non-local visitors to Katmai National Park and Preserve spent an estimated $3,316,000, generating 66 jobs and $1,151,000 in personal income. The payroll for Katmai National Park and Preserve supported an additional 56 jobs and $2,943,000 in personal income.

The Bureau of Land Management administers other federal lands in the regional study area. The State of Alaska manages fish and wildlife resources on those lands.

Across the regional study area, sportfishing supports a recreation-based economy that includes air taxi services, lodges, guides, outfitters and suppliers, and other businesses. The sport fishery is primarily a catch-and-release freshwater fishery. In a typical year, it is estimated that more than 15,000 sportfishers make about 35,000 trips to the region, spend about 70,000 days fishing, and catch 400,000 fish. In 2004, 88 percent of sportfishers came from outside Alaska. Access is by small plane or riverboat.

Freshwater sportfishing accounted for about 90 percent of all sportfishing in 1999 through 2005. In 2004, more than 90 percent of the catch was released. The primary species caught in the sportfishing study area were rainbow trout (36 percent), grayling (14 percent), king salmon (almost 13 percent), sockeye salmon (more than 10 percent), Dolly Varden (9 percent), and coho salmon (6 percent).

The central study area accounted for 8.4 percent of angler days and 7.4 percent of the catch in the regional study area. About 16 percent of the total catch in the central study area was retained as harvest. The most frequently caught species in the central study area, by annual average, were sockeye salmon (9,127), rainbow trout (7,197), grayling (6,056), Dolly Varden (3,987), coho salmon (848), and king salmon (412). Analysis of data indicated a decline in angler days and total catch between 1999 and 2005.

The type of hunting relevant to this study is the general-season hunt, which is open to most people and includes some subsistence hunting. Caribou, moose, and brown bear are the main big game species hunted across the hunting study area. There was also some hunting for black bear, Dall sheep, and wolves. Generally, state lands are open for hunting as allowed by regulation, but national parks, though not the preserves, and other parts of the study area are wholly or partly closed to hunting. Overall, the data over the past decade showed a steep decline in caribou herd size, hunting, and harvest in the regional and central study areas, and a modest drop in moose hunting. Brown bear hunting was stable.

The caribou harvest from the two primary caribou herds (Mulchatna and Alaska Peninsula North, both of which are declining) fell from 9,684 in 2000 to 2,179 in 2005, not including harvest from restricted permit hunts. The annual harvest in the hunting study area ranged from a high of 2,426 in 1999 to only 312 in 2006. The average number of caribou hunters in the hunting study area fell from 3,615 in 2000 to 1,936 in 2005, and hunter days dropped by 55 percent. In 2005, two-thirds of caribou hunters in the hunting study area were Alaska residents. Resident hunters were more successful than nonresident hunters—75 percent of resident hunters harvested a caribou. Hunters accessed the area mostly by plane and spent an average of 5.3 days per trip. Between July 1, 2004 and June 30, 2006, most of the Mulchatna Herd harvest occurred in August and September; the Alaska Peninsula North Herd harvest was spread more evenly.

The hunting study area yielded an annual average harvest of 285 moose during the years 2000 through 2005. The total annual moose harvest for the hunting study area dropped by almost half in that period, and the central study area showed a similar trend. In the hunting study area in 2005, more moose hunters were residents (56 percent) than were nonresidents (43 percent). The rate of success for both was about 29 percent. Most moose hunters (64 percent) in 2005 accessed the hunt area by airplane. From 2000 through 2005, more than 90 percent of the annual harvest occurred in September.

The brown bear harvest in the hunting study area during 2000 through 2005 averaged 111 bears annually. Year-to-year harvest fluctuations stemmed largely from alternate-year hunting restrictions.

An inventory of 73 recreational lodges in the sportfishing study area was compiled for 2006 through 2008. The inventory does not include unimproved, transient camp facilities, but does include lodges that may be closed or used for other purposes in any given season. Lodges typically are owner-operated.

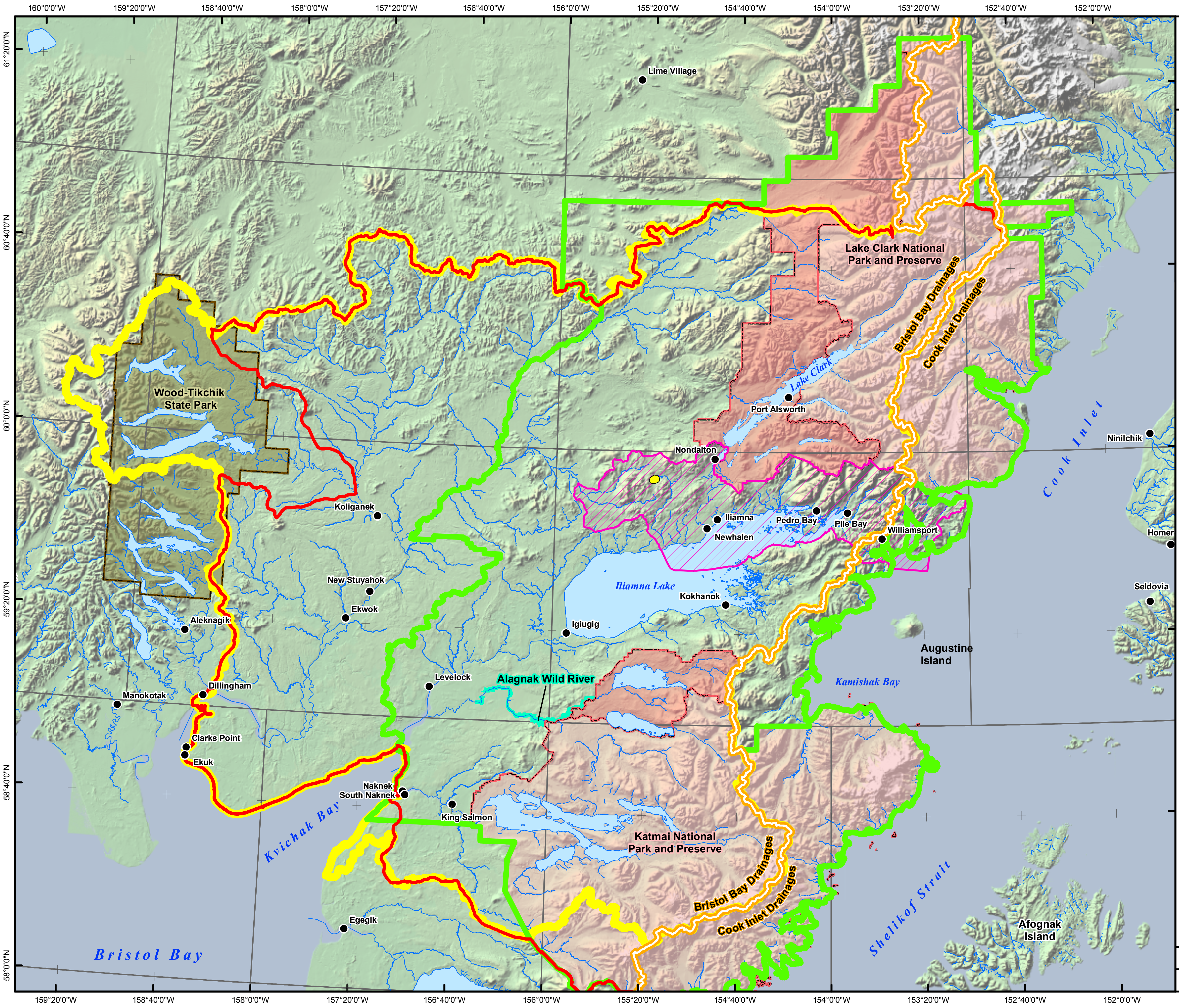
Lodges are primarily geared to the sportfishing season (June through September), but some cater to big game hunters. The rate for a sportfishing trip may range from $3,500 to $8,000 or more per person, depending in part on the length of stay and the services provided. High-end trips typically include guide services, flights to more remote areas, gear, fish packaging, accommodations, and food. Several lodges maintain planes and boats to provide transportation services. Low-end lodges typically offer simpler facilities and fewer services.

Most lodges are owned by nonresidents of the region. The lodges employ mostly nonlocal seasonal workers and import most of their fuel, foodstuffs, and other supplies. As a result, the lodges’ contribution to resident earnings and local economies is limited.

25.3 References

Alaska Department of Natural Resources (ADNR). 2005a. Bristol Bay Area Plan for State Lands. Division of Mining, Land and Water, Anchorage, AK.

———. 2005b. Nushagak and Mulchatna Rivers Recreation Management Plan. Division of Mining, Land and Water, Anchorage, AK.



THE pebble PARTNERSHIP

Figure 25-1
Recreation Study Areas
Bristol Bay Drainages

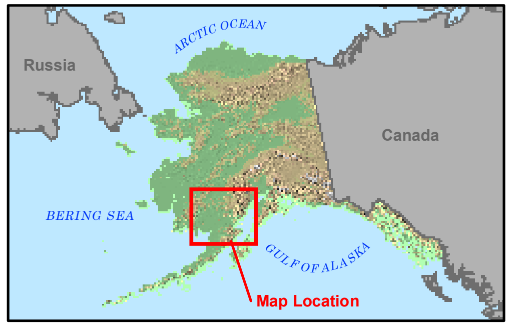
Legend

- Bristol Bay/Cook Inlet Drainages Boundary

Regional Study Area Components

- Land Use Study Area
- Big Game Hunting Study Area
- Sportfishing Study Area
- Anadromous Fish Streams
- ▨ Central Study Area
- National Park
- National Preserve
- Alagnak Wild River
- Wood-Tikchik State Park
- General Deposit Location
- ● Communities

Note:
The Bristol Bay/Cook Inlet drainages boundary is the eastern boundary for all Bristol Bay drainages study areas, except within the national park units



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Alaska State Plane Zone 5 (units feet)
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26. CLIMATE AND METEOROLOGY

26.1 Introduction

The objective of the meteorological data-collection program for the Cook Inlet drainages study area was to collect representative meteorological surface data in accordance with the guidance provided for Prevention of Significant Deterioration (PSD) air quality permit requirements for the Cook Inlet study area. Meteorological monitoring stations were installed at three locations in the Cook Inlet study area: at Port Site 1 near Knoll Head (Knoll Head/Port Site 1) on the western side of the entrance to Iniskin Bay, at Williamsport on the west side of upper Iliamna Bay, and at North Head on the northern side of the entrance of Iliamna Bay (Figure 26-1). Meteorological data presented in the EBD cover the following data-collection periods: Knoll Head/Port Site 1—August 1, 2005 through December 31, 2008; Williamsport and North Head—January 1, 2008 through December 31, 2008.

The scope of work for the meteorological study in the Cook Inlet study area is to measure and report the following meteorological parameters:

- Wind speed.
- Wind direction.
- Wind direction standard deviation (sigma-theta).
- Temperature.
- Precipitation.
- Evaporation.

Precipitation and evaporation were observed only at the Knoll/Head/Port Site 1 meteorological station, and those measurements are considered representative of the entire Cook Inlet study area.

26.2 Results and Discussion

The wind direction in Iniskin Bay at the Knoll Head/Port Site 1 station is generally from the north and northeast because of local terrain influences. The wind direction in Iliamna Bay at Williamsport is generally from the west because of slope-drainage influences from the mountains. The wind direction for North Head is generally from the northwest because of westerly winds being influenced by the nearby mountains. No hourly mean calm winds were observed in the Cook Inlet study area. The highest maximum hourly mean wind speeds were observed at the North Head station (29.3 meters per second or 65.5 miles per hour) in February 2008.

Daily mean temperatures in the Cook Inlet study area ranged from a minimum of -25.2°C (-13.4°F) at Williamsport in January, 2008 to a maximum of 20.3°C (68.5°F) at Knoll Head/Port Site 1 in June, 2007. Temperatures are moderated by the cool open waters of Iniskin and Iliamna bays.

Precipitation monitoring began at the Knoll Head/Port Site 1 station on July 15, 2008 and is ongoing. The highest total monthly precipitation recorded through the 2008 study period was 370.8 millimeters (14.6 inches) in September 2008; the lowest total monthly precipitation was 45.5 millimeters (0.5 inches) in October, 2008. Evaporation monitoring began at Knoll Head/Port Site 1 in July 2008 and stopped in October, 2008 for the winter. Although the July monitoring did not begin until July 15, it produced the highest total monthly evaporation recorded during this study period: 50.6 millimeters (2.0 inches).

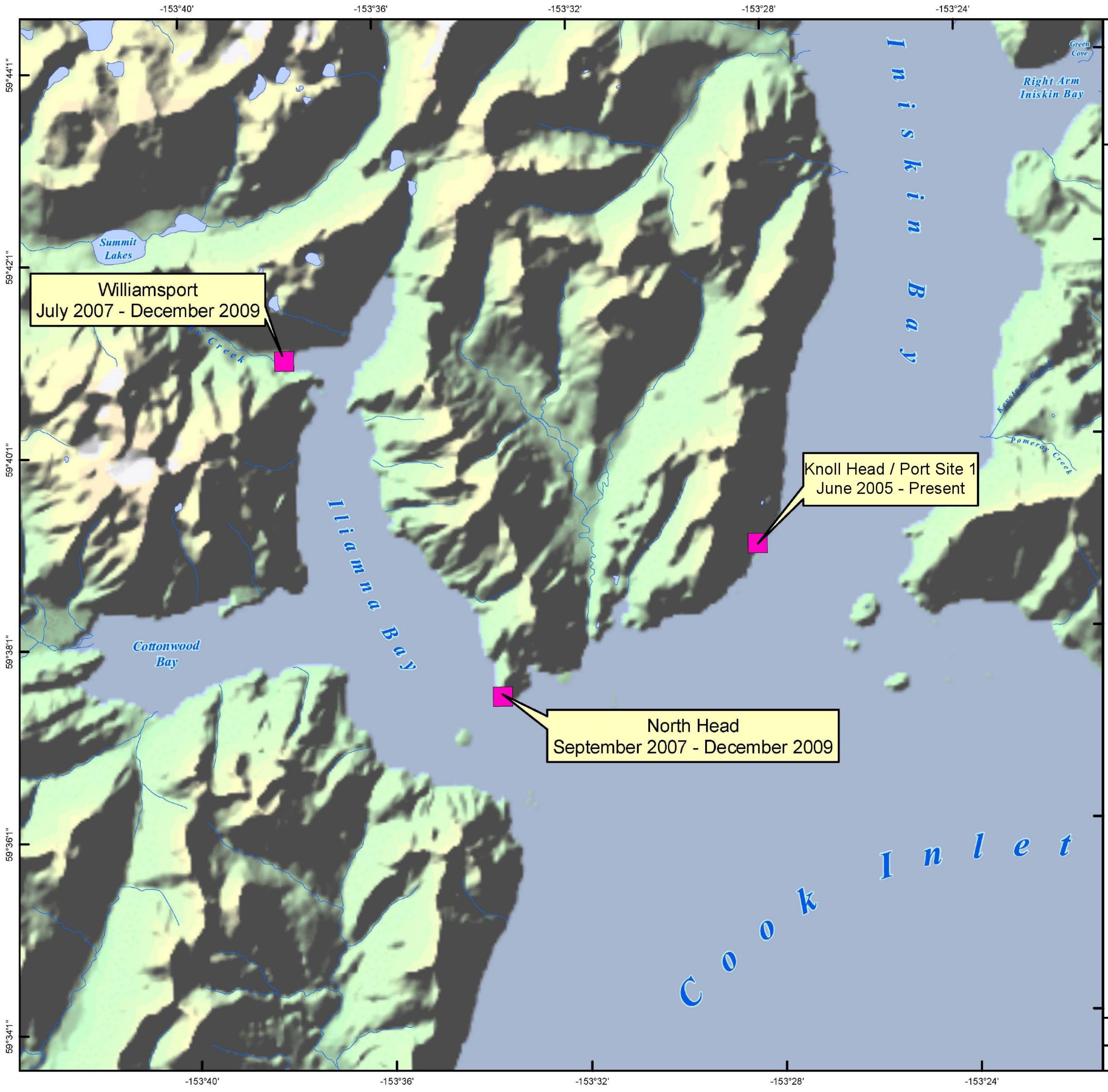
The climate in the study area is transitional, with a strong maritime influence because of its proximity to Cook Inlet. Summer temperatures are moderated by the open waters of Iniskin Bay, Iliamna Bay, and Cook Inlet. Winter temperatures are more continental because of ice accumulation in Iniskin Bay and Iliamna Bay. Weather systems typically travel into the region from the Bering Sea to the west, from along the Aleutian Island chain to the southwest, and from the Gulf of Alaska to the south. Depending on the season, these weather systems consist of cool to cold air that is saturated with moisture, resulting in frequent clouds, rain, and snow. Less frequent wintertime incursions of frigid, stable arctic air masses bring shorter periods of clear, but very cold, conditions to the region. In the summer, incursions of very warm air masses from interior Alaska can cause atmospheric instability that result in cumulus cloud development and occasional thunderstorm activity.

Knoll Head/Port Site 1 meteorological monitoring station in the Cook Inlet drainages study area, March 2006

Knoll Head/Port Site 1 anemometers in the Cook Inlet drainages study area, June 2005

Knoll Head/Port Site 1 meteorological monitoring station in the Cook Inlet drainages study area, August 2009

Williamsport meteorological monitoring station in the Cook Inlet drainages study area, July 2007

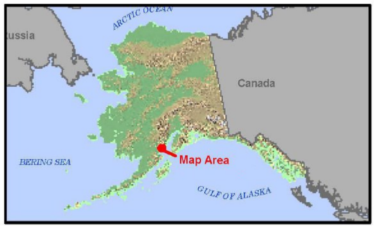


THE pebble PARTNERSHIP

Figure 26-1
Locations of Meteorological Monitoring Stations with Dates of Operation, Cook Inlet Drainage Study Area

Legend

🟪 Meteorological Stations



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Alaska State Plane Zone 5 (units feet)
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Author: RDI-MRA, LS

27. GEOLOGY

27.1 Introduction

This chapter discusses the baseline study of geology characteristics for the Cook Inlet drainages study area. The study area is in the southern part of the Alaska Range physiographic division, as defined by Detterman and Reed (1973). The Cook Inlet drainages study area is shown on Figure 1-4 in Chapter 1.

The geology study in the Cook Inlet drainages was based on a review of published information, a previous offshore site investigation program, and a surficial geology assessment using interpretation of aerial photographs. The offshore site-investigation program included primarily the collection of geological data from drillholes and geophysical surveys in Iniskin and Iliamna bays.

27.2 Results and Discussion

27.2.1 Surficial Geology

U.S. Geological Survey mapping indicates that the study area consists of predominantly exposed bedrock from the shoreline to the ridge tops, with scattered talus deposits on the slopes. There are scattered moraine deposits on the upper slopes from Pleistocene glaciation and Holocene glaciers. Mass movement deposits of talus and rubble are scattered on the exposed bedrock of the upper slopes. Holocene alluvial deposits are located in the Y Valley, which runs through the peninsula between Iliamna and Iniskin bays. The northernmost shoreline of Iliamna Bay and the shoreline north of Knoll Head have Holocene estuarine silt deposits in the tidal flat area, where bedrock does not make up the shoreline (Detterman and Reed, 1973).

Surficial geology along the existing road from Pile Bay to Williamsport is composed of predominantly lake-terrace deposits and alluvium, with some weathered bedrock and talus deposits at the base of the valley slopes. Weathered bedrock and talus become the predominant deposits encountered at the coastline.

Geophysical measurements and samples of the surficial and subsurface materials taken by the U. S. Army Corps of Engineers at Williamsport and Iliamna Bay indicate that the depth to bedrock ranges from approximately 130 to 200 feet in the tidal flat area and is mainly overlain by fine-grained sediments. The depth to bedrock in the vicinity of the existing landing at Williamsport is shallower, ranging from approximately 65 to 130 feet deep (USACE, 1995).

Iliamna Bay tidal deposits consist primarily of clays, silts, and fine sands. The deposits are black in color, indicating the presence of organic matter. These tidal deposits also contain angular gravel, as well as occasional cobbles and boulders. The existing tidelands have scattered, large boulders protruding from the tidal flats and also have higher gravel content closer to the existing landing at Williamsport. A gravelly subgrade is exposed along the natural tidal-drainage channels. The coastline of Iliamna Bay consists of weathered bedrock and talus deposits.

The surface and subsurface materials in Iniskin Bay are composed of unconsolidated sediments that increase in thickness from the shoreline to the main channel. Coarse-grained sediment with cobbles and boulders mantle the shoreline. Sediment in the main channel was interpreted to be medium to fine-grained. The measured thickness of unconsolidated sediment ranges from 30 to 35 feet in the main channel and 10 to 15 feet along the shoreline; however, the depth to bedrock may be deeper because the maximum range of measurement of the side-scan sonar survey was 15 feet in unconsolidated, fine-grained sediments and 35 feet in unconsolidated, coarser sediments. There was no evidence of rock outcrops on the bay floor (Golder, 2005).

27.2.2 Bedrock Geology

The exposed bedrock that makes up the rugged mountains along the Cook Inlet shoreline is predominately Middle and Late Jurassic sedimentary rocks. The sedimentary rocks are marine in origin and contain numerous fossils. These rocks are part of the Tuxedni Group and the Chinitna and Naknek Formations (Detterman and Reed, 1973).

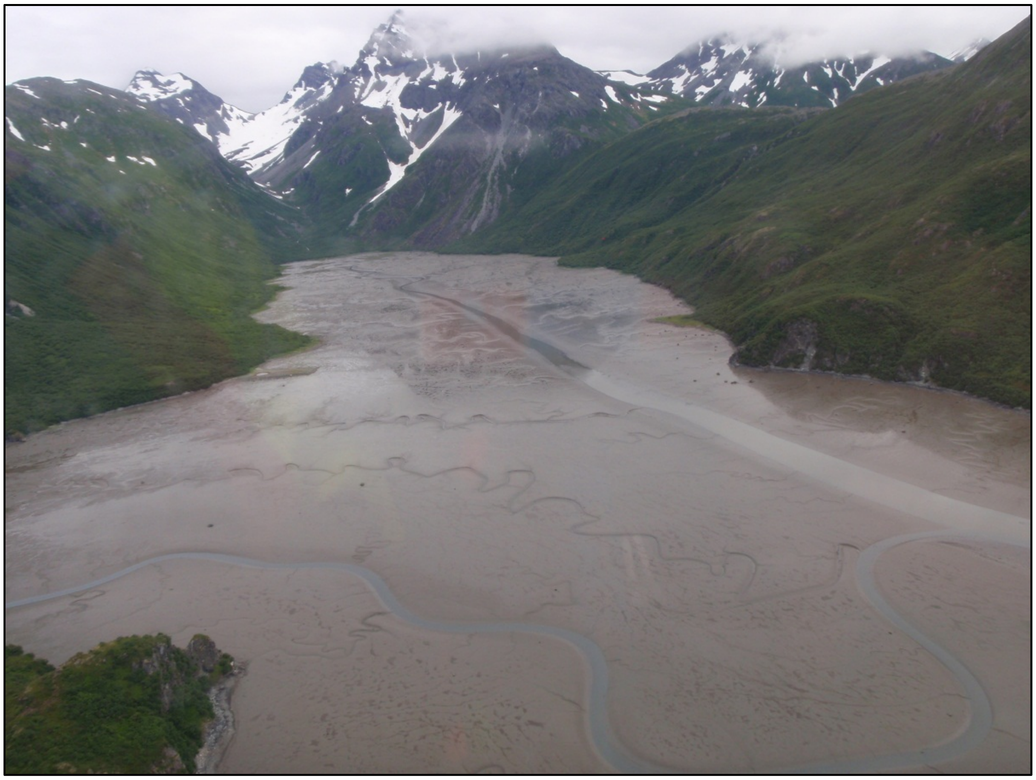
27.2.3 References

Detterman, R.L., and B.L. Reed. 1973. Surficial Geology of the Iliamna Quadrangle, Alaska. U.S. Department of the Interior. Geological Survey Bulletin # 1368-A.

Golder Associates Inc. 2005. Bathymetric and Geophysical Survey—Iniskin Bay, Alaska. Ref. No. 053-5727. August.

U.S. Army Corps of Engineers (USACE). 1995. Navigation Channel Feasibility Report and Environmental Assessment, Williamsport, Alaska. Anchorage, Alaska. December.

Bedrock outcrop in Cook Inlet drainages study area.



Tidal flats in Iliamna Bay.

28. PHYSIOGRAPHY

28.1 Introduction

This chapter discusses the physiography of the Cook Inlet drainages study area (Figure 1-4 in Chapter 1), including topography, landforms, stream drainage patterns, and coastal features. This study was based on reviews of published information and interpretation of oblique aerial photographs taken during reconnaissance and mapping exercises.

The Cook Inlet study area is located in the southern part of the Alaska Range physiographic division, as defined by Detterman and Reed (1973), in a subordinate mountain range called the Chigmit Mountains. The study area is defined by the drainage boundaries of Iliamna and Iniskin bays, two fjords with a common mouth on the west side of Cook Inlet (Figure 1-4 in Chapter 1).

28.2 Results and Discussion

The Cook Inlet study area is characterized by rugged mountains, glacially carved valleys, and fjord inlets created by glacial-valley scour to depths below present sea level. The mountains rise abruptly along the coast and form a climatic barrier between the coast and the interior. The glacially carved valley on the peninsula between Iliamna and Iniskin bays (the two main fjords in the study area) is called Y Valley. Shoreline terrain along the sides of the fjords is generally steep and rocky. In contrast, broad tidal mud flats are located at the heads of the fjords as a result of sediment deposition from tributary watercourses. The largest watercourses in the study area are the Iniskin River, which flows into the head of Iniskin Bay; Cottonwood Creek, which flows into the head of Cottonwood Bay, an arm of Iliamna Bay; and the unnamed stream that drains the Y Valley. Williams Creek flows parallel to the existing road from the pass between the Bristol Bay and Cook Inlet drainages east to Iliamna Bay at Williamsport. Mountains east of Iliamna Bay rise to 2,735 feet above sea level, and mountains adjacent to the Y Valley rise to 2,805 feet above sea level (Detterman and Reed, 1973). Numerous small glaciers and alpine lakes occupying glacial cirque basins are present in the Iliamna Bay and Iniskin Bay drainages. Rocky headlands, located to the west and east of the Y Valley mouth, are called North Head and Knoll Head, respectively.

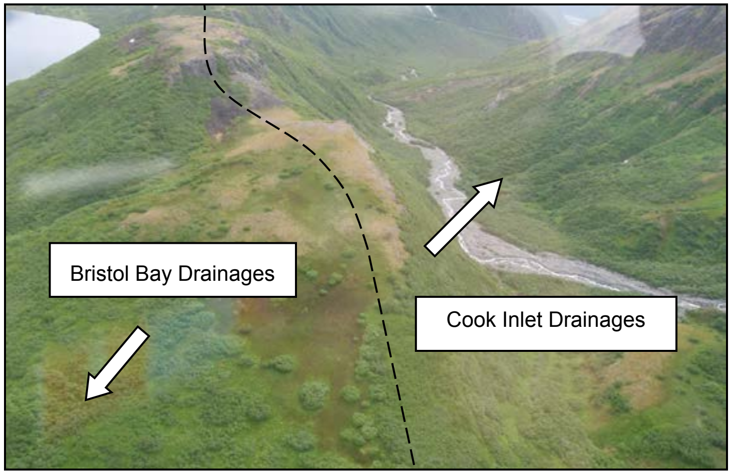
A preliminary evaluation of the physiography of the Iniskin Bay channel offshore of Knoll Head indicates that the bay floor drops off at approximately a 10 percent grade from the western shoreline to a maximum depth of 80 feet near mid-channel, and then gradually slopes up to the eastern shoreline from mid-channel (Golder, 2005). The water depth in the vicinity of Williamsport is very shallow, and vessels having a draft of 5 feet or greater are likely to be beached between high tides (Golder, 1995).

28.3 References

Detterman, R.L., and B.L. Reed. 1973. Surficial Geology of the Iliamna Quadrangle, Alaska. U.S. Department of the Interior. Geological Survey Bulletin # 1368-A.

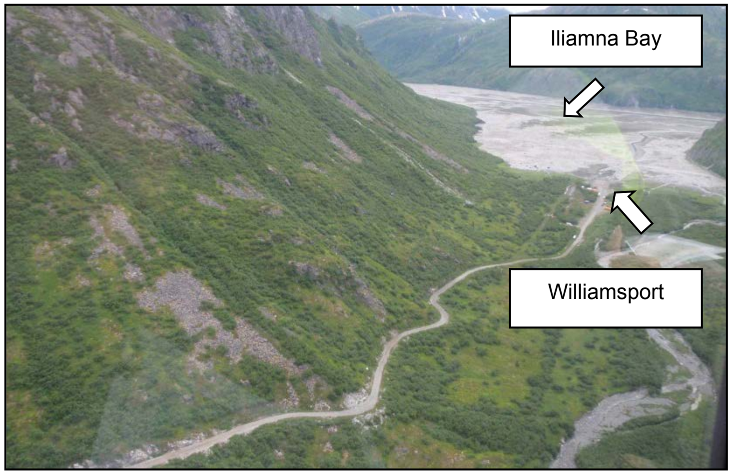
Golder Associates Inc. (Golder). 2005. Bathymetric and Geophysical Survey—Iniskin Bay, Alaska. Ref. No. 053-5727. August.

Golder Associates Inc. (Golder). 1995. Dredge Slopes in Iliamna Bay near Williamsport, Alaska. August.

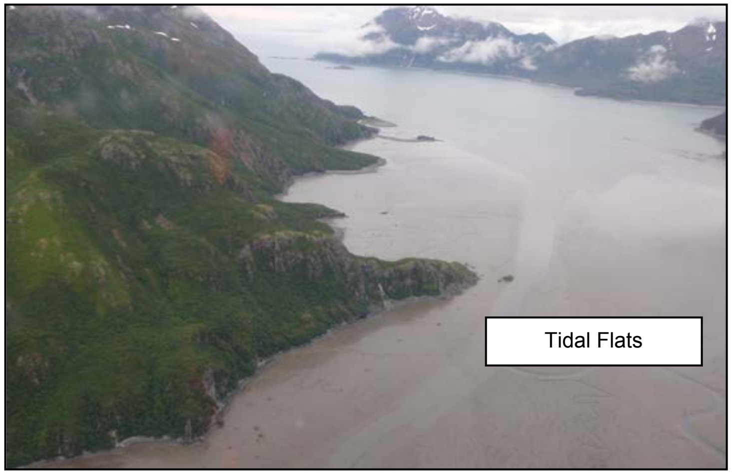


The boundary between the Bristol Bay/Cook Inlet drainages near Summit Lake (Bristol Bay drainages) and the headwaters of Williams Creek (Cook Inlet drainages), July 2008.

View to the northeast toward the head of Iliamna Bay, July 2008.



View to the east along the existing Pile Bay to Williamsport Road and Williams Creek to Williamsport and Iliamna Bay, July 2008.



View to the southeast along the eastern coast of Iliamna Bay, July 2008.

29. SOILS

29.1 Introduction

The Pebble Project study area within the Cook Inlet region is comprised of a transportation corridor study area (EBD Figure 29-1). The soils study for this area had one main component: to gain an understanding of the general types of soils that occur within the area.

The objectives of the Cook Inlet Region soils study included reviewing historical soils data from the region to determine the typical and common soil types occurring in the study area.

Summarize the soil map unit descriptions provided by the *Exploratory Soil Survey of Alaska* (ESS) (Rieger et al., 1979) for the study area.

29.2 Results and Discussion

The study area was glaciated during the Pleistocene and is in relatively close proximity to several active volcanoes in the Alaska Range. The soil parent materials are influenced by volcanic ash and the nearest source is Augustine Volcano, about 15 miles southeast of the study area.

A comprehensive literature review provided information on existing soil survey coverage for the study area. It also provided information relative to properties of volcanic-ash derived soils in Alaska.

The study area is covered by the broad-scale *Exploratory Soil Survey of Alaska* (ESS) (Rieger et al., 1979). A soil investigation is also available for Chisik Island (Clark and Ping, 1995), located within the Cook Inlet region about 20 miles northeast of the study area.

The two existing publications describe the prevalent soil types in or near the study area and indicate that many of the soils in the study area are influenced to some degree by volcanic ash within the parent materials. The ESS classifies the dominant soils of the area as typic cryandepts and describes their ash-influenced, or andic, properties. The Chisik Island soil investigation describes similar soils. Both publications provide soil classification terminology based on the version of *Soil Taxonomy* (USDA, 1999) current at the time of each publication. The soil descriptions and data presented were used to determine how the earlier soil classifications would translate to the 2006 classification system (Soil Survey Staff, 2006).

29.3 References

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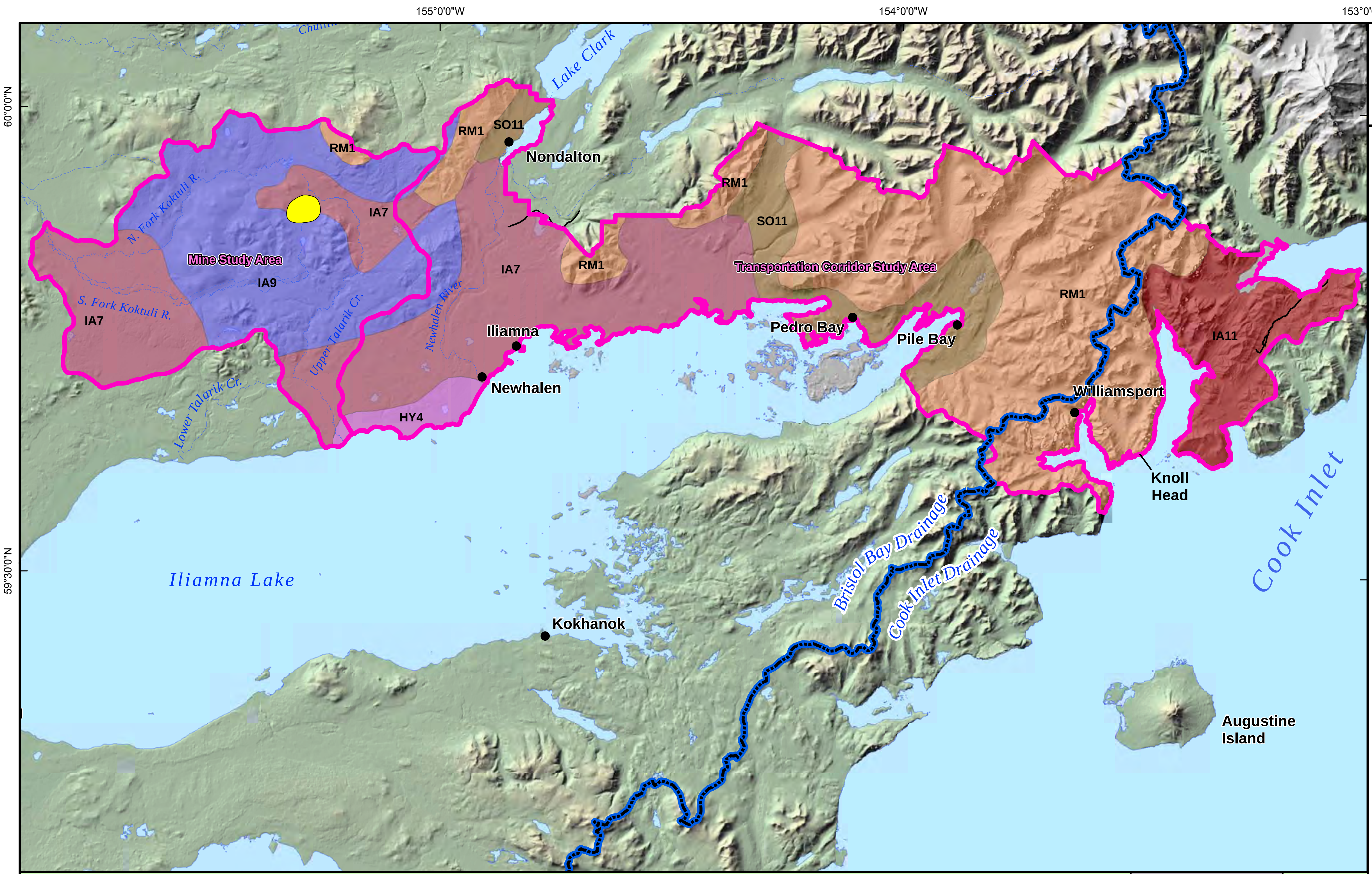

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Figure 29.1-1
Bristol Bay and Cook Inlet Drainages Exploratory Soil Survey

Legend

General Deposit Location

Bristol Bay/Cook Inlet Drainage Divide

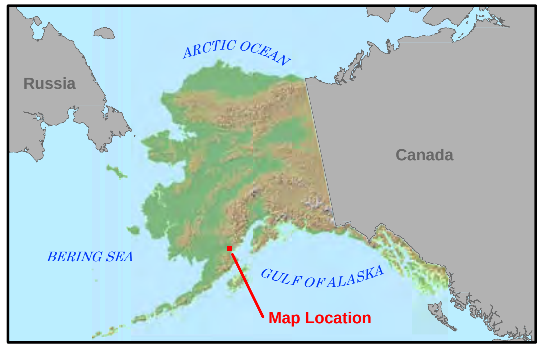
Study Areas

Soil Types

- HY4 - Pergelic Cryofibrists, nearly level
- IA11 - Typic Cryandepts, very gravelly, hilly to steep-rough mountainous land association.
- IA7 - Cryandepts, very gravelly, nearly level to rolling-Pergelic Cryofibrists, nearly level.
- IA9 - Typic Cryandepts, very gravelly, hilly to steep association
- RM1 - Rough mountainous land
- SO11 - Humic Cryorthods, very gravelly, hilly to steep-Pergelic Cryofibrists, nearly level association.

NOTES:
Based on *Exploratory Soil Survey of Alaska*, Sheet Number 19 (USDA SCS, 1979). The map is a broad-based inventory of soils and nonsoil areas that occur in a repeatable pattern on the landscape and that can be cartographically shown at the 1:1,000,000 scale.

These data compiled in 1971 by the U.S Department of Agriculture, Soil Conservation Service, and coorperating agencies.



Scale 1:510,000

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

STUDY AREA	CODE	DESCRIPTION	LAND FORM	Acres by Drainage Bristol Bay	Acres by Drainage Cook Inlet	Total Acres
Mine Study Area	HY4	Pergelic Cryofibrists, nearly level association.	Broad, nearly level, wet lowland neat large lakes and coastal areas.	1,251		1,251
	IA7	Typic Cryandepts, very gravelly, nearly level to rolling-Pergelic Cryofibrists, nearly level association.	Rolling plains bordering Iliamna Lake. Inactive and active stream channels, uplifted beaches, hilly terminal moraines, and glacial outwash plains.	105,227		105,227
	IA9	Typic Cryandepts, very gravelly, hilly to steep association	Low rounded mountains, moraine-covered mountain foot slopes and foothills.	154,723		154,723
	RM1	Rough mountainous land	Steep rocky slopes, ice fields, and glaciers.	3,463		3,463
Transportation Corridor Study Area	HY4	Pergelic Cryofibrists, nearly level association.	Broad, nearly level, wet lowland neat large lakes and coastal areas.	14,384		14,384
	IA11	Typic Cryandepts, very gravelly, hilly to steep-Rough mountainous land association.	Steep mountainous areas, dissected by streams and braided rivers, glacier fed.		73,944	73,944
	IA7	Typic Cryandepts, very gravelly, nearly level to rolling-Pergelic Cryofibrists, nearly level association.	Rolling plains bordering Iliamna Lake. Inactive and active stream channels, uplifted beaches, hilly terminal moraines, and glacial outwash plains.	155,145		155,145
	IA9	Typic Cryandepts, very gravelly, hilly to steep association	Low rounded mountains, moraine-covered mountain foot slopes and foothills.	17,981		17,981
	RM1	Rough mountainous land	Steep rocky slopes, ice fields, and glaciers.	248,146	71,380	319,526
	SO11	Humic Cryorthods, very gravelly, hilly to steep-Pergelic Cryofibrists, nearly level association.	Mountain foot slopes and moraine hills, small streams, sloping valleys, and nearly level muskegs.	72,458		72,458
Grand Total				772,777	145,324	**918,101**

155°0'0"W 154°0'0"W

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Date: December 27, 2010
Version: 3
Author: RDI-DWR, LS

30. GEOTECHNICAL STUDIES, SEISMICITY, AND VOLCANISM

30.1 Introduction

The geotechnical, seismic, and volcanism characteristics of the Cook Inlet drainages study area were investigated through desktop studies and reviews of published information. No geotechnical site investigations were completed in the study area for the baseline study. The study area is defined by the drainage boundaries of Iliamna and Iniskin Bays, two fjords with a common mouth on the west side of Cook Inlet (Figure 1-4 in Chapter 1).

30.2 Results and Discussion

30.2.1 Local Geotechnical Conditions

The discussion on the geotechnical conditions of the study area is limited to the estuarine deposits in northern Iliamna Bay in the vicinity of Williamsport. A 1995 preliminary evaluation of the geotechnical conditions for a dredged channel in the estuarine deposits in northern Iliamna Bay at Williamsport was based on a review of the USACE report, *Navigation Channel Feasibility Report and Environmental Assessment, Williamsport, Alaska* (USACE, 1995).

The USACE drilled five holes in the northwest arm of Iliamna Bay. The holes ranged from 11 to 23 feet deep. The USACE also collected geophysical measurements near Williamsport and in Iliamna Bay.

The seismic-refraction survey data indicated that there are approximately 100 to 130 feet of unconsolidated sediments in Iliamna Bay within approximately 3,000 feet of the existing landing at Williamsport.

The tidal flats in northern Iliamna Bay consist primarily of clays, silts, and fine sands, and are dark brown to black in color, indicating the presence of organic matter. These tidal deposits also contain angular gravel and occasional cobbles and boulders. The existing tidelands have scattered large boulders protruding from the tidal flats. A gravelly subgrade is exposed along the natural tidal drainage channels. The gravel content of the sediments is higher closer to the existing landing at Williamsport. The soils range from nonplastic to plastic (with liquid limits and plasticity indices to about 50 and 20, respectively). Moisture contents range from about 20 to 50 percent.

An estimate of the in situ soil density and index properties was obtained using standard penetration tests (SPTs). This process involves driving a split-spoon sampler into the soil at the base of the hole using a hammer of standard energy. The standard penetration test “N value” is the number of blows required to advance the sampler from 6 to 18 inches. In the tidal flat area the N value ranged from two to 10 in the upper 10 feet of the deposits and up to 30 below a depth of 10 feet. The N values ranged from 24 to 48 in the area of the existing landing at Williamsport; however, a loose sand zone (N value less than 10) was encountered at a depth of about 15 feet in this area. Details of the site investigation in Iliamna Bay near Williamsport can be found in the USACE, 1995.

The data indicate that the existing marine and glaciofluvial sediments include localized zones with low N values and are potentially subject to liquefaction during seismic events.

30.2.2 Regional Seismicity and Faulting

Alaska is the most seismically active state in the United States, with the level of seismic activity being highest along the south coast, where earthquakes are generated by the Pacific plate subducting under the North American plate. A regional overview of seismicity in southern Alaska, including Cook Inlet, is presented in Chapter 6 and is not repeated in this chapter.

30.2.3 Regional Volcanism

Four active volcanoes along the west shore of Cook Inlet are associated with the convergence of the North American and Pacific plates: Mount Spurr, Mount Redoubt, Mount Iliamna, and Augustine Volcano (also called Mount Augustine or Mount St. Augustine). These four Quaternary volcanoes are aligned in a relatively straight line, trending north-northeast to south-southwest. Mount Iliamna and Augustine Volcano are the closest volcanoes to the Cook Inlet drainages study area. The Cook Inlet volcanoes represent the eastern limit of the 1,616-mile-long Aleutian volcanic arc formed by tectonic plate collision and subduction (Miller and Chouet, 1994).

Evaluation of lake cores indicate that volcanic eruptions occurred in the Cook Inlet area every 10 to 35 years during the 20th century, with Mount Redoubt, Mount Spurr, and Augustine Volcano being the most important sources of tephra (i.e., airborne volcanic debris; Begét et al., 1994). In contrast, the last confirmed eruption of Mount Iliamna was in 1876. Begét and Kienle (1992) provided evidence that the summit edifice of Augustine Volcano has repeatedly collapsed and regenerated every 150 to 200 years over the last 2,000 years because of sustained lava effusion rates 10 times those normally seen in plate-margin volcanoes.

The major effects of volcanoes include the burial of old substrate by lava, debris, or ash and creation of new substrate; rapid release of meltwater; corrosive rains; noxious gas and dust clouds; and tsunamis (Peterson, 1979). The 1883 eruption of Augustine Volcano produced a debris avalanche that covered at least 8 square miles on the north side of the mountain and extended the coastline by more than 1.2 miles. The avalanche created a tsunami that registered 33 feet in height more than 62 miles from the volcano. Given its history of eruption, Augustine Volcano is likely to repeat this behavior at any time, and it entered a new active phase in January 2006. Collapse of the summit could be brought on by earthquakes (Begét and Kienle, 1992). The hazard from a tsunami generated by the eruption of Augustine Volcano is considered to be minor, unless a very large debris avalanche occurred at high tide (Waythomas, 2000), as occurred in 1883. A tsunami also could occur as a result of an earthquake in the area or elsewhere around the Pacific Rim.

30.3 References

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Begét, J.E., S.D. Stihler, and D.B. Stone. 1994. “A 500-year-long Record of Tephra Falls from Redoubt Volcano and Other Volcanoes in Upper Cook Inlet, Alaska.” Journal of Volcanology and Geothermal Research, Vol. 62, Issues 1-4, Pp. 55-67.

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31. SURFACE WATER HYDROLOGY

31.1 Introduction

Chapter 31 of the environmental baseline document presents the findings of the baseline surface water hydrology studies for the Cook Inlet drainages study area. These studies consisted of a field component to characterize stream channels crossing the linear study area and to collect spot measurements of instantaneous discharge (streamflow), a basin-analysis component to characterize physical and climatic aspects for the drainage basins of the studied streams, and a regional analysis component to estimate high and low flow statistics for each stream based on published guidelines and regression analyses.

The Cook Inlet drainages study area encompasses two surface water gaging stations, one on Williams Creek near the head of Iliamna Bay and one on Y Valley Creek near the mouth of Iniskin Bay (Figure 31-1). Williams Creek flows eastward from the drainage boundary between Bristol Bay and Cook Inlet and flows into Iliamna Bay at Williamsport. The Y Valley is located on the peninsula between Iliamna Bay and Iniskin Bay, and Y Valley Creek flows southward into Cook Inlet near the headland between the two bays.

Drainage basin characteristics—including drainage area, lake and pond area, mean basin elevation, mean annual precipitation, and mean minimum January temperature—were compiled for each of these two creeks. Instantaneous discharge measurements were collected monthly in the Y Valley Creek from August 2004 through October 2005, while monthly discharge measurements were measured in Williams Creek from July 2005 through October 2005.

The U.S. Geological Survey (USGS) provides regional regression equations for estimating low-duration, high-duration, and peak flow statistics based on basin characteristics (Wiley and Curran, 2003; Curran et al., 2003). These equations were used to estimate flow statistics in Williams Creek and Y Valley Creek. Low-duration flows are flows that are exceeded much of the time; the USGS equations provide results for flows that are predicted to be exceeded 50 percent to 98 percent of the time. High-duration flows are flows that are exceeded relatively infrequently; the USGS equations provide results for flows that are predicted to be exceeded 1 percent to 15 percent of the time. Peak flows are extreme high flows that are predicted to be exceeded only once, on average, within specified return periods expressed in years.

31.2 Results and Discussion

Drainage basin characteristics for Williams Creek and Y Valley Creek are summarized in Table 31-1.

The instantaneous discharge measurements collected in the Y Valley and Williams creeks are in general agreement with regional low-duration and high-duration flow estimates. The low-duration flow statistics for July, August, and September, estimated based on the USGS regression equations in Wiley and Curran (2003), are presented in Table 31-2.

No field data on peak flows were collected to compare to the peak flow estimates from USGS regression equations, as is commonly the case in remote areas. Table 31-3 shows the estimated peak flow values for each creek for recurrence intervals of 2 through 500 years based on the USGS regression equations in Curran et al. (2003). Two sets of estimates are presented because the study area lies near the boundary of two USGS streamflow regions with differing equations for estimating peak flows. It is difficult to determine which region is more representative of the study area, so both sets of results were considered.

31.3 References

Curran, J.H., D.F. Meyer, and G.D. Tasker. 2003. Estimating the Magnitude and Frequency of Peak Streamflows for Ungaged Sites on Streams in Alaska and Conterminous Basins. U.S. Geological Survey Water Resources Investigations Report 03-4188.

Wiley, J.B., and J.H. Curran. 2003. Estimating Annual High-Flow Statistics and Monthly and Seasonal Low-Flow Statistics for Ungaged Sites on Streams in Alaska and Conterminous Basins in Canada. Water Resources Investigations Report 03-4114. U.S. Geological Survey.

TABLE 31-1
Drainage Basin Characteristics, Cook Inlet Drainages Study Area

			Drainage Basin Characteristics					
Station	**Stream**	**Period of Record**	**Basin Area (mi^2)**	**Lake & Pond Area (mi^2)**	**Lake & Pond Area (%)**	**Mean Basin Elev. (ft)**	**Mean Annual Precipitation (in)**	**Mean Minimum January Temp. (°F)**
GS-21	Y Valley Creek	2004-05	12.39	0	0.0	1165	70	12
GS-22	Williams Creek	2004-05	4.60	0	0.0	1775	70	11

in = inches

°F = degrees Fahrenheit

ft = feet

mi^2 = square miles

TABLE 31-2
Estimated Monthly Low-duration Flows[a] at Gage Stations in the Cook Inlet Drainages Study Area

JULY		**Low-duration Flows Estimated from Regression Equations for July (cfs)**							
Station	**Stream**	**98%**	**95%**	**90%**	**85%**	**80%**	**70%**	**60%**	**50%**
GS-21	Creek in Y Valley	25.5	30.0	35.0	39.2	42.7	49.0	55.6	62.4
GS-22	Williams Creek	11.1	12.9	15.4	17.2	18.9	21.8	24.8	27.9
AUGUST		**Low-duration Flows Estimated from Regression Equations for August (cfs)**							
Station	**Stream**	**98%**	**95%**	**90%**	**85%**	**80%**	**70%**	**60%**	**50%**
GS-21	Creek in Y Valley	18.4	21.8	25.2	28.1	30.7	36.2	41.7	48.1
GS-22	Williams Creek	7.4	8.8	10.2	11.4	12.5	14.8	17.1	19.7
SEPTEMBER		**Low-duration Flows Estimated from Regression Equations for September (cfs)**							
Station	**Stream**	**98%**	**95%**	**90%**	**85%**	**80%**	**70%**	**60%**	**50%**
GS-21	Creek in Y Valley	16.4	19.9	24.6	28.1	31.4	37.8	44.8	53.2
GS-22	Williams Creek	5.4	6.5	8.2	9.4	10.5	12.8	15.3	18.3

Notes:

a. Based on U.S. Geological Survey Region 3 and 4 regression equations.

cfs = cubic feet per second

TABLE 31-3
Estimated Peak Flows [a] at Gage Stations in the Cook Inlet Drainages Study Area

REGION 3		**Peak Flows Estimated from Regression Equations for Region 3 (cfs)**							
Station	**Stream**	**Q_2**	**Q_5**	**Q_{10}**	**Q_{20}**	**Q_{50}**	**Q_{100}**	**Q_{200}**	**Q_{500}**
GS-21	Creek in Y Valley	788	1148	1404	1738	1998	2259	2542	2920
GS-22	Williams Creek	332	485	594	737	848	960	1082	1245
REGION 4		**Peak Flows Estimated from Regression Equations for Region 4 (cfs)**							
Station	**Stream**	**Q_2**	**Q_5**	**Q_{10}**	**Q_{20}**	**Q_{50}**	**Q_{100}**	**Q_{200}**	**Q_{500}**
GS-21	Creek in Y Valley	451	709	911	1186	1403	1624	1858	2196
GS-22	Williams Creek	177	288	378	502	601	703	811	969

Notes:

a. Based on U.S. Geological Survey regional regression equations.

cfs = cubic feet per second.

Q_T = peak flow with average recurrence interval of T years.

Field crew taking a discharge measurement using the wading method on Williams Creek.

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Figure 31-1
Surface Water Gage Stations
Transportation Corridor
Cook Inlet Study Area
2004-2005

Legend

● Surface Water Gage Station (Pebble Project)

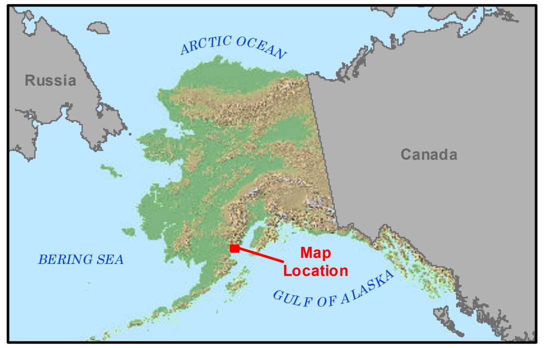
GS21: Example of Pebble Project Surface Water Gage Station Identification Number

● Knoll Head

⊙ Communities

— Existing Roads

▭ Bristol Bay/Cook Inlet Drainage Boundary



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Scale 1:119,028

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

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Version: 8	Author: BEESC-ME

32. GROUNDWATER HYDROLOGY

This study has not yet been conducted. Results will be published as an independent document upon study completion.

33. SURFACE FRESHWATER QUALITY AND SEDIMENT

33.1 Introduction

The surface water quality study in the Cook Inlet drainages was conducted to acquire baseline data on naturally occurring constituents in freshwater streams. The Cook Inlet study area is depicted on Figure 1-4 in Chapter 1.

Surface water was sampled at eight locations. These locations include freshwater streams listed in the *Catalog of Waters Important for Spawning, Rearing, or Migration of Anadromous Fishes — Southwestern Region* (Johnson and Weiss, 2006) and additional sites that coincide with sampling stations used in fish and hydrology studies. Station GS-21 located on Y Valley Creek was sampled multiple times in 2004 and 2005, station GS-22 located on Williams Creek was sampled multiple times in 2005 only, four locations in the Y Valley (stations SWQ1 through SWQ4) were sampled once each in 2006 and 2007, and stations PSC and PSD, located near Diamond Point and North Head, respectively, were sampled once in 2005. (See Figure 1-3c in Chapter 1 for the locations of the cited landmarks.) Overall, 25 water samples were collected. Samples were analyzed for physical and chemical parameters and inorganic constituents.

Sediment samples were collected from four sample locations in the study area (Y Valley Creek, Williams Creek, Diamond Point, and North Head) during May, July, and September in 2004 and 2005. Chapter 35 summarizes the stream sediment study in the Cook Inlet drainages study area.

33.2 Results and Discussion

The surface water quality study in the Cook Inlet drainages demonstrated that concentrations of nitrate plus nitrite (as nitrogen), phosphorus, aluminum, barium, iron, copper, zinc, lead, arsenic, nickel, molybdenum, and manganese were detectable in water samples. The water quality data were compared to the most stringent water quality criteria from the Alaska Department of Environmental Conservation. Where those criteria vary depending on site-specific hardness values, preliminary estimates were calculated and used for comparison. In most samples, the concentrations of individual trace elements were below the most stringent water quality criteria Exceptions included aluminum, copper, lead, and zinc, all of which were present at levels above criteria in a small number of samples. Typically, samples with a low field pH had higher concentrations of metals.

Overall, at least one sample from each location had naturally occurring concentrations above the most stringent water quality criteria for at least one parameter in at least one sampling event. The parameters for which existing concentrations above estimated criteria were most common included aluminum and copper. The detected concentrations are ascribed to natural conditions and are documented as existing conditions at the time of the study.

Based on analysis of the field data and physical parameter data, surface water in the Cook Inlet drainages study area is characterized by low dissolved solids, slightly acidic pH, high dissolved oxygen, and seasonally variable temperatures and specific conductance.

No seasonal variations in concentrations of the major ions (i.e., calcium, magnesium, sodium, potassium, alkalinity as bicarbonate, chloride, and sulfate) were observed in the data from the one station (GS21) that was sampled during all four seasons. Based on an evaluation (in a piper plot) of major ion distribution, the streams in the study area are classified as calcium bicarbonate water.

33.3 REFRENCES

Johnson, J., and E. Weiss. 2006. Catalog of Waters Important for Spawning, Rearing, or Migration of Anadromous Fishes — Southwestern Region, Effective March 1, 2006. Alaska Department of Fish and Game and Alaska Department of Natural Resources.

34. PHYSICAL OCEANOGRAPHY AND MARINE WATER QUALITY

34.1 Introduction

Data collection for the study of physical oceanography and marine water quality were undertaken from 2004 through 2008 to provide a physical context for observed biological conditions in the Iliamna/Iniskin Estuary (IIE) and to characterize the existing water quality conditions in the estuary's marine environment. The study area for characterization of the marine nearshore habitat included all marine waters and shorelines in Iliamna and Iniskin bays (except inner Cottonwood Bay and inner Iniskin Bay) and along the bight between the bays (see Figure 1-4 in Chapter 1 for these landmarks, but note that the study area specific to this chapter is not the Cook Inlet study area depicted on that figure).

The characterization of physical oceanography and marine water quality for the Pebble Project included the following elements:

- A thorough search of literature related to the natural environment of Cook Inlet, with emphasis on the lower west side of the inlet.
- Personal experience of the investigators in the Iliamna/Iniskin Estuary and Cook Inlet dating back to the mid-1970's.
- Observations made during marine biological field work conducted from 2004 through 2008 in the Iliamna/Iniskin Estuary.

Marine water quality parameters included various chemical constituents for which laboratory analyses were done, as well as salinity, temperature, and turbidity, which were measured in the field. Field parameters were measured in conjunction with the marine habitat assessments of the Iliamna/Iniskin Estuary conducted from August 2004 through November 2008. Water samples for chemical analysis were collected in August and September 2004 and May, July, and September 2008 and were analyzed for trace elements, and inorganic and organic constituents.

34.2 Results and Discussion

34.2.1 Physical Oceanography

Iliamna and Iniskin bays were formed by glacial scouring and subsequent infilling with sediment over recent geologic time. The waters in both bays are generally well mixed by waves and tidal currents, added to, in part, by the bays' shallow bathymetry and minimal freshwater inputs during most of the year. An exception to this occurs during periods of high seasonal snowmelt runoff when a freshwater surface layer temporarily develops.

The bays are characterized by extensive mudflats in their upper reaches with deeper channels extending into the outer bay entrances adjacent to Black Reef and into Cook Inlet. Extensive reefs, shoals, offshore rocks, and islands dot the entrances to both bays and the waters in between.

Iniskin Bay has a relatively deep trough along its western shoreline (maximum depth 24 meters).This trough shallows quickly to mudflats to the west and north. The eastern side of the trough steps up more gradually to a broad shelf that extends to the eastern shore of the bay.

Iliamna Bay is smaller and generally shallower than Iniskin Bay. The upper northward-trending portion of the bay and westward-trending Cottonwood Bay are dominated by mudflats that are exposed at lower tides. Cottonwood Bay also has a number of boulders scattered across the mudflats, while central Iliamna Bay has a mud/sand bottom with a limited number of intertidal reefs and subtidal hard-bottom areas. Turtle Reef partially blocks the entrance to Iliamna Bay off South Head, and White Gull Island is located just south of the center of the entrance to the bay (Figure 1-3c in Chapter 1). The only deeper water in the bay is on either side of White Gull Island, where average depths are approximately 10 meters and the maximum depth is 12 meters.

The Iliamna/Iniskin Estuary has an extreme tidal range of approximately 7.6 meters, with a mean tidal range of about 3.75 meters. Maximum currents are estimated to be in the range of approximately 300 centimeters per second (5.8 knots), based on observed ice movement during the April 2006 marine sampling event and data from Kamishak Bay. Average ebb currents in Iniskin Bay are approximately 62 centimeters per second (1.2 knots), and average maximum flood currents are 46 centimeters per second (0.9 knots).

Field observations indicate that tidal currents generally follow the primary direction of the bays, particularly in the deeper trough sections. Small eddies have been observed in the lee of several points of land and behind islands, shoals, and other obstructions, thus providing refuge for smaller fish and areas of calmer water during peak tidal flow. A few tide rips, resulting from the often strong wave and tidal action, were observed in the bays during marine field sampling events. Tidal fluctuations and wind forcing are the primary drivers of mixing in both bays of the Iliamna/Iniskin Estuary. Sea swell, wind waves, and tidally generated waves all affect exposed shorelines from Knoll Head to North Head, as well as beaches within the bays that face the bay entrances.

The extent of ice coverage varies yearly, but ice is consistently present from January through March in the Iliamna/Iniskin Estuary and can extend from December into April in the coldest years. Relatively continuous floating masses of ice have been observed in the outer portions of the bay, at times cutting off access to certain portions of the bays, but constantly moving with tidal and wind fluctuations.

34.2.2 Marine Water Quality

Water quality in the Iliamna/Iniskin Estuary during the period from 2004 through 2008 appeared to be dominated by tidal exchange with Cook Inlet and Kamishak Bay, with smaller, localized effects from freshwater inputs and local wind waves. Observed gradients in salinity between the inner (lower salinity) and outer (higher salinity) portions of Iliamna Bay are consistent with this conclusion. Average salinity was observed to decrease from the outer stations of Iliamna Bay to the inner stations. This is likely a result of freshwater inputs at the head of Iliamna Bay. Salinity decreases from spring to late summer and increases again in the fall, thus providing an additional indicator of the influence of regional water on the bays. A certain amount of stratification was observed during both the spring snowmelt season and during the warmer summer months, particularly during calmer weather and in more sheltered portions of the bays. Snowmelt or significant rain events create a freshwater surface lens in areas adjacent to freshwater inputs; these lenses were never observed to be greater than a few centimeters deep and are expected to rapidly diminish as a result of tidal and wind-driven mixing.

Water temperatures are driven by insolation and seasonal variations; ice is present through the winter months, a warming trend occurs during the spring and summer, and temperatures decline again in the fall. Temperatures also vary with water depth, thus reinforcing the idea of insolation as a factor in temperature trends. The lowest water temperatures were recorded during March sampling events, while the highest water temperatures were generally recorded during August sampling events. There was an indication of higher temperatures in inner Iliamna Bay than in the outer bay, with exceptions that could be attributed to local physical characteristics, such as colder freshwater inputs reducing temperature locally. This temperature differential between the inner and outer bay supports the expectation that solar radiation in summer (when the majority of temperature readings were collected) has a greater influence on shallow inner-bay waters than on deeper outer-bay waters. The findings suggest that the primary factors influencing water temperature are tidal exchange with Cook Inlet and nearshore solar heating.

Analysis of available data indicates that turbidity is generally moderate and does not exhibit any obvious trends that indicate point-source inputs. Turbidity in Iliamna Bay is greatest in the late summer and early fall and, in the Iniskin Bay, is at a maximum in early spring and in late fall. Overall, though, on a monthly basis, average turbidity among all sites remained relatively constant over the study period, generally ranging between 3.1 and 13.0 nephelometric turbidity units.

Analyses of hydrocarbon concentrations in marine water from the Iliamna/Iniskin Estuary in 2004 and of metal and trace element concentrations in 2008 showed little to no connection to anthropogenic effects. Concentrations of all inorganic constituents were less than water quality maximum criteria recommended by the Environmental Protection Agency and others for marine habitat, many by orders of magnitude. Organic constituents were similarly at low levels and appeared to be derived from biologic, petrogenic, and anthropogenic sources. Data analyses show the marine waters of the Iliamna/Iniskin Estuary to be high-quality habitat for marine biota. The data provide some support for a relationship between increased concentrations of inorganic constituents and total suspended solids, but demonstrate no strong patterns with respect to depth in the water column, to geography, or to tidal elevation.

Wind and waves churn the Iliamna-Iniskin Estuary in March 2008.

Pancake ice covers the entrance of Iniskin Bay, March 2008.

The quiescent waters of summer in the Iliamna/Iniskin Estuary, June 2008.

Collecting a discrete water sample for physio-chemical analysis, July 2008.

35. TRACE ELEMENTS

35.1 Introduction

The trace element studies in the Cook Inlet drainages study area were conducted to acquire baseline data on naturally occurring constituents in upland soil and plants, freshwater river and pond sediment, and freshwater fish, as well as in marine sediments and biota in the Iliamna/Iniskin Estuary. Samples from these media were analyzed for physical and chemical parameters and inorganic constituents; marine samples were additionally analyzed for organic compounds.

The objectives for the trace elements studies were as follows:

- Collect and analyze baseline data on the levels of naturally occurring constituents in surface soil, vegetation, stream and pond sediment, and the tissues of fish from streams.
- Collect and analyze baseline data on the levels of naturally occurring constituents in sediment and biota tissues from the marine environment in the Iliamna/Iniskin Estuary.

Upland soil was sampled in 2004 and 2006 at 11 locations, and 23 species of plants from seven locations were sampled in 2004, 2006, and 2007. During 2004 through 2007, freshwater sediment was sampled at nine locations. Two species of fish were collected from two streams in 2004 and 2005.

In the marine environment in the Iliamna/Iniskin Estuary, intertidal sediments were sampled in 2004, 2005, and 2008 at eight locations. Subtidal sediments from four locations were sampled in 2004 and 2008. Sediments were sampled only at sites classified as soft bottom (silty to sandy) where coring or grab sampling was possible. One plant species, nine invertebrate species, and nine fish species were sampled in 2004, 2005, and 2008.

35.2 Results and Discussion

The upland study of soil and plants demonstrated that concentrations of all 26 elements for which samples were analyzed were detectable in soil samples and most elements also were detectable in plant tissues. Elements varied greatly in concentration across sampling locations and also in their relative abundance in a given location. In soil, aluminum and iron were the most abundant elements, with mean concentrations of 31,000 and 9,900 milligrams per kilogram, respectively. Both diesel-range organics and residual-range organics were detected at respective concentrations of 103 and 1,300 milligrams per kilogram in the single soil sample analyzed for these constituents. Since no development was present in the area where this soil sample was collected, the petroleum-range hydrocarbons detected were assumed to originate from biogenic sources. Total organic carbon was detected at a mean concentration of 15.4 percent.

Differences in elemental concentrations were apparent among plant species and between vegetative tissues and fruit tissues (i.e., berries) within individual species. Among plant groups, shrubs were sampled most often (46 samples) and lichens least often (5 samples). In each of the plant groups (trees, shrubs, forbs, grasses, lichens, mosses, and berries), the essential nutrients calcium, potassium, and magnesium were present in the highest concentrations. There were significant differences in concentrations of metals, anions, and cations between vegetative and fruit tissues. Both crowberry and low bush cranberry shared several of the same elements with significant differences. These included aluminum, barium, calcium, cobalt, magnesium, manganese, potassium, and zinc. Each of these elements, except potassium, had higher concentrations in vegetative tissues than in fruit tissue.

The study of trace elements in freshwater sediment and fish indicated that juvenile or young-of-the-year Dolly Varden and coho salmon contained detectable levels of most elements, cations, and anions. Zinc was present at the highest concentrations in fish tissue; the mean zinc concentration was 151 milligrams per kilogram, which is much higher than the observed concentrations of copper, the next most abundant element, which averaged 6.23 and 7.65 milligrams per kilogram for the two species. These relative concentrations are consistent with the essential nutrient status of zinc, for which fish have active uptake and homeostatic mechanisms in place to handle a wide range of concentrations. The greatest difference in elemental concentrations in fish between the two years was observed for cadmium; the mean cadmium concentration in Dolly Varden from Y Valley Creek in 2005 was more than 16 times higher than that in Dolly Varden from Y Valley Creek in 2004. In addition, the mean cadmium concentration in coho salmon from Y Valley Creek (in 2004) was nearly three times lower than in Dolly Varden from the same creek (in 2005). This is much greater than the range of detected cadmium concentrations in sediment from the two streams from which fish were collected (Y Valley Creek and Unnamed Creek; 0.05 to 0.45 milligrams per kilogram).

Except for zinc, concentrations in sediment were higher than concentrations in fish tissue (e.g., copper concentrations in sediment averaged 42.5 milligrams per kilogram relative to whole fish copper concentrations of 6 to 8 mg/kg). The most abundant elements in sediment were aluminum, calcium, iron, and magnesium, each with mean concentrations of over 4,000 milligrams per kilogram. Mercury was detected at the lowest concentrations in sediment (mean concentration of 0.015 milligrams per kilogram). Concentrations of trace elements in pond sediment were generally lower than concentrations in stream sediment; this pattern was not evident for cations and anions however.

The study of trace elements in marine sediments and biota documented a heterogeneous marine environment in the Iliamna/Iniskin Estuary. For sediments, grain size, as measured by percent fines, varied widely in intertidal sediments (1 to 96 percent) and showed substantial variation in subtidal sediments (25 to 85 percent). Concentrations for total organic carbon also were variable, ranging between 0.1 and 1.3 percent in intertidal sediments and between 0.2 and 0.7 percent in subtidal sediments. Concentrations of inorganic constituents varied by seven orders of magnitude, from mercury at 3 micrograms per kilogram (0.000003 grams per kilogram) to iron at 30 grams per kilogram. Concentrations of organic and inorganic constituents measured in sediment from the Iliamna/Iniskin Estuary agreed moderately well with values in existing literature for previous sediment studies in Cook Inlet. However, differences from previous studies were noted and demonstrate the need for an empirical baseline to document existing environmental conditions in the Iliamna/Iniskin Estuary. Arsenic, copper, nickel, and to a lesser extent, zinc were measured in Iliamna/Iniskin Estuary sediment samples at concentrations greater than concentrations identified with the threshold of biological response. This is an important finding because there has been little development in Iliamna/Iniskin Estuary. The concentrations of “fingerprint” hydrocarbons (i.e., an array of chemicals diagnostic of a likely source) did not rule out any of the three potential sources of low-level petroleum hydrocarbons—biogenic (from biological organisms), petrogenic (from petroleum), or pyrogenic (from combustion)—however, the information from the Pebble Project study provides some support for biogenic and pyrogenic sources.

Trace element concentrations in biotic tissues ranged by over five orders of magnitude from 1 microgram per kilogram for thallium in three fish species to 589,000 micrograms per kilogram for copper in a species of snail. Although there were few available and comparable data sets, concentrations of inorganic constituents measured in tissue samples in Iliamna/Iniskin Estuary compared quite well with values cited in literature for relatively pristine sites.

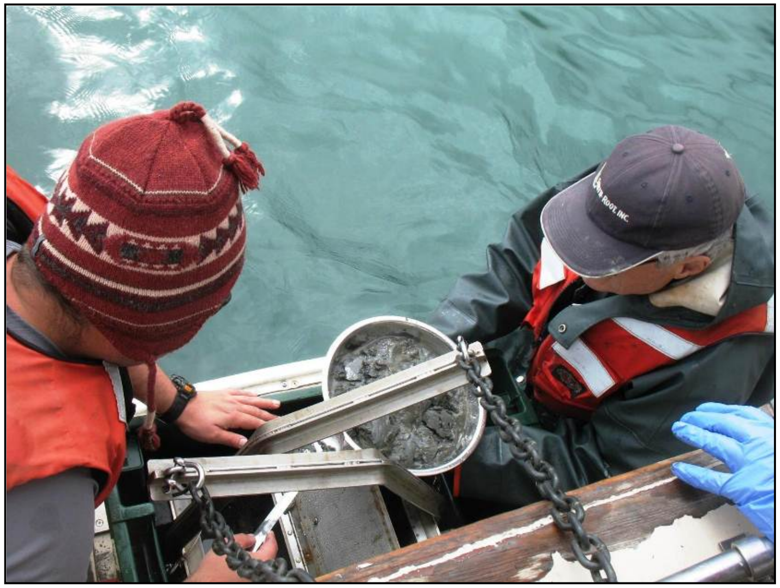
One observation was evident for cadmium. For adult salmonids and for Pacific halibut, the median concentrations were all less than 10 micrograms per kilogram. For juvenile Dolly Varden, starry flounder, and yellow sole, the median concentrations were between 10 and 100 micrograms per kilogram. For mussels, they were greater than 2,000 micrograms per kilogram. Furthermore, cockles and clams had substantially lower concentrations of cadmium than the mussels. On the other hand, the concentrations of cadmium in the habitat of these organisms—intertidal sediment, subtidal sediment, and water (marine water quality is described in Chapter 34)—is quite constant; cadmium was one of the constituents with the least variation. Thus it is clear that different organisms handle cadmium in different ways. Given the niche of mussels as filter feeders, it would appear that the high concentrations in their tissues arise from bioconcentration of cadmium directly from water, a phenomenon not shared by other filter feeders, i.e., clams and cockles—that had lower values for cadmium. However, bioaccumulation apparently does not cause high concentrations of cadmium in top predators such as salmonids.

Similar patterns of distribution among species were observed for boron and to a lesser extent for beryllium, chromium, lead, molybdenum, and thallium in the 2008 samples. One constituent that ran noticeably counter to this pattern was mercury. Median concentrations for mercury were highest in Pacific halibut, while mussels had relatively low concentrations. The data from the Pebble Project study are too limited to establish this observation as a certain case; however, the values from literature do support a pattern of elevated mercury in longer-lived carnivorous fish such as halibut.

Overall, analysis of the trace element data collected from 2004 through 2008 showed low concentrations of constituents as would be expected based on the general known history of the Iliamna/Iniskin Estuary as a marine habitat with virtually no recent development. However, some constituents were detected in samples at concentrations above the most conservative level that may cause a biological response, as reported in the literature. The detected concentrations are ascribed to natural conditions and are documented as existing conditions at the time of the study.

View of sampling location TE23, September 2007.

View of sampling location TE22, September 2007.



Benthic sediment sample collection with a Van Veen bottom sampler, July, 2008

Beach sediment core sampling, July, 2008.

Adult chum salmon sampled for tissue metals at MPS4, August 2004.

Sampling sediments from a mudflat, July 2008.

36. MARINE HABITATS

36.1 Introduction

Marine nearshore habitats in the Cook Inlet study area were studied to provide the physical context for descriptions of the biological conditions observed. The study area for the marine nearshore-habitat characterization included all marine waters and shorelines in Iliamna and Iniskin bays (except inner Cottonwood Bay and inner Iniskin Bay) and shorelines along the bight between the bays (see Figure 1-4 in Chapter 1 for these landmarks, but note that the study area specific to this chapter is not the Cook Inlet study area depicted on that figure).

The study of marine nearshore habitats was designed to characterize nearshore habitats in the Iniskin/Iliamna Estuary and included the following elements:

- A thorough search of literature related to the natural environment of Cook Inlet, with emphasis on the lower west side of the inlet.
- Personal experience of the investigators in the Iniskin/Iliamna Estuary and Cook Inlet dating back to the mid-1970's.
- Observations made during marine biological field work conducted from 2004 through 2008 in the Iniskin/Iliamna Estuary.

36.2 Results and Discussion

The shorelines of the Iniskin/Iliamna Estuary are composed of a diversity of habitats, including steep rocky cliffs, cobble/pebble beaches, and extensive sand/mud flats. Wave and surge energy is high at the headlands and along the outer portions of the bays during high tides. Swells are dampened considerably in the inner bays by reefs and islets at the bay entrances and by mudflats. Subtidal habitat is similarly varied, ranging from mud and sand in central portions of the bays to a variety of gravel, boulder, and rock substrates in channel bottoms swept by strong currents. These ranges of substrate types, slope, and exposure create a diversity of ecological niches that provide habitat for a variety of marine biota. The following descriptions summarize the major habitat features in the Iniskin/Iliamna Estuary.

36.2.1 Iniskin Bay

Iniskin, Vert, and Scott islands are the largest of several islands and shoals guarding the center and east side of the entrance to Iniskin Bay (Figure 1-3c in Chapter 1). Iniskin and Vert are smaller islands south of Scott Island and are surrounded by flat to gently sloping reefs. Iniskin Island is the larger and more offshore of the two. The sheltered reef to the north and west of the island is well vegetated with a variety of kelp and red algae. Vert Island is slightly smaller than Iniskin Island, but includes several nearby islets and shoals. The reef surrounding Vert Island is flatter than that around Iniskin Island and, during spring 2008, was well vegetated, especially with red algae (*Palmaria* spp.). Scott Island is heavily wooded and is mostly surrounded by steep cliffs that extend down to the intertidal zone. The island's shorelines are mostly conglomerate bedrock, although small pockets of cobble/gravel beach are present.

The entrance to Iniskin Bay is bordered by rocky cliffs and sand/pebble beaches, sloping conglomerate rock, and an intertidal rocky point extending to Blackie Reef. To the south lies a broad, silty sand flat that at times supports patches of eelgrass (*Zostera marina*); laminarian kelp and other algae are found farther offshore. North of Blackie Reef, Iniskin Bay is generally shallow and slopes up to a steeper upper beach. The shallow east-central part of the bay is divided by a large flat reef, called Fossil Reef, which extends approximately a quarter of the way across the bay. The lower intertidal shoreline and subtidal bottom of the bay are predominantly mud and sand with occasional bedrock reefs or glacial erratic boulders. Long pebble beaches cover much of the upper shoreline north to Right Arm. A broad mudflat characterizes the northern part of Iniskin Bay through which a drainage channel conveys the Iniskin River and other drainages during low tide.

The transition from rubble to mudflat occurs at the lower intertidal zone at a reference site located approximately a half mile north of the west entrance to the bay. The upper beach at this site is a rock cliff, with steep slopes ascending to the east side of Knoll Head; however, the toe of the cliff is in the upper-to-middle tide range, and a rocky/shingle beach extends down to the mudflat at the lower tide zone. Cobble- and boulder-sized rocks on the upper beach are angular, indicating relatively little movement by waves. To the south, another reference site (called Port Site 1) has a similar composition of rock and sediment substrate, while the upper shoreline is a nearly vertical cliff. Limited diving along the southwest shoreline of Iniskin Bay showed that the substrate was composed of sand, silt, and gravel.

36.2.2 Knoll Head to North Head

Between Iniskin Bay and Iliamna Bay the shoreline consists of a series of fairly steep pebble/cobble beaches delineated by rocky outcrops and offshore rock reefs and sea stacks. The wave-exposed beaches are composed of rounded pebbles and cobbles and are backed by nearly vertical rock cliffs. Numerous natural arches are present, along with several waterfalls that flow during periods of snowmelt or rainfall. Sampling Station MPS1A lies along this complex rocky shore east of the entrance to a small rock-bound lagoon at the opening to the large valley known as the Y Valley (Figure 1-3c in Chapter 1). At MPS1A, the terrain above the cliff is much more gentle to the west leading into the east side of the Y Valley than the steeper slopes above the sea cliffs to the east toward Knoll Head. Sediment, when found in pocket beaches, is composed of predominantly coarse sand and angular gravel or cobbles recently broken or eroded from the cliffs or slopes above. The Y Valley lagoon is well protected from waves and swells by its narrow and sea-stack-studded entrance. Because of this sheltering, the lagoon has areas of mixed-soft sediment: a mix of sand and cobbles in a silt matrix. These mixed-soft beaches are interspersed with rocky reefs.

West and south of the Y Valley lagoon, the primary stream draining the Y Valley enters the marine environment after passing through a perched semi-tidal lagoon. Otherwise, the shoreline to the southwest is much the same as that to the east: a mix of nearly vertical rock, offshore reefs and shoals, and an occasional cobble pocket beach. Biota on these rock faces is much impoverished compared to other areas of comparable substrate and elevation and is composed of early successional species over large portions of the shoreline. It is presumed that this reflects the abrasive effects of ice scour. The generally steep, rocky shoreline extends around a rocky point under North Head and into the east side of Iliamna Bay. Shallow subtidal diving surveys conducted in the early 1980s off Knoll Head (Y Valley lagoon) revealed smooth bedrock and boulders sloping gently from the mid-intertidal range to a depth 22 feet below mean lower low water, where rock was replaced by gravel. Below this zone the substrate consisted of mixed sand and silt over gravel.

36.2.3 Iliamna Bay

White Gull Island is situated just inside of the entrance to Iliamna Bay (Figure 1-3c in Chapter 1) and has rocky shorelines with pockets of coarse cobble and pebbles along the shorelines. On the west side of the island, the intertidal zone is composed of moderately sloping gravel beaches and sheer rock faces. On the wave-exposed east side of the island a bedrock shelf extends from the intertidal range to 5 feet below mean lower low water. On the west side of the small peninsula (North Head) at the east entrance to Iliamna Bay, the upper beach is a mix of bedrock and broken rock rubble. To the north, an arcuate pocket beach of pebble-sized gravel is contained to the west by a rocky outcrop. The lower beach sediment is a mix of cobbles and boulders in a sand matrix. Subtidal surveys revealed a series of large boulders below 8 feet below mean lower low water with increasing amounts of sand bottom down to 20 feet below mean lower low water.

The entire eastern shore of Iliamna Bay, except for the area near AC Point, midway up the bay, lies at the foot of steep mountainsides. The upper beach consists of broken boulders and cobbles fallen from the mountains (coarse colluvium) or steep rock cliffs. Northwest of Diamond Point, at the north entrance to Cottonwood Bay. the middle to lower beach consists of a sand/mud flat that broadens to the north; below mean lower low water the bottom becomes increasingly muddy.

AC Point is a spit that has formed a relatively broad, flat gravel bar or bench with approximately 6.5 acres at elevations above the extreme high-water line. A shallow pebble/sand channel leads to a small tidal lagoon within the elevated gravel bench of AC Point. This shallow/brackish lagoon (AC Point Lagoon) is a unique habitat feature that supports sparse but widespread eelgrass, several species of algae, and seasonally abundant fish. North of a line from AC Point to Diamond Point, a mudflat extends across the entire bay except for a central drainage channel, occasional offshore rocks and reefs, and two rocky islands.

Twin rocky points considerably narrow Iliamna Bay just southeast of Williamsport. North of the western rocky point, a channel has been dredged through the mudflat to improve navigable access to the beach at Williamsport. This channel and beach constitute the only man-made alterations to the shorelines of the study area. Limited amounts of eelgrass are present around an island just southwest of the Williamsport entrance channel. Northeast of Williamsport, the inner bay is shallow and strewn with boulders.

The west side of Iliamna Bay consists of angular rubble or rocky upper beaches transitioning to mudflats at middle tidal elevations. A rock buttress projects into the intertidal zone from the base of a high cliff at the face of Diamond Point (at the north entrance to Cottonwood Bay). At the base of this rocky habitat, a sand/mud flat extends to the west into Cottonwood Bay and to the north into Iliamna Bay. Substantial patches of eelgrass were identified on the Cottonwood Bay side of Diamond Point.

Overall the habitats in the Iniskin/Iliamna Estuary study area are summarized as follows:

- The entrances of the bays consist of well-vegetated wave-exposed islands and shoals.
- Protected inner areas of the bays contain large sand/mud flats and subtidal accumulations of fine sediments.
- Shorelines above these flats are largely dominated by bedrock and cobble beaches.
- The Iniskin/Iliamna Estuary provides a wide range of habitat types resulting in a rich mosaic of biological assemblages.

Mudflat near the head of Iniskin Bay, September 8, 2007.

Wave-exposed boulder field at Knoll Head, May 6, 2008.

Cobble beach at AC Point, May 26, 2010.

Protected AC Point Lagoon with adjacent meadow, September 6, 2007.

37. NOISE

37.1 Introduction

Because sound is a fundamental component of daily life, noise-monitoring surveys were conducted in and around Williamsport, at the head of Iliamna Bay (Figure 1-4), to describe baseline noise levels and to characterize the existing noise environment.

Land near Williamsport and Iliamna and Iniskin bays is virtually all undeveloped. There is a single residential/commercial use area at Williamsport that is occupied during summer when residents operate a boat-hauling service, moving vessels back and forth between Cook Inlet and Iliamna Lake. The operation requires use of a large tractor-trailer powered by a diesel engine. During winter, there are no residents in the study area.

Ambient noise levels for the study area were not specifically measured, but were predicted using measured noise levels from two sites in the Bristol Bay drainages—one north of the Iliamna Airport along Newhalen River Road and another southeast of the community of Pedro Bay (Figure 1-4). In addition, the predictions relied on general experience and measured noise levels from other areas in central Alaska.

Actual noise measurements were taken in accordance with guidelines from the American National Standards Institute (ANSI). Noise levels are stated in terms of decibels on the A-scale (dBA). Examples of familiar sounds are shown in Table 37-1.

37.2 Results

While some sounds (e.g., floatplane takeoffs) registered very high on the dBA scale, these were only of short duration. A more useful measurement averages all sounds over a given period, e.g., an hour; therefore, the results below are reported in average hourly noise levels.

Overall noise levels in the areas around Williamsport and Iliamna and Iniskin bays were predicted to range from below 30 dBA to over 60 dBA.

Noise levels during summer were predicted to range from 36 to over 60 dBA, with the highest levels expected during the transportation of vessels in both directions between Cook Inlet and Iliamna Lake. Typical maximum noise levels for a tractor-trailer range from 86 to 90 dBA at 50 feet from the source of the noise. The haul vehicle is likely the major noise source in the area during summer. Other noise sources include the loading and unloading of boats, general residential activity, occasional aircraft overflights, fishing boats, all-terrain vehicles, wind, and birds and other animals.

Typical noise levels during winter, when no humans reside in the area, were predicted to range from 28 to 32 dBA. Major noise sources during the winter include wind and some additional noise from aircraft overflights and animals.

TABLE 37-1
Typical Noise Sources and Equivalent dBA

Noise Source	Sound Level (dBA)	Subjective Impression
Recording studio	20	Just audible to very quiet
Soft whisper, library	30	Very quiet
Bedroom, bird calls	40	Very quiet to quiet
Light auto traffic (50 ft)	50	Quiet
Typical office	60	Quiet
Vacuum cleaner (10 ft)	70	Quiet to moderately loud
Garbage disposal (3 ft)	80	Moderately loud
Heavy truck / motorcycle (50 mph at 50 ft)	90	Moderately loud to very loud
Jet takeoff (2,000 ft)	100	Very loud
Float plane takeoff (100 ft)	110	Very loud to uncomfortably loud

Sources:

Beranek, Leo L. 1988. Noise and Vibration Control. Revised edition. Cambridge, Massachusetts: Institute of Noise Control Engineering.

U.S. Environmental Protection Agency, Office of Noise Abatement and Control. 1971. Transportation Noise and Noise from Equipment by Internal Combustion Engines. Washington DC. December.

38. VEGETATION

38.1 Introduction

The vegetation study describes the predominant vegetation types found in the Cook Inlet drainages study area. This information also helps to support wetland and habitat studies. The specific objectives of the vegetation study are as follows:

- Customize an existing vegetation classification system to include Project Vegetation Types amenable to photo-interpretation.
- Provide descriptions of Project Vegetation Types.
- Map Project Vegetation Types in the Cook Inlet drainages mapping area within the larger Cook Inlet drainages study area.
- Compile and document information on plant species observed

The objectives and methodology used for the Cook Inlet drainages study area were similar to those for the Bristol Bay drainages study areas (Chapter 13). HDR Alaska, Inc. conducted field work for this study primarily in summer and early autumn of 2004 and 2005.

Vegetation field data were collected as part of the wetland mapping program. Because the vegetation study was conducted as part of the wetland studies (Chapter 39), study sites were selected primarily to assist in the identification and mapping of wetlands and non-wetlands. Study sites also were selected to ensure data collection from each Project Vegetation Type across landscapes and soil types, as noted both on aerial photographs and while conducting field work.

Vegetation data collected at detailed-data collection plots included estimates of the percent cover of each plant species, site photographs, and initial classification of the Project Vegetation Type. The classification system incorporated information on canopy cover, needleleaf versus broadleaf tree species, shrub height and density, and dominant species.

Researchers analyzed vegetation data and aerial photo signatures to develop a system for describing and identifying Project Vegetation Types for the Pebble Project. This classification system (3PPI, 2008) is based on an existing standard vegetation classification system (Viereck et al, 1992; Wibbenmeyer et al, 1982) modified to accommodate interpretation of available aerial imagery. Thirty-seven Project Vegetation Types have been defined in the Cook Inlet drainages study area.

Vegetation mapping was completed for a portion of the Cook Inlet drainages study area. This mapping area—a 2,000-foot-wide corridor—extends from the Bristol Bay/Cook Inlet drainages boundary east to the head of Iliamna Bay, south along the east side of Iliamna Bay to its mouth, then northeast to the mouth of Iniskin Bay (Figure 38-1).

For clearer display on maps, the Project Vegetation Types in each study area were aggregated into nine Grouped Vegetation Types based on the dominant structure and growth form (forested, shrub, or herbaceous), vegetation density (open or closed canopy), and average height (dwarf, low, or tall).

A list of vascular plant species observed in the study area was developed, including incidental observations of non-vascular plant species and species considered rare by the Alaska Natural Heritage Program. For rare species observations, supporting data were collected, and a plant sample (voucher specimen) was taken if the population was large enough to support loss of a specimen.

All data from the vegetation study have been entered into a relational database for the Pebble Project.

38.2 Results and Discussion

The vegetation does not vary greatly throughout the Cook Inlet drainages study area; it is all strongly affected by the steep mountainous terrain and the maritime climate of lower Cook Inlet. The mountain slopes support dense alder thickets (Open and Closed Tall Shrub Types, and Open Low Shrub Types) interspersed, in some areas, with herb meadows (Dry to Moist Herbaceous Types). Along the coast, mudflats (Open Water) are extensive, and bedrock outcrops (Unvegetated Cover Types) form cliffs in some areas. Salt-tolerant vegetation (Wet Herbaceous Types) occupies relatively protected areas in the upper intertidal zone along the coast. The mountain slopes are dissected by streams that flow directly down the mountainsides to the ocean. Forested areas are limited.

Researchers collected data at 174 sites in the Cook Inlet study area. These sites included limited-data collection sites and detailed-data collection sites. Vegetation data from the field and site photographs were compared to aerial photo signatures to produce a vegetation map for the approximately 3,870-acre Cook Inlet drainages mapping area (Figure 38-1). The maps identify 33 Project Vegetation Types (including vegetation types and unvegetated land cover types) in the mapping area. Detailed descriptions of the Project Vegetation Types, including plant species composition and percent coverage, were developed based on information from 139 detailed-data collection plots.

Shrub vegetation types represented 57 percent of the mapping area, with closed tall shrub types being most common. Open water (primarily subtidal waters and intertidal mudflats) represented 29 percent of the area. Unvegetated/partially cover types comprised approximately 12 percent. Herbaceous vegetation represented about 1 percent, and forest represented less than 1 percent of the mapping area. Table 38-1 lists the Grouped Vegetation Types, with the acreage of each and the percentage of the Cook Inlet drainages mapping area that each type comprises.

Investigators observed one plant species tracked by the Alaska Natural Heritage Program, Kamchatka spikerush (*Eleocharis kamtschatica*), in the Cook Inlet drainages study area, but outside the current mapping area.

38.3 References

Three Parameters Plus, Inc. (3PPI). 2008. Pebble Project Vegetation Type Photo Signature Guide, Draft Report. Version XVII. Palmer, AK. May.

Viereck, L.A., C.T. Dyrness, A.R. Batten, and K.J. Wenzlick. 1992. The Alaska Vegetation Classification. General Technical Report PNW-GTR-286. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. Portland, Oregon.

Wibbenmeyer, M., J. Grunblatt, and L. Shea. 1982. User's Guide for Bristol Bay Land Cover Maps. Bristol Bay Cooperative Management Plan. Alaska Department of Natural Resources and Alaska Department of Fish and Game, Anchorage, AK.

38.4 Glossary

Aerial photo signature—a unique texture, pattern, or color that vegetation has when captured in photographs taken from an airplane.

Herbaceous plants—plants that have leaves and stems that die to the soil level at the end of the growing season.

Non-wetlands—uplands and lowland areas that are neither aquatic habitats, wetlands, nor other special aquatic sites. Non-wetlands are seldom or never inundated, or if frequently inundated, they have saturated soils for only brief periods during the growing season, and if vegetated, they normally support a prevalence of vegetation typically adapted for life only in aerobic soil conditions.

Project Vegetation Types—dominant vegetation types that include typical plant-species composition and vegetation structure.

Voucher specimen—any specimen that serves as a basis of study and is retained as a reference; it should be in a publicly accessible scientific reference collection. For purposes of this study, voucher specimens of Alaska Natural Heritage Program tracked species were collected and sent to the University of Alaska, Fairbanks, herbarium for species verification.

Wetlands—areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support—and that under normal circumstances do support—a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands include swamps, marshes, bogs, and similar areas.

TABLE 38-1
Grouped Vegetation Types and their Acreages within the Cook Inlet Drainages Mapping Area

Grouped Vegetation Type	Acres[a]	Percent of Mapping Area[a]
Open Forest	22.8	0.6
Open Tall Shrub	453.9	11.7
Closed Tall Shrub	1,211.9	31.3
Open Low Shrub	504.4	13.0
Dwarf Shrub	37.4	1.0
Dry to Moist Herbaceous	37.9	1.0
Wet Herbaceous Types	12.8	0.3
Open Water	1,130.3	29.2
Unvegetated Cover Types	458.4	11.8
Total Mapping Area	**3,869.9**	**100.0**

a. All numbers are rounded. Apparent inconsistencies in sums are the result of rounding.

PHOTO 38-1. A common vegetation type in the Cook Inlet drainages mapping area: Closed Alder Tall Shrub .

PHOTO 38-2. A common vegetation type in the Cook Inlet drainages mapping area: Open Alder Tall Shrub.

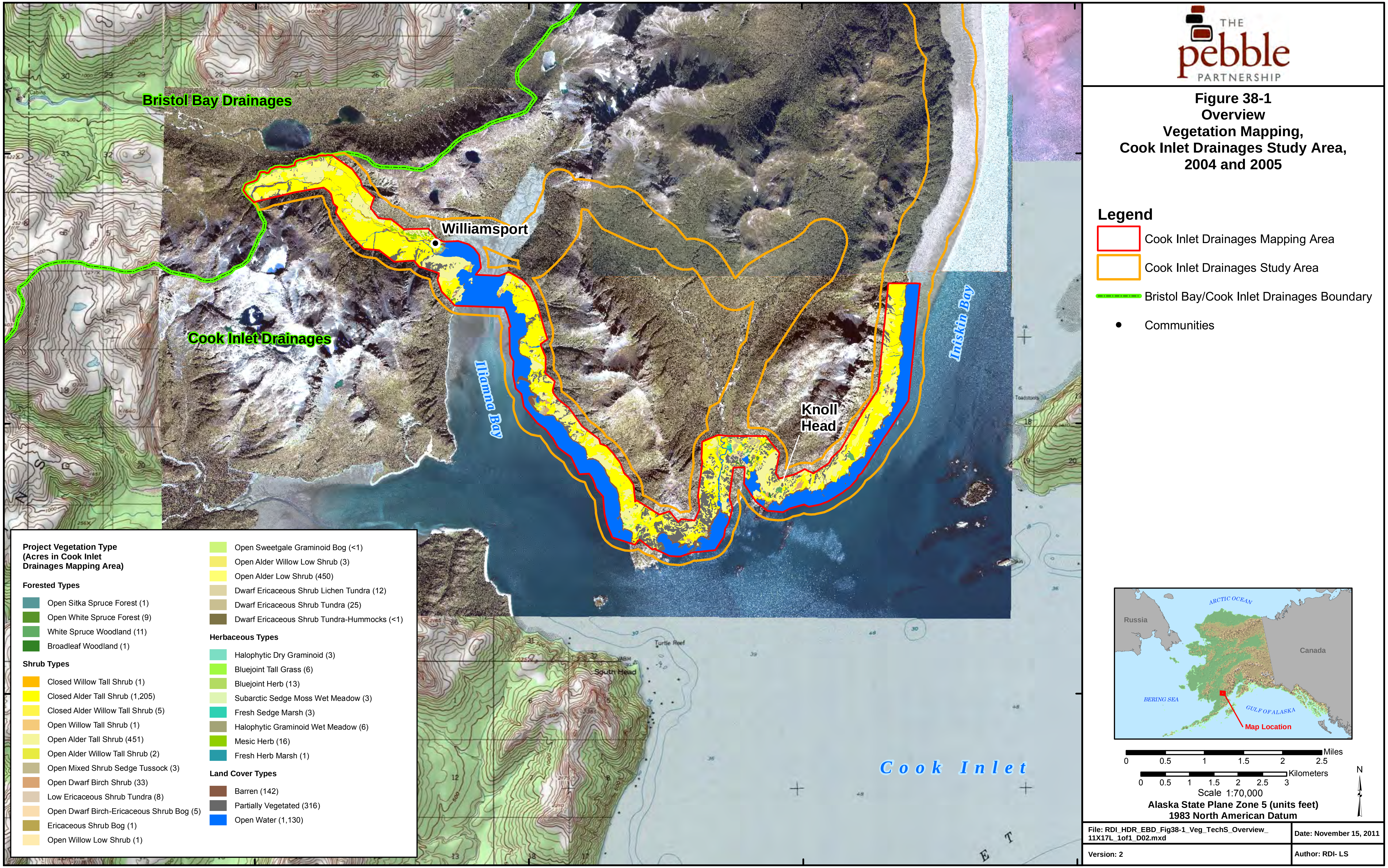


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Figure 38-1
Overview
Vegetation Mapping,
Cook Inlet Drainages Study Area,
2004 and 2005

Legend

- 🟥 Cook Inlet Drainages Mapping Area
- 🟧 Cook Inlet Drainages Study Area
- Bristol Bay/Cook Inlet Drainages Boundary
- ● Communities

Project Vegetation Type (Acres in Cook Inlet Drainages Mapping Area)

Forested Types

- Open Sitka Spruce Forest (1)
- Open White Spruce Forest (9)
- White Spruce Woodland (11)
- Broadleaf Woodland (1)

Shrub Types

- Closed Willow Tall Shrub (1)
- Closed Alder Tall Shrub (1,205)
- Closed Alder Willow Tall Shrub (5)
- Open Willow Tall Shrub (1)
- Open Alder Tall Shrub (451)
- Open Alder Willow Tall Shrub (2)
- Open Mixed Shrub Sedge Tussock (3)
- Open Dwarf Birch Shrub (33)
- Low Ericaceous Shrub Tundra (8)
- Open Dwarf Birch-Ericaceous Shrub Bog (5)
- Ericaceous Shrub Bog (1)
- Open Willow Low Shrub (1)
- Open Sweetgale Graminoid Bog (<1)
- Open Alder Willow Low Shrub (3)
- Open Alder Low Shrub (450)
- Dwarf Ericaceous Shrub Lichen Tundra (12)
- Dwarf Ericaceous Shrub Tundra (25)
- Dwarf Ericaceous Shrub Tundra-Hummocks (<1)

Herbaceous Types

- Halophytic Dry Graminoid (3)
- Bluejoint Tall Grass (6)
- Bluejoint Herb (13)
- Subarctic Sedge Moss Wet Meadow (3)
- Fresh Sedge Marsh (3)
- Halophytic Graminoid Wet Meadow (6)
- Mesic Herb (16)
- Fresh Herb Marsh (1)

Land Cover Types

- Barren (142)
- Partially Vegetated (316)
- Open Water (1,130)

Miles: 0 0.5 1 1.5 2 2.5

Kilometers: 0 0.5 1 1.5 2 2.5 3

Scale 1:70,000

Alaska State Plane Zone 5 (units feet)

1983 North American Datum

File: RDI_HDR_EBD_Fig38-1_Veg_TechS_Overview_11X17L_1of1_D02.mxd	Date: November 15, 2011
Version: 2	Author: RDI- LS

39. WETLANDS

39.1 Introduction

This chapter summarizes the wetlands and waterbodies study for the Cook Inlet drainages study area (Figure 39-1). The objectives of the study were to determine and map the location and extent of wetlands and waterbodies in the Cook Inlet drainages study area and to map the extent of human-caused disturbances of soil or vegetation. The vegetation study (Chapter 38) provides data and mapping that are integral to the wetlands and waterbodies study.

Investigators from HDR Alaska, Inc. conducted field work primarily in 2004 and 2005.The study area, mapping area, investigators, and field work dates are the same as for the vegetation study (Chapter 38). Scientists evaluated wetland versus non-wetland status at field study sites representative of the major vegetation types and landforms in the study area. Their methods at wetland determination plots followed the 1987 U.S. Army *Corps of Engineers Wetlands Delineation Manual* (USACE, 1987), which requires detailed analysis of site vegetation, hydrology, and soils. If the results of the analysis for each of those three parameters meet criteria that indicate wetland conditions, then the site is determined to be a wetland; otherwise, it is not.

Study sites were selected to sample unique vegetation signatures on aerial photographs and each major vegetation type across the full range of landscape positions. Wetland and non-wetland plots were sampled. Photo points were used to document additional wetlands and non-wetlands as a supplement to the more in-depth data-collection plots. Stream crossings and waterbodies were documented and water chemistry information was collected. If a plot was determined to be a wetland, then additional data were gathered for use in future analyses. Observations such as soil disturbance, habitat observations, or cultural sites also were recorded.

Wetland mapping used primarily a base map of orthophotographs with 4-foot contours, derived from 2004 and 2005 aerial photographs and light detection and ranging (LIDAR) imagery from 2004 and 2008. Digital maps were drawn to a scale ranging between 1:1,200 and 1:1,500, and open water was drawn at 1:400. Wetland status was assigned to a polygon used in mapping after careful review of plot data, photo points, site photos, and other available data for the area within the polygon. Data from plots in nearby or similar polygons also were evaluated when assigning wetland status.

Investigators collected vegetation data at the sampling plots to determine whether the vegetation was hydrophytic. The presence of hydric soil indicators was determined by digging a soil pit and recording standardized property data for each soil horizon. The soil sampling and documentation followed protocols outlined in the *Field Book for Describing and Sampling Soils* (Shoeneberger et al., 2002). Additional soil data regarding the presence of restrictive layers, soil temperature, oxidation reduction potential, and drainage class also were recorded. Data collected for wetland hydrology indicators included both surface observations and subsurface observations in the soil pit and soil profile.

During field data collection and wetland mapping, all wetlands were classified according to the hydrogeomorphic classification system (Brinson, 1993). In addition, as part of the data collection and mapping inventory for the Pebble Project, wetlands and other aquatic habitats/waters were classified using Enhanced National Wetlands Inventory codes. This classification was based on *Classification of Wetlands and Deepwater Habitats of the United States* (Cowardin et al., 1979) and National Wetlands Inventory mapping conventions (USFWS, 1995). The resulting Enhanced National Wetlands Inventory mapping is much more detailed than the original National Wetlands Inventory effort.

Disturbance to soil and/or vegetation was noted in the mapping if there was evidence from field data or if it was visible on aerial photographs. Human-caused soil or vegetation disturbance in the study area was minimal and appears to be limited to a road, building pads, a dredged area, and an abandoned commercial site.

39.2 Results and Discussion

The only previous wetland mapping in the study area was preliminary National Wetlands Inventory coverage completed by the U.S. Fish and Wildlife Service in 1985. As part of the Pebble Project study, investigators collected data at 227 locations in the study area. Specific wetland data, including hydrology, soils, and vegetation, were collected at 139 plots. In the Cook Inlet drainages mapping area, 3,869.9 acres were mapped (Table 39-1). Table 39-1 lists the mapped acreages of wetlands, waterbodies, and non-wetlands, grouped according to the U.S. Fish and Wildlife Service's National Wetland Inventory classification system, which is based largely on vegetation structure. The second and third columns in the table show the acreage of each type mapped in the Pebble Project study and the percentage of the mapping area that each comprises. Scientists identified 1,293.0 acres of wetlands and waters within the Cook Inlet mapping area; thus, approximately 33.4 percent of the mapping area was mapped as wetlands or waterbodies. Most of these wetlands or waterbodies (1,260.7 acres) were open water habitats such as estuarine and marine waters and streams. Approximately 1 percent of the mapping area and approximately 2 percent of area that is not tidal waters is wetlands. The low proportion of wetland acreage is related to the high proportion of the mapping area that is composed of steep mountain slopes.

The last two columns on Table 39-1 list the acreages of the wetland, waterbody, and non-wetland types that had previously been mapped by the U.S. Fish and Wildlife Service, and the percentages of the mapping area that those acreages comprise. The previous National Wetlands Inventory mapping showed 29.5 percent of the mapping area as wetlands or waterbodies. Comparison of the acreages shows that the Pebble Project study identified 4 percent more of the mapping area as wetland and waterbody than did the less detail-scaled U.S. Fish and Wildlife Service effort.

According to the hydrogeomorphic wetland classification system (Table 39-2), which is based on landscape position and water source and dynamics, the mapping area is dominated by the coastal fringe class (1,219.5 acres), followed, in descending order, by riverine channels (34.4 acres), depressional wetlands (22.4 acres), and riverine wetlands, which are regularly flooded by streams (12.7 acres).

39.3 References

Brinson, M.M. 1993. A Hydrogeomorphic Classification for Wetlands. Wetlands. Research Program Technical Report WRP-DE-4. U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS. August.

Cowardin L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C.

Shoeneberger, P.J., D.A. Wysocki, E.C. Benham, and W.D. Broderson. 2002. Field Book for Describing and Sampling Soils, Version 2.0. U.S. Department of Agriculture, Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE.

U.S. Army Corps of Engineers (USACE). 1987. Corps of Engineers Wetlands Delineation Manual. U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS.

United States Fish and Wildlife Service (USFWS). 1995. Photointerpretation conventions for the National Wetlands Inventory. National Wetlands Inventory Center, St. Petersburg, FL.

39.4 Glossary

Hydric soil—soil that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part.

Hydrophytic vegetation—vegetation typically adapted for life in saturated soil conditions.

Non-wetlands—include uplands and lowland areas that are neither deepwater aquatic habitats, wetlands, nor other special aquatic sites. They are seldom or never inundated, or if frequently inundated, they have saturated soils for only brief periods during the growing season, and if vegetated, they normally support a prevalence of vegetation typically adapted for life only in aerobic soil conditions.

Orthophotographs—digital imagery in which distortion from the camera angle and topography has been removed, thus equalizing the distances represented on the image.

Vegetation signature—a unique texture, pattern, or color that vegetation has when captured in photographs taken from an airplane.

Wetlands—those areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.

TABLE 39-1
Comparison of Wetland and Waterbody Acreages Identified in the Cook Inlet Drainages Mapping Area in the Pebble Project Study and by the National Wetlands Inventory

	Pebble Project		National Wetlands Inventory	
Grouped National Wetland Inventory Type	**Total Acres Mapped [a]**	**Percent of Mapped Area**	**Total Acres Mapped**	**Percent of Mapping Area [a]**
Total Shrub Types	15.3	0.4	34.1	0.9
Total Herbaceous Types	16.9	0.4	3.3	0.1
Total Wetlands Mapped	32.2	0.8	37.4	1.0
Total Waters Mapped	1,260.7	32.6	1,105.9	28.6
Total Wetlands and Waters Mapped	1,293.0	33.4	1,143.3	29.5
Non-Wetlands	2,576.9	66.6	2,726.6	70.5
TOTAL MAPPED	**3,869.9**	**100**	**3,869.9**	**100**

Note:

a. Apparent inconsistencies in sums are the result of rounding.

TABLE 39-2
Hydrogeomorphic Classifications in the Cook Inlet Drainages Mapping Area

Classification	**Number of Acres [a]**	**Percent of Mapping Area**	**Percent of Wetlands/ Waters**
Riverine	12.7	0.3	1.0
Slope	3.5	0.1	0.3
Depressional	22.4	0.6	1.7
Flat	0.3	0.0	0.0
Riverine Channel	34.4	0.9	2.7
Coastal Fringe	1,219.5	31.5	94.3
Total Wetlands and Waters	1,293.0	33.4	
Total Non-wetland	2,576.9	66.6	
TOTAL MAPPING AREA	**3,869.9**	**100**	

Note:

a. Apparent inconsistencies in sums are the result of rounding.

Representative wetland near high tide line at Williamsport on Iliamna Bay. August 2004.

Representative unvegetated (barren) waterbody on Cook Inlet. August 2004.

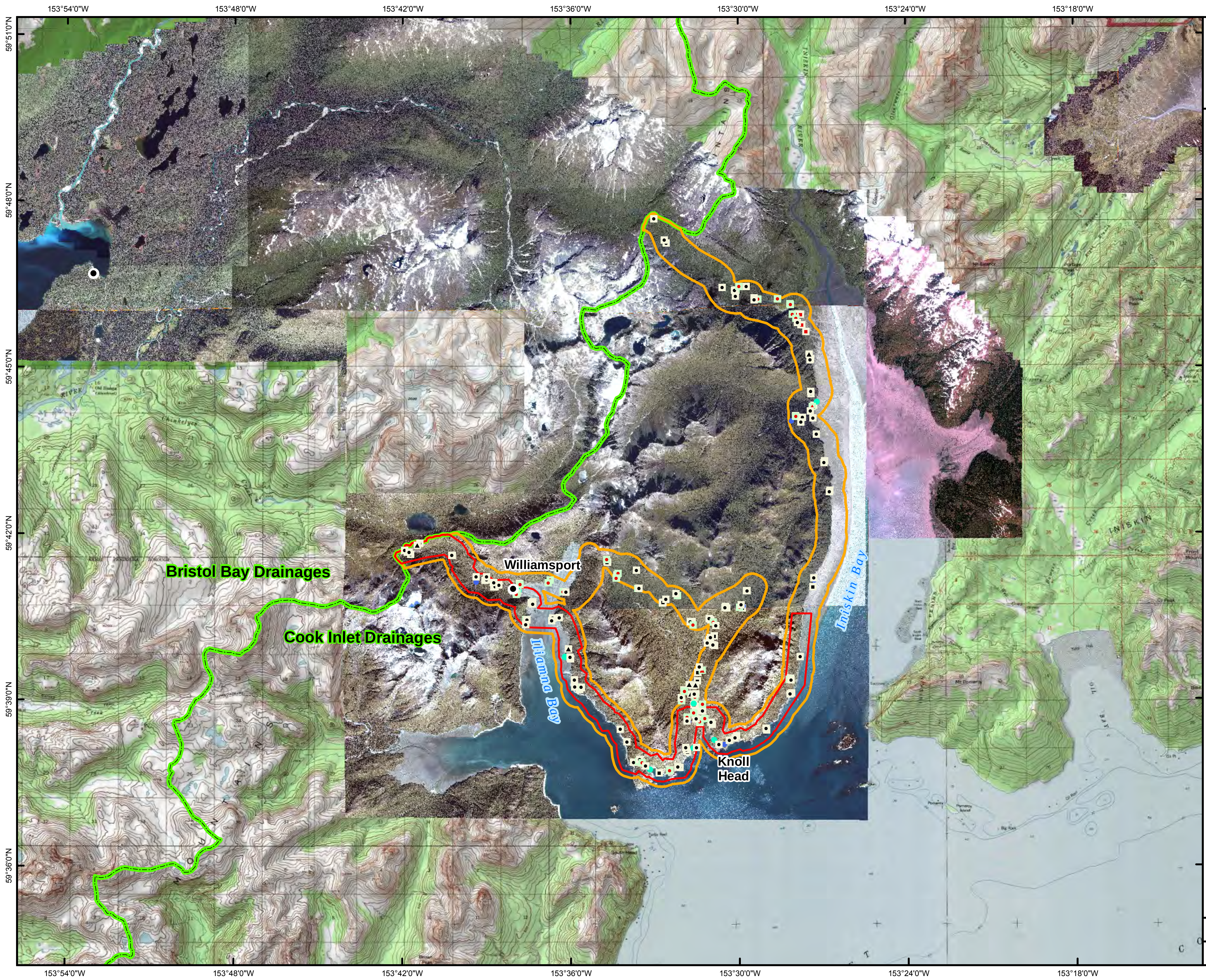

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Figure 39-1
Overview
Field Plot Locations,
Cook Inlet Drainages Study Area,
2004 and 2005

Legend

☐ Cook Inlet Drainages Mapping Area

☐ Cook Inlet Drainages Study Area

— Bristol Bay/Cook Inlet Drainages Boundary

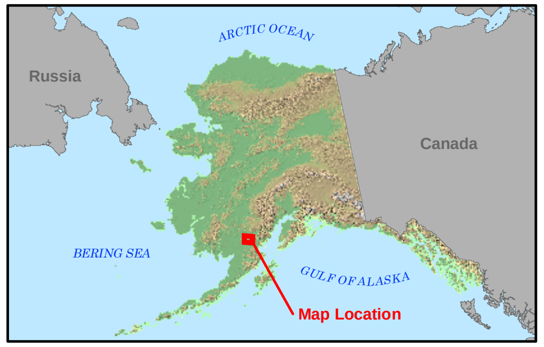
● Communities

Wetland Determination Plot Type (Count)

- Wetland (35)
- ▲ Transitional Wetland (5)
- Non-wetland (91)
- ▲ Transitional Non-wetland (8)

Other Plot/Photo Point Type (Count)

- ● Stream Crossing (25)
- ● Waterbody (13)
- ■ Representative Upland (30)
- ■ Representative Wetland (20)



0 1 2 3 4 5 Miles

0 1 2 3 4 5 6 Kilometers

N

Scale 1:125,000

Alaska State Plane Zone 5 (units feet)

1983 North American Datum

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Version: 1	Author: RDI- LS

40. FISH AND AQUATIC INVERTEBRATES

40.1 Fish

40.1.1 Introduction

Fish and aquatic habitat surveys were conducted in the Cook Inlet drainages study area from July through October in 2004, 2005, 2007, and 2008 to characterize channel conditions, water quality, fish assemblages, and habitat use at possible stream-crossing locations along a representative road alignment. The representative road alignment crosses three creeks that drain into Cook Inlet: Williams Creek (four crossings), Y Valley Creek (one crossing), and a tributary to Iniskin Bay (one crossing). These six primary survey sites (stream-crossing sites located on the representative road alignment) and two support survey sites (located upstream or downstream of primary survey sites or on nearby tributaries) were surveyed during the study period. (Figure 40-1)

40.1.2 Results and Discussion

Overall, the surveyed stream channels were moderately wide, with widths ranging from 6 to 18 meters, and shallow. In Williams Creek and Iniskin Bay Tributary 1, stream gradients were high and variable, ranging from 1 to 12.5 percent. In contrast, with a 1 percent documented gradient, Y Valley Creek is relatively flat at the location of the crossing. One of the four crossing sites in Williams Creek was dry at the time of the survey, although flow was present at Williams Creek sites both upstream and downstream of this location.

Fast-water habitats dominated the survey areas. The habitat at the site on Y Valley Creek was almost all glide habitat, while the sites on Williams Creek and the Iniskin Bay Tributary 1 were dominated by steep cascades. Not surprisingly, streambed materials in the cascades were large cobbles and boulders, whereas the Y Valley Creek bottom was primarily sand/silt and gravels.

Documented water quality was generally good, with seasonable stream temperatures, saturated levels of dissolved oxygen, and generally neutral pH. Specific conductivity of the water was low and was similar to sites in the transportation-corridor study area in the Bristol Bay drainages and mine study area sites.

Fish presence was documented only in Y Valley Creek and at one support survey site in Williams Creek. The species observed in Y Valley Creek included adult chum, pink, and sockeye salmon; juvenile coho and Chinook salmon; and both adult and juvenile Dolly Varden. Although arctic char were not observed during sampling, the 2009 anadromous waters catalog (ADF&G, 2010) indicates that arctic char are present in Y Valley Creek. Only juvenile and adult Dolly Varden were documented at the Williams Creek support survey site. No fish were found at the Iniskin Bay tributary sites.

40.1.3 References

Alaska Department of Fish and Game (ADF&G). 2010. Catalog of Waters Important for the Spawning, Rearing or Migration of Anadromous Fishes. http://www.adfg.alaska.gov/sf/SARR/AWC/

40.2 Aquatic Invertebrates

40.2.1 Introduction

The objective of the macroinvertebrate and periphyton study was to characterize populations of macroinvertebrates and periphyton and their habitat conditions in the Cook Inlet study area. Baseline information on macroinvertebrate and periphyton community assemblages is valued because these creatures are essential components of the aquatic food web and their community structure, particularly with respect to the more sensitive taxa, is an indicator of habitat and water quality. The objective of the macroinvertebrate and periphyton field and laboratory program was to characterize the diversity, abundance, and density of macroinvertebrates and periphyton within freshwater habitats in the study area.

Macroinvertebrates are organisms without a backbone that are large enough to be seen without the aid of a microscope. Sampling of macroinvertebrates typically targets those organisms that live in or on the substrate of streams and lakes (usually in larval and pupal life stages). Periphyton, defined as micro-algae attached to rocks or other solid surfaces, has been sampled in order to describe the primary producers within freshwater habitats in the study area. As with macroinvertebrates, periphyton is also sensitive to changes in the aquatic environment and can be used as a monitoring tool for in situ primary productivity.

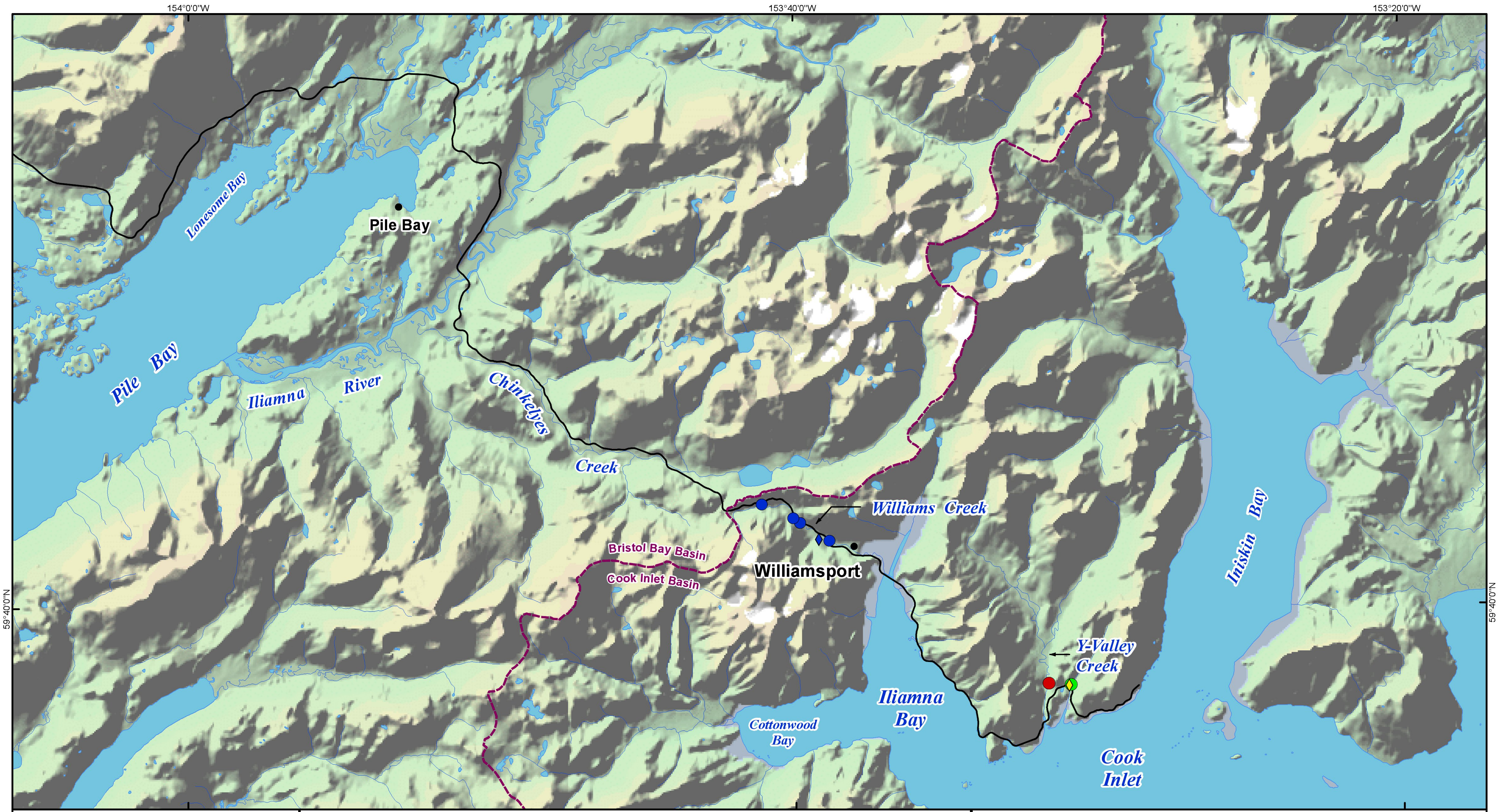
Two sites, Y Valley Creek and an unnamed creek, were selected for sampling in 2004. Y Valley Creek was sampled again in 2005. Sampling methods were modified after the 2004 field sampling. Drift-net sampling for macroinvertebrates resulted in very low densities and was replaced in 2005 with Surber sampling, with the objective of gathering more quantitative information. For similar reasons, diatom identification of periphyton samples in 2004 was replaced in 2005 with analysis of chlorophyll-*a* concentrations. Chlorophyll-*a* concentrations from multiple samples per site provide a more quantitative measure of periphyton productivity.

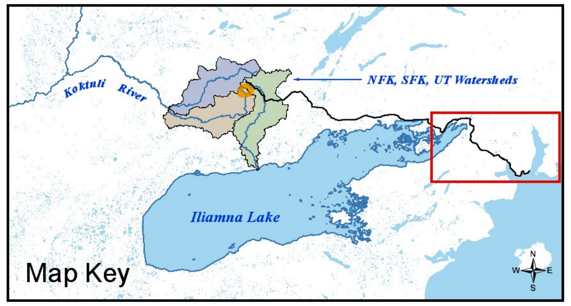
40.2.2 Results and Discussion

Thirty-six macroinvertebrate taxa, including 11 Chironomidae taxa, have been identified in the Cook Inlet drainages study area. Of these 36 taxa, 14 were identified only in samples from 2004, 11 were identified only in samples from 2005, and 11 occurred in both years. Samples were collected in different months in 2004 and in 2005, which may account for the differences in taxa collected.

Results of the diatom identifications of periphyton samples indicate that 19 diatom genera were present in samples collected in 2004 in the Cook Inlet drainages study area. Taxa richness was greater for Y Valley Creek (17 taxa) than for the unnamed creek (eight taxa). Conversely, the percent dominant taxon was much higher for the unnamed creek (79 percent) than for Y Valley Creek (35 percent). These results suggest that, in 2004, Y Valley Creek provided better periphyton habitat than the unnamed creek.

The concentration of chlorophyll-*a* (corrected for phaeophyton) was calculated from analysis of samples collected from Y Valley Creek in 2005, and the result was 2.4 ±0.83 milligrams per square meter.





Legend

Stream Crossing Sites
Supporting Data Sites

● ◆	Williams Creek
●	Y-Valley Creek
● ◆	Iniskin Bay T1
—	Representative Road Alignment
- - -	Bristol Bay/Cook Inlet Basin Divide

Miles
0 1 2

Kilometers
0 2 4

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Figure 40-1
Primary and Support Survey Sites for
the Representative Road Alignment
by Cook Inlet Watershed

November 2011

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

Author: R2 - JJZ

41. TERRESTRIAL WILDLIFE AND HABITAT

41.1 Habitat Mapping and Habitat-value Assessments

41.1.1 Introduction

Wildlife habitats in the Cook Inlet drainages study area (Figure 1-4 in Chapter 1) were mapped to provide a baseline inventory of the availability of terrestrial, freshwater, and marine wildlife habitats and were evaluated for use by wildlife to assess the value of those mapped habitats to a selected set of bird and mammal species of concern.

Field surveys to collect information on vegetation, physiography, landforms, and surface forms in the Cook Inlet drainages study area were conducted in August of 2004 and 2005. Physiography was mapped by interpretation of true-color aerial photographs acquired for the study area in October 2004 and September 2008. Multivariate terrestrial and freshwater wildlife habitats were derived by adding physiographic information (and landform and surface-form information, as needed) to the mapping polygons prepared for the study area as part of the vegetation study by HDR Alaska, Inc.

Marine wildlife habitats in the Cook Inlet drainages study area were mapped using publicly available bathymetry and shoreline mapping data from the National Oceanic and Atmospheric Administration. Several variables from the National Oceanic and Atmospheric Administration data set, which were derived from low-altitude aerial digital imagery, were combined to produce a simplified set of map polygons representing supratidal, intertidal, and subtidal marine wildlife habitats in the study area.

To assess use of the mapped habitat types by important species of wildlife, 61 bird and mammal species of concern (45 birds and 16 mammals) that are known or have the potential to occur in the Cook Inlet drainages study area were selected for their conservation, cultural, and/or ecological importance. Habitat use for each species in each mapped habitat was qualitatively categorized into one of four value classes—high, moderate, low, or negligible—based primarily on wildlife survey data specific to the Cook Inlet drainages and Cook Inlet marine study areas and habitat-use information from the scientific literature.

41.1.2 Results and Discussion

Twenty terrestrial and freshwater wildlife habitat types were mapped in the Cook Inlet drainages study area. Tall-scrub habitats strongly dominated in the study area, and one habitat (Upland Moist Tall Alder Scrub[1]) covered 80 percent of the study area. Three other habitats (Upland Dry Barrens, Upland Moist Dwarf Scrub, and Alpine Dry Barrens) covered another 14 percent of the

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[1] The names of habitat types that were mapped in this study are capitalized, while the names of general habitat types that were not mapped, such as forest, scrub, meadow, etc., are not capitalized.

study area. The remaining 16 habitat types, including forest, scrub, scrub-bog, meadow, marsh, and freshwater aquatic habitats, were uncommon, each covering less than one percent of the study area.

Prominent streams in the study area, all of which drain into Cook Inlet, include Williams Creek and the unnamed stream that drains the Y Valley area north of Knoll Head. The Y Valley stream supports anadromous fish populations and provides foraging opportunities for wildlife.

Seventeen marine wildlife habitat types were mapped in the study area. Only one vegetated marine habitat type (Protected Estuary) occurred in the study area; most of this type was supratidal saltmarsh that occurred above the mean higher high water level. Another prominent habitat type occurring in supratidal areas was Supratidal Cliff. The study area, as mapped at mean lower low water, was dominated by nearshore marine waters, and two habitats (Shallow and Deep Subtidal Waters) comprised 50 percent of the study area. Three soft-sediment intertidal habitats (Protected Mud Flat, Protected Sand Flat, and Exposed Sand Flat) also were prominent and together comprised 39 percent of the study area. Other marine habitats in the study included gravel/sand beaches, rocky ramps and platforms, rocky cliffs, and various combinations of these habitats (e.g., rocky ramp–platform with gravel/sand beach) in both protected and exposed locations.

Results of the wildlife habitat-value assessments for the Cook Inlet drainages study area indicate that the most species-rich terrestrial and freshwater habitats in the Cook Inlet drainages study area are the forest types, which have the greatest numbers (17–18 species) of bird and mammal species with moderate- or high-value rankings. These forested habitats, however, are uncommon in the study area. The most common terrestrial or freshwater habitat in the study area (Upland Moist Tall Alder Scrub) has 10 species with moderate- or high-value habitat rankings.

For marine habitats, the most species-rich are the soft-sediment habitats. Two habitats (Protected Mud Flat and Protected Sand Flat) have the greatest numbers (26–27 species) of bird and mammal species of concern with moderate- or high-value habitat rankings. These soft-sediment intertidal habitats are common in the study area and occur most prominently in the upper portions of Iliamna and Iniskin bays and, to a lesser extent, at Knoll Head.

The Cook Inlet drainages study area provides at least some suitable habitat (moderate- and/or high-value habitat rankings) for 13 terrestrial mammal species of concern—wolf, red fox, river otter, wolverine, black bear, brown bear, moose, arctic ground squirrel, red squirrel, beaver, northern red-backed vole, tundra vole, and snowshoe hare—and for three marine mammal species of concern—sea otter, harbor seal, and harbor porpoise.

Habitats suitable for black and brown bears are common and widespread in the study area. Black bears favor habitats that provide cover, and in the Cook Inlet drainages study area, most forest and tall-scrub habitats were considered to be of high value for black bears. Other forest, scrub, scrub-bog, meadow, and marsh habitats, and Rivers and Streams (Anadromous) were considered to be of moderate value for black bears. None of the marine habitats in the study area were considered to be of high or moderate value for black bears. In contrast, brown bears are known to use a broader array of habitats than black bears and 15 terrestrial and freshwater habitats in the study area were considered to be of moderate value for brown bears. One habitat (Rivers and Streams [Anadromous]) was considered to be of high value for brown bears, because salmon streams are heavily used by foraging brown bears in late summer. Five marine habitats, including beaches, cliffs with beaches, and supratidal estuarine habitats (the latter providing important plant foods for brown bears during early spring), were considered to be of moderate value for brown bears. For moose, low and/or tall willow-scrub habitats, and Lakes and Ponds were considered to be of high value, primarily for forage. These high-value moose habitats, however, are uncommon in the study area. Other scrub, scrub-bog, forest, meadow, and marsh habitats were considered to be of moderate value for moose, also for forage. None of the marine habitats in the study area were considered to be of high or moderate value for moose.

For marine mammals, a single marine habitat type (Deep Subtidal Waters) was considered to be of moderate value for harbor porpoises for foraging. Two habitat types (Shallow and Deep Subtidal Waters) were considered to be of moderate value for sea otters for foraging. No marine habitat in the study area was considered to be of high value for these two species. For harbor seals, two marine habitats (Shallow and Deep Subtidal Waters) were considered to be of high value for foraging, and one habitat (Protected Sand Flat) was categorized as of moderate value.

For birds, the Cook Inlet drainages study area provides at least some suitable habitat (moderate- and/or high-value habitat rankings) for 38 species of concern: six raptors (Bald Eagle, Northern Goshawk, Golden Eagle, Merlin, Peregrine Falcon, Great Horned Owl), 16 waterbirds (Trumpeter Swan, American Wigeon, Mallard, Northern Pintail, Green-winged Teal, Greater Scaup, Harlequin Duck, Surf Scoter, American Scoter, Long-tailed Duck, Red-throated Loon, Horned Grebe, Red-faced Cormorant, Pelagic Cormorant, Arctic Tern, Marbled Murrelet), nine shorebirds (American Golden-Plover, Black Oystercatcher, Lesser Yellowlegs, Whimbrel, Hudsonian Godwit, Surfbird, Rock Sandpiper, Dunlin, Short-billed Dowitcher), and seven landbirds (Spruce Grouse, Willow Ptarmigan, Rock Ptarmigan, Olive-sided Flycatcher, Gray-cheeked Thrush, Varied Thrush, and Blackpoll Warbler).

Terrestrial and freshwater habitats considered suitable for nesting and/or foraging by tree-nesting raptors (forests, some scrub and barren habitats, meadows, marshes, and lacustrine and riverine waterbodies) are uncommon in the study area. In contrast, marine habitats considered suitable for foraging by tree-nesting raptors (estuaries, mud and sand flats, gravel/sand beaches, rocky cliffs, and subtidal waters) are common and widespread in the study area. For cliff-nesting raptors, a set of higher-elevation, open dwarf-scrub and barren habitats, and some forest, scrub, scrub-bog, meadow, marsh, and aquatic habitats were considered suitable for nesting and/or foraging. These terrestrial and freshwater habitats are uncommon in the study area. Marine habitats considered suitable for foraging by cliff-nesting raptors, however, are common and occur throughout the study area. These habitats include estuaries, mud and sand flats, rocky cliffs, and subtidal waters.

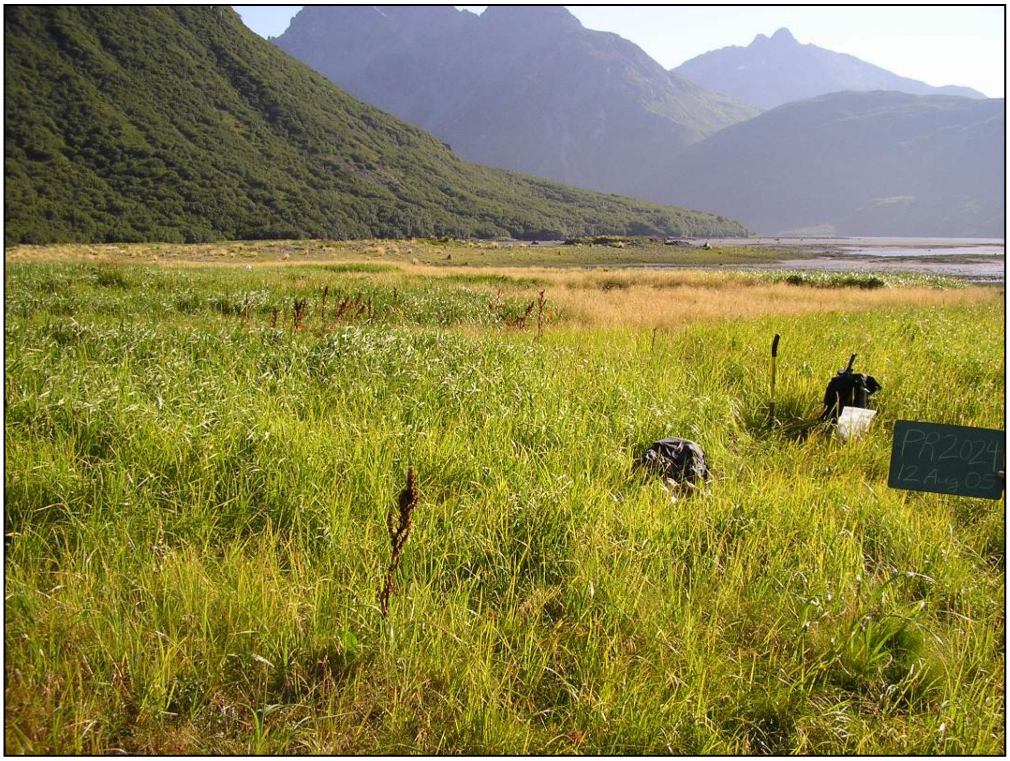
For breeding and migrant waterbirds, several terrestrial and freshwater habitats, including anadromous fish streams and associated riverine habitats, were considered to be of high value, and lacustrine waterbodies were considered to be of moderate value. These suitable habitats for breeding and migrant waterbirds are uncommon in the study area. In contrast, a wide variety of marine habitats is available and considered suitable for migrant and overwintering waterbirds. These suitable marine habitats include estuaries, mud and sand flats, beaches, rocky ramps, rocky platforms, rocky cliffs, and subtidal waters.

Open terrestrial habitats considered suitable for breeding shorebirds in the study area are limited in occurrence and include many of the higher-elevation, dwarf-scrub and barren habitats. However, marine habitats that were considered suitable for migrant shorebirds and for a few species of overwintering and breeding shorebirds are common and widespread in the study area. The marine habitats considered suitable for shorebirds include estuaries, mud and sand flats, beaches, rocky ramps, rocky platforms, and rocky cliffs.

Habitats in the study area suitable for breeding landbirds include forests and tall-scrub, low-scrub, dwarf-scrub, and barren types in a variety of physiographic settings. Tall-scrub habitats suitable for some breeding landbird species are common and widespread across the study area. Forested and open habitats suitable for other breeding landbirds are uncommon. None of the marine habitats mapped in the study area was evaluated for use by landbirds because the landbird species addressed in this study do not occur in marine habitats.

Ground-truth sampling, Upland Moist Dwarf Scrub, August 2005

Ground-truth sampling, Riverine Low Willow Scrub (foreground), and Upland Tall Alder Scrub (on upland slopes in background), August 2005



Ground-truth sampling, Protected Estuary (in the supratidal zone), August 2005

Exposed Rocky Cliff with Gravel/Sand Beach, August 2005

41.2 Terrestrial Mammals

41.2.1 Introduction

Based on historical reports and recent field inventories, 40 species of mammals are known (or are strongly suspected) to occur in the geographic region of the Pebble Project. Information on terrestrial mammals in the Cook Inlet drainages study area (Figure 1-4 in Chapter 1) was compiled to determine the general pattern of use, relative abundance, and spatial distribution.

The terrestrial mammal study had five objectives:

- Collect and review relevant literature and harvest records on all species of mammals inhabiting the region.
- Conduct multiple aerial surveys to estimate seasonal abundance and location of large mammals in the study area.
- Conduct aerial survey of brown bears along salmon-spawning streams and examine bear dens.
- Summarize observations recorded by other researchers in the study area.
- Acquire and analyze radio-telemetry data for caribou from the Mulchatna Caribou Herd Technical Working Group.

A small fixed-wing airplane was used for most aerial surveys, although a helicopter was used for several surveys. Five large-mammal surveys and one stream survey were flown in 2004 and nine large-mammal surveys were flown in 2005. Additional observations of large mammals were recorded during other wildlife surveys for waterfowl and raptors in 2004 and 2005, harbor seals in 2005 and 2007, and marine wildlife in 2006 and 2007.

41.2.2 Results and Discussion

Brown bears are common in the Cook Inlet drainages and were found in high densities in sedge meadows at the heads of Iniskin and Chinitna bays in early summer. During late summer and autumn, brown bears concentrated along salmon spawning streams, including the Iniskin River and Portage Creek on Iniskin Bay and the stream in the Y Valley between Iliamna and Iniskin bays. The maximum numbers of brown bears observed during single surveys were 38 in 2004, 75 in 2005, and 104 in 2007. The increase in numbers during those years was due to increased survey effort and differences in seasonal timing of surveys, rather than to an increase in the bear population.

Black bears are found in lower densities than brown bears in the Cook Inlet drainages study area, and were observed most frequently on the Iniskin Peninsula between Iniskin and Chinitna bays. Black bears generally are found in forested areas with thick vegetation and, therefore, were less visible during aerial surveys than were brown bears.

Suitable habitat for moose in the Cook Inlet drainages study area was restricted mostly to the Y Valley and the Iniskin Peninsula. Most of the few moose seen on surveys were on the Iniskin Peninsula.

No caribou were observed in the study area, which is almost completely out of the range of the Mulchatna Caribou Herd; the steep coastal mountains and intertidal areas that dominate the study area are not preferred caribou habitats. In the 29 years of caribou telemetry data analyzed for the Pebble Project studies, only one radio-collared caribou was found in the Cook Inlet drainages study area.

Red foxes and river otters were observed occasionally in the study area during aerial surveys.

Brown bear feeding in the salmon-spawning stream at the mouth of the Y Valley, August 2005.

41.3 Raptors

41.3.1 Introduction

Studies were undertaken in the Cook Inlet drainages study area (Figure 1-4 in Chapter 1) in 2004 and 2005 to collect baseline data on the distribution, abundance, nesting status, and habitat use of large tree- and cliff-nesting birds of prey (raptors). Records of all raptors and Common Ravens were recorded, but special emphasis was placed on species of conservation concern, protected species, and species potentially sensitivity to disturbance (Bald and Golden eagles, Gyrfalcon, Peregrine Falcon, Rough-legged Hawk, Northern Goshawk, Osprey, and Great Horned Owl). In addition, researchers developed aircraft guidelines to avoid disturbance of wildlife, including nesting raptors.

Field work was conducted primarily during April and May 2004, May through August 2005, and late fall and mid-winter 2005 and 2006. Aerial surveys were conducted by helicopter for all nest occupancy and productivity surveys.

41.3.2 Results and Discussion

During aerial surveys, researchers recorded five raptor species and Common Ravens in the Cook Inlet drainages study area, but as many as 18 species of raptors may occur in the region. Twenty-three nests of four species (Bald and Golden eagles, Peregrine Falcon, and Common Raven) were located in the study area. The behavior of sighted birds and suitable habitats for two other species (Rough-legged Hawk and Merlin) suggested these species may nest in the area as well, and during ground-based surveys for landbirds and shorebirds in the study area in 2005, an active Merlin nest in fact was found. Additional species, such as woodland raptors (e.g., Northern Goshawks, Great Horned Owls), may nest in this area but were not found during aerial surveys.

Bald Eagles were the most abundant nesting species (70 percent of total nests), and 55 percent of occupied nests were successful. Golden Eagles were the next most common nesting raptor (17 percent of nests); 100 percent of occupied nests were successful. Peregrine Falcons were also recorded nesting in both years, at one coastal cliff location. Nesting success and productivity for these species fit within the range of statistics for other subpopulations of these species in southern Alaska.

The best woodland habitats suitable for tree-nesting raptors (including large cottonwoods) occur in the lower to middle reaches of the major drainages entering the bays in the Cook Inlet drainages study area. In addition, scattered cottonwood and spruce trees are found along the shoreline from Cottonwood Bay to outer Iniskin Bay and are more abundant from the east side of Iniskin Bay to the south shoreline of Chinitna Bay. Finally, most of the Iniskin Peninsula is covered by large, homogenous stands of spruce and riparian stands of cottonwood, which offer potential substrates for many tree-nesting raptors.

Habitat for cliff-nesting species is abundant along the coast at low elevations fronting the ocean from Cottonwood Bay to Chinitna Bay and at higher elevations in the same coastal area, as well as inland in Y Valley and along Mt. Pomeroy, the Tilted Hills, and in the northern portions of the

Iniskin Peninsula. Use of these habitats, however, seems spotty and might be constrained by other factors (e.g., weather, food supply, density).

Fledged Peregrine Falcon near Diamond Point nest site, Cottonwood Bay, August 2005.

Cliff-nesting raptor habitat, Tilted Hills, August 2005.

Cliff Habitat, western Iniskin Bay coastline, May 2004 (Bald Eagles nested on the top of these cliffs in 2004).

Looking north into Iliamna Bay (Diamond Point in left center showing cliffs used by nesting Peregrine Falcons), August 2005

41.4 Waterbirds

41.4.1 Introduction

The waterbird study was conducted in the Cook Inlet drainages study area (Figure 1-4 in Chapter 1) to collect baseline data on the distribution, abundance, and species composition of, and use of riverine habitats by waterbirds during spring and fall migration, as well as the occurrence of breeding Harlequin Ducks. (Waterbird surveys of the marine environment [bays and mudflats] in the study area during spring and fall migration are summarized in Chapter 44.) Waterbirds included geese, swans, ducks, loons, grebes, cormorants, cranes, shorebirds, gulls, terns, and jaegers. Species-specific surveys were conducted during the breeding season for Harlequin Ducks, because they are a key indicator species for the environmental health of rivers.

Field work was conducted during April through October 2004 and 2005. Surveys were conducted using helicopter or fixed-wing aircraft and followed standard survey techniques.

41.4.2 Results and Discussion

Rivers in the western part of the Cook Inlet drainages study area have a steep gradient and are fast flowing, whereas rivers in the eastern part are slow and meandering. The Iniskin River is slow and meandering and was a popular staging location for dabbling ducks during spring and fall migration in 2004 and 2005. Hundreds of dabblers were recorded near the lower section of the river, with the peak in spring occurring in late April/early May and the peak in fall occurring in mid-September. Diving ducks were observed all along the surveyed section of the Iniskin River. Glaucous-winged Gulls were found feeding on salmon carcasses in the middle section of the river during fall.

Small numbers of dabbling and diving ducks were observed using Bowser and Fitz creeks during the breeding season and in fall. Both creeks were not used during spring migration because they did not thaw until mid-May, after most ducks had already migrated through the area. One Trumpeter Swan nest was found adjacent to Bowser Creek, and a brood was observed later in the same area.

Harlequin Ducks prefer fast-flowing rivers for nesting and brood-rearing. Ten rivers were surveyed, and Harlequin Ducks were found as pairs and with broods on the creeks of the Y Valley. Other waterfowl species using fast-flowing rivers for brood-rearing included Mallard, Green-winged Teal, and Common and Red-breasted mergansers.

Glaucous-winged Gulls feeding on salmon carcasses at the mouth of Cottonwood Creek during a fall migration survey, September 2004.

Surveying the lower section of the Iniskin River for waterbirds during a fall migration survey, September 2004.

Surveying Cottonwood Creek for Harlequin Duck broods, August 2005.

Aerial view of the creek in the Y Valley that supports breeding Harlequin Ducks, November 2009.

41.5 Breeding Landbirds and Shorebirds

41.5.1 Introduction

Field surveys for breeding landbirds and shorebirds were conducted to collect baseline data on the distribution, abundance, and habitat use of these species during the nesting season in the Cook Inlet drainages study area (Figure 1-4 in Chapter 1). Researchers recorded all bird species observed in the field, paying special attention to species of conservation concern. Only observations of landbirds and shorebirds, however, are discussed in this summary. Observations of raptors and waterbirds made during this study in the Cook Inlet drainages study area are summarized in Sections 41.3 and 41.4, respectively.

The ground-based field work for this study was conducted during June 2005, using standard point-count survey methods. All birds seen or heard were recorded and, as is typical in point-count surveys, most observations were made by sound (songs and calls of breeding birds).

41.5.2 Results and Discussion

The only landbirds recorded in the Cook Inlet drainages study area were passerines (songbirds), and only two shorebird species were recorded. Including observations recorded outside the point-count periods, researchers identified 30 landbird species and two shorebird species in the Cook Inlet drainages study area. In addition to a greater number of species, landbirds also were numerically more abundant than shorebirds in the study area.

Six of the 30 landbird species (Wilson’s Warbler, Golden-crowned Sparrow, Yellow Warbler, Hermit Thrush, Orange-crowned Warbler, and Savannah Sparrow) were considered to be abundant breeders in the Cook Inlet drainages study area. Four of these species (Wilson’s Warbler, Golden-crowned Sparrow, Yellow Warbler, and Hermit Thrush) were especially abundant and accounted for 67 percent of the point-count observations. Two additional landbird species (Fox Sparrow and Gray-cheeked Thrush) occurred less frequently and were considered to be common in the Cook Inlet drainages study area. The two shorebird species observed (Black Oystercatcher and Short-billed Dowitcher) were considered to be uncommon in the study area, but both were recorded in intertidal habitats, which were not directly sampled during point-count surveys. Black Oystercatchers, in particular, occur nearly exclusively in intertidal and supratidal habitats and were recorded more commonly during focused surveys for marine birds and mammals (Chapter 44). Of the landbird and shorebird species-groups observed, warblers were by far the most abundant breeders, and Wilson’s Warblers, in particular, were very abundant and accounted for more than 20 percent of the bird observations in the Cook Inlet drainages study area. Sparrows and thrushes also were common bird species-groups. The remainder of the landbird species-groups were much less common in the study area.

Landbirds were recorded in 10 of the 13 wildlife habitat types sampled in the study area, while shorebirds were recorded only in marine intertidal areas (not directly sampled with point-counts). One scrub habitat (Upland Moist Tall Alder Scrub) had the greatest number of breeding landbird species. In terms of bird abundance, four forest and scrub habitats (Upland and Lowland Spruce Forest, Upland and Lowland Moist Mixed Forest, Upland Moist Tall Alder

Scrub, and Riverine Tall Alder or Willow Scrub) were the most productive and supported five or more birds per point-count. Individual landbird species often used a range of different forest, scrub, bog, and meadow habitats, with the more common species using a larger set of habitats than uncommon species. Shorebirds were observed only near the coast and were not observed to be breeding in terrestrial habitats in the study area.

Point-count surveys start near dawn, June 2005.

Point-count sampling in Lowland Ericaceous Scrub Bog, June 2005.

Point-count sampling in Upland Moist Dwarf Scrub (transitioning to Upland Moist Tall Alder Scrub), June 2005.

Moving between point-count locations, Lowland Ericaceous Scrub Bog, June 2005.

42. MARINE BENTHOS

42.1 Introduction

The littoral and subtidal habitats in lower Cook Inlet support diverse communities of marine and anadromous species of ecological and economic importance. The overall objective of the marine benthos study was to characterize benthic assemblages in marine habitats of Iniskin and Iliamna bays. Specific objectives of the study were as follows:

- Review and synthesize available information from past studies of regional and local marine conditions and resources.
- Conduct new field studies and analyses to supplement information from these past studies to gain an updated and broader understanding of the benthic ecology of the Iliamna/Iniskin Estuary.
- Establish a baseline that describes, to the extent practical, variations in plant and animal assemblages associated with elevation, season, and year.
- Identify and quantify specific sites, habitats, and benthic resources that are particularly productive or important (e.g., kelp and eelgrass beds, marshes at stream mouths, shellfish resource areas, fish spawning habitats, threatened or endangered species habitats, etc.).
- Document the food web and ecological relationships among key species in the Iliamna/Iniskin Estuary. (This study element was conducted in conjunction with the marine fish and invertebrate studies summarized in Chapter 43.)

Marine investigations under this study occurred over the 5-year period from 2004 through 2008 and included several habitat sampling events, mostly in mid to late summer. Field work consisted of various efforts largely divided between intertidal and subtidal studies as summarized below:

- Intertidal Studies:
  - Intertidal habitat surveys, including both quantitative and qualitative data collection, were conducted 2004, 2005, 2006, and 2008.
  - Intertidal samples, including samples of sediment, infauna, and biological tissue, were collected in 2004, 2005, and 2008 for analysis.
- Subtidal Studies:
  - Subtidal habitat surveys, including both quantitative and qualitative data collection and underwater photography were conducted 2004 and 2008.
  - Subtidal samples, including samples of sediment, water, infauna, and biological tissue, were collected in 2004 and 2008 for analysis.

Several sampling methods were used and included fixed quadrat transect sampling for the rocky and boulder/cobble intertidal habitats, quantitative core and quadrat sampling in soft sediment habitats for infauna (in concert with sampling for chemical analysis), and diver survey transects where fauna and habitat types were quantified by diver-biologists in situ and by video and still photographs taken during the surveys. Habitat and community composition, and the similarities and differences between sites were investigated. Specific measures examined included species abundance, species diversity, species dominance, and multivariate clustering of sites based on species similarities and composition.

42.2 Results and Discussion

This summary covers the biological and ecological baseline condition of marine benthos in the study area. The studies of intertidal and subtidal habitats and of oceanographic and water-quality physical characteristics are summarized in Chapter 36 and Chapter 34, respectively.

42.2.1 Intertidal Epibiota

Field surveys were conducted to investigate typical ecological conditions and assemblages along shorelines in the Iliamna/Iniskin Estuary. The different timing of sampling in various years, combined with consideration of seasonal data that were gathered at stations in the Iliamna/Iniskin Estuary and elsewhere in Cook Inlet in 1978 (Lees et al., 1980), aided in evaluation of seasonal patterns.

The intertidal areas sampled represent a wide range of habitat types from bedrock to mudflat. Each habitat type supports a distinct assemblage of resident organisms that have adapted to the physically rigorous environment in the Iliamna/Iniskin Estuary.

For rocky intertidal habitats the distribution of vegetation and invertebrates is determined by elevation, substrate, time of year, and exposure to physical stressors, such as waves, sun, and ice scour. These physical factors have variable seasonal and interannual influences on these habitats and associated organisms. Ice, in particular, is a major stressor on organisms found on rocky intertidal habitats. As seen at certain sampling stations in April 2006 and March 2008, ice, coupled with low wintertime light levels, largely removed sessile epibiota from all rock surfaces except crevices and tide pools during the winter months. The reach of shoreline from the mouth of Y Valley Creek to North Head (Figure 1-3c in Chapter 1) has many nearly vertical rock faces that never develop mature intertidal assemblages, suggesting a consistent annual scouring by wave-driven ice. Potentially all of the Iliamna/Iniskin Estuary shorelines may experience such icing-related effects at some point during the winter. The effects of moving ice are exacerbated by swells that repeatedly move the ice against the shore. In summary, ice damage and low light levels combine to greatly reduce intertidal epibiota each winter.

Throughout the intertidal zone, plants generally recolonize the exposed substrate each spring from ice-resistant holdfasts or encrusting life phases or through settlement of gametes from plankton. In many ice-affected areas, sessile animals appear to persist through the winter in cracks and crevices or under boulders and also recolonize from planktonic larvae. More motile animals also may take shelter in cracks, crevices, or under boulders or may migrate to subtidal areas. They also may recolonize from planktonic larvae. Early in the spring, as light levels increase, algal growth may be preceded by blooms of unicellular diatoms, as was seen in April 2006. These diatoms, some green algae, and early colonizing films of other algae encourage grazers such as limpets and periwinkles to move out of winter refuges to graze. This cycle of spring renewal is followed by an early summer peak in abundances of many algae that then decline after releasing reproductive products.

The monthly monitoring conducted at Scott Island (at the entrance to Iniskin Bay) in April through September 1978 (Lees et al., 1980) generally supports these findings. In the 1978 data from Scott Island, the algae at upper elevations were relatively constant over the spring to early fall, while those at middle and lower elevations exhibited greater seasonality. Green algae were more abundant in the early part of the season at the lower elevation, while red and brown algae developed high abundances in July to September.

The diversity of both plants and animals among the rocky stations also tended to decrease with declining wave exposure and salinity and increasing suspended-sediment load. Generally, the number of species of algae that tolerate less saline and variable light (i.e., more estuarine) conditions are fewer, and areas with high wave exposure had the highest potential for high macroalgal diversity because of the high levels of disturbance and greatest exposure to a larger recruiting stock (i.e., Cook Inlet waters). Scott Island and sampling station MPS1 (Knoll Head) were the most exposed and had the greatest diversity of algae. Station MPS1A (Knoll Head West) was only slightly less diverse. Sampling stations MPS2 (inside the western shore of Iniskin Bay) and MPS4 (North Head in Iliamna Bay) were intermediate in exposure and richness, while station MPS3 (Diamond Point at the mouth of Cottonwood Bay) had the least diverse biota, reflecting its semi-protected location and the influence of higher suspended-sediment loads from Iliamna Bay. (See Figure 1-3c in Chapter 1 for the locations of the landmarks cited here.)

An analysis of long-term temporal changes at two stations in the Iliamna/Iniskin Estuary has been possible using data from 1978 (Lees et al., 1978), 1996 (Pentec, 1996), and the Pebble Project study. As of 2004, intertidal conditions had not changed dramatically since the previous studies, and descriptions based on the previous studies remained largely valid. An exception was an apparent shift in algal dominance at middle intertidal rocky stations at Scott Island and Knoll Head West between 1978/1996 and 2004: the dominant algae shifted from rapidly recolonizing red algae (e.g., from remnant holdfasts) to a co-dominance between the red algae and rockweed, a perennial brown alga that requires a few years without disturbance to reach maturity. There also was an increase in the cover by barnacles. These shifts suggest that fewer ice-scouring events may have occurred at these sites in the winters prior to the 2004 sampling event than prior to either the 1978 or 1996 sampling events. The co-dominance of red algae and rockweed persisted at the Scott Island middle station through July 2005. In 2005, at the Knoll Head West (MPS1A) middle station and in April 2006 and July 2008 at the Scott Island middle station, there was a return to red algal dominance. The low cover of rockweed in April 2006 at Scott Island may reflect more severe ice damage over the winter of 2006.

Each intertidal habitat type provides feeding areas for different pelagic and demersal fish and invertebrates that forage over the intertidal zone during high tides. The estuarine and nearshore rearing habitats of juvenile salmonids are an important component of the intertidal zone, especially for pink and chum salmon that outmigrate from streams along the shoreline of the Iliamna/Iniskin Estuary and elsewhere in Cook Inlet. Another important component of the intertidal zone is the substrate used for spawning by Pacific herring. In Spring 2008, herring spawn was moderately abundant along lower intertidal rocky habitats from Entrance Rock nearly to Knoll Head, with less spawning intensity observed toward the Y Valley lagoon and around Scott Island. Spawn was also common on eelgrass in beach drift and in trawl samples during late May and early June. In addition, rearing of larval and juvenile herring resulting from nearby spawning is clearly important along Iliamna/Iniskin Estuary shorelines, as indicated by beach seine sampling (Chapter 43).

42.2.2 Subtidal Habitats

Six qualitative reconnaissance dives were performed in 2004 and revisited in 2008 for the nearshore region of the Iliamna/Iniskin Estuary to survey the habitats and benthic assemblages in areas of interest. Along diver transects, the substrate generally graded from coarsest nearshore to finest offshore, with a mixture throughout. Attached fauna at the shallowest depths tended to be relatively sparse, presumably because of occasional scouring by ice. Kelp (Laminariales) was most abundant closest to shore at station MPS4 (inside North Head) and at White Gull Island, and also at station MPS1B (inside Iniskin Bay), but at relatively low density.

For coarse substrates (e.g., cobble and small boulder) invertebrate fauna was dominated by attached and mobile organisms and not by burrowing infauna. Common attached invertebrates included sponges, hydroids, sea anemones, the rock jingle, and bryozoans. Common mobile invertebrates included several species of snails, chitons, nudibranchs, hermit crabs, and sea stars.

Dominant macroinvertebrates on soft subtidal substrates were mainly a tube-dwelling sabellid polychaete, probably *Schizobranchia insignis*. Dense mats of this suspension-feeding worm also were present in the Iliamna/Iniskin Estuary area in the 1970s (Lees et al., 1980). A few other sponges, the fleshy moose-horn bryozoan (*Alcyonidium* sp.) and seastars (*Leptasterias* spp. and *Henricia leviuscula*) also were noted.

Few pelagic fish were observed on diver transects. Instead, more bottom-oriented fish like the whitespotted greenling, starry flounder, and unidentified juvenile flatfishes were most common. All of the common plants, invertebrates, and fishes seen in 2004 and 2008 also were present in dive surveys in the Iliamna/Iniskin Estuary area in the 1970s (Lees et al., 1980), indicating a moderate degree of temporal stability in subtidal plants and animals.

42.2.3 Infauna

Infauna samples were collected in conjunction with sediment samples collected for chemical analyses. The infaunal assemblages of the sampled intertidal sites were composed of organisms commonly found in Alaskan waters. Polychaetes generally dominated in terms of abundance, while in terms of biomass, bivalves (because of their typically larger size) shared dominance with a few larger polychaetes. In 2008, there were a few exceptions where small polychaetes dominated in biomass in the absence of large polychaete and bivalve species. At the genus level, all of the animals identified during the Pebble Project marine benthos study are abundant in marine assemblages elsewhere in Alaska (e.g., Jewett et al., 1999; Blanchard and Feder, 2003; Blanchard et al., 2003).

A few worms—*Capitella capitata*, *Chaetozone* sp., *Prionospio* sp., and *Polydora* sp.—are known to occur in disturbed environments in Alaskan coastal environments (Jewett et al., 1999; Blanchard et al., 2002, 2003; Blanchard and Feder, 2003). Their presence in moderately high numbers in the Iliamna/Iniskin Estuary during some years may reflect frequent movement or disturbance of sediments within the intertidal region, a result of the moderate- to high-energy physical environment. From 2004 to 2008 several shifts in abundance, biomass, and diversity, such as the generally greater abundances and biomass of bivalves in 2005 and to some extent in 2008, were noted. However, these changes likely reflect small-scale spatial and temporal phenomena and demonstrate the constantly changing baseline condition in the intertidal infaunal assemblage.

For the subtidal assemblage, the dominant taxa collected were polychaetes (e.g., *Lumbrineris, Nephtys, Cossura*, and *Prionospio steenstrupi*) and the clams *Ennucula* and *Macoma moesta alaskana* (depending on the year sampled). In general, these taxa are widely observed in infaunal assemblages in Alaska (Jewett et al., 1999; Blanchard and Feder, 2003) and are generally distinct from the intertidal assemblages. Despite these generalizations, species varied widely from site to site and year to year, though relative contribution by functional group explained many of the differences between sites.

The variability of the results of subtidal faunal measures among sampling locations and elevations was substantial but falls largely within the range expected based on the results of studies of similar marine assemblages elsewhere (Jewett et al., 1999; Blanchard et al., 2002; Blanchard and Feder, 2003; Feder et al., 2005). For example, the average July abundance of subtidal infauna decreased by 50 percent or more and average July biomass decreased by an order of magnitude between 2004 and 2008. On the whole, fewer taxa were encountered in the subtidal samples in 2008, with many of the dominant taxa differing between the two years. Nonetheless, most of the species in both years fell into two functional groups (molluscs and annelids) that dominated infaunal biomass or abundance at most of the sites. High variability was noted among replicate samples from within sites, suggesting a lack of homogeneity within the sites over very small spatial scales. Only one site, station MPS1 at Knoll Head, had groupings of replicate samples in multivariate analysis that were indicative of a homogenous marine environment. Conversely, station MPS4, and to a lesser extent station MPS2, had much scattering and a low similarity among replicate samples in multivariate analysis, indicating a lack of homogeneity. The low similarity of replicates reflected in the cluster analysis and ordination may be due to sampling multiple habitats within a site, possibly as a result of a high diversity of habitats (from either horizontal zonation or habitat mosaics/patchiness) within a site; such diversity is not uncommon for these types of subtidal marine assemblages (Jewett et al., 1999; Blanchard et al., 2002; Blanchard and Feder, 2003; Feder et al., 2005).

Overall, subtidal infauna was generally more abundant and more diverse than was intertidal infauna. These differences reflect the greater stability and lower stress of subtidal environments compared to intertidal environments where wave action, large temperature and salinity shifts, and seasonal ice-gouging exert influences not seen in subtidal habitats. Despite these stresses, some areas of the intertidal environment showed substantial biomass of large infauna that far exceeded the subtidal biomass. This difference may reflect the minimal influence of large predators (e.g., sea stars) on bivalves in these intertidal areas. In addition, the infauna at subtidal stations exhibited a higher degree of within-station similarity than did the infauna at intertidal stations, a reflection of the greater diversity of intertidal substrates, again, likely a consequence of the harsher nature of the intertidal environment.

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Middle intertidal zone dominated by red algae, June 17, 2008.

Transect in the rocky mid-intertidal zone dominated by *Fucus*, July 16, 2008.

Extensive eelgrass meadow, July 5, 2008.

Collecting infauna samples on mudflats, July 14, 2008.

43. NEARSHORE FISH AND INVERTEBRATES

43.1 Introduction

The study of nearshore fish and macroinvertebrates was undertaken to collect baseline data on the abundance, distribution, and seasonality of major aquatic species in Iliamna and Iniskin bays (the Iniskin/Iliamna Estuary or IIE) on the western side of Cook Inlet. See Figure 1-4. The studies had four principal objectives:

- Build on the limited knowledge available from past studies to gain a broader understanding of the nearshore ecology of the Iliamna/Iniskin Estuary.
- Describe specific fish habitats of each sampling station.
- Document the food web and ecological relationships among key species of the marine ecosystem.
- Investigate local spawning by Pacific herring.

Marine investigations under this study occurred over the 5-year period from 2004 through 2008. The study included numerous sampling events of fish and macroinvertebrate populations in the Iliamna/Iniskin Estuary in all seasons but mid-winter, when ice and weather conditions prevent safe access. Reconnaissance surveys were first conducted during August and September 2004. Monthly surveys were conducted in 2005 (May-August), 2006 (April, May, and September), 2007 (September and October), and 2008 (March-November).

Several sampling methods were used and included beach seines, gill nets, and trammel nets in littoral areas and bottom trawling in subtidal areas. The sampling targeted fish and macroinvertebrate populations that may use the Iliamna/Iniskin Estuary. Herring spawn surveys were conducted in the intertidal zone by direct observation at minus tidal elevations during known spawning periods. Food web and fish dietary studies were conducted by collecting and analyzing stomach contents of several ecologically important fish species in the Iliamna/Iniskin Estuary.

43.2 Results and Discussion

The Iliamna/Iniskin Estuary is a complex marine ecosystem with numerous fish and macroinvertebrate species that use the area for juvenile rearing, refuge, adult residence, migration, foraging, staging, and reproduction. The array of marine habitats available includes cobble/sand and rocky intertidal areas, intertidal and subtidal mud/sand flats, intertidal and subtidal reefs, and intertidal lagoons. Over 50 species of fish were captured over the course of the study.

One ecological function of the Iliamna/Iniskin Estuary is as a rearing area for juvenile Pacific herring. Herring was the dominant fish species and young-of-the-year and 1-year-olds were the dominant life stages found from March through November in the several sampling years, with peak occurrences noted during the summer. The range of sizes in young-of-the-year herring suggests that herring from different areas of Cook Inlet may recruit to the Iliamna/Iniskin Estuary annually, in addition to the progeny derived from Iliamna/Iniskin Estuary spawning. Substantial rearing of herring occurs in the nearshore environment for at least 1 year after the fish hatch, followed by an offshore movement as fish reach approximately 100 millimeters in length. Juvenile herring had a distinct preference among the areas sampled for inner Iliamna Bay, and extremely high catch rates of juveniles were observed there at times during the summer. Analysis of data suggests that this preference may be related to the availability of sheltered habitats in the inner bay. Substantially lower use was observed in nearly all areas studied in the Iliamna/Iniskin Estuary. Herring in the nearshore Iliamna/Iniskin Estuary fed heavily on copepods.

Adult herring spawned in Iniskin Bay in 2008 from late May through mid-June, the first documented spawn deposition on beaches in the study area since 1994. Herring spawned in two general areas in the Iliamna/Iniskin Estuary: along the western shore of outer Iniskin Bay near Knoll Head, and along the outer shorelines of Scott Island and adjacent islands, islets, and reefs of eastern Iniskin Bay (Figure 1-3c in Chapter 1). Trace amounts to low densities of spawn were observed along eastern, outer Iniskin Bay near Scott Island and adjacent reefs. Trace to moderate amounts were observed along the western shore of the bay. Historically, herring spawned annually in Kamishak Bay (south of the Iliamna/Iniskin Estuary), expanding into reaches of the Iliamna/Iniskin Estuary during large biomass years. It is not known whether herring spawn detected in 2008 represents a long-term recolonization of the study area by spawning fish. Areas used by spawning fish in 2008 were generally the same areas most consistently used between 1979 and 1991 (Otis et al. 1998). The presence of spawning fish was confirmed by the capture of gravid adults in floating gill-net sets in May 2008.

The nearshore area of the Iliamna/Iniskin Estuary also is a rearing area for juvenile salmon, which as a group, were second to herring in abundance. Juvenile pink and chum salmon were the most abundant salmonid species and showed a typical spring and summer outmigration as young-of-the-year fish. Juvenile chum displayed a short outmigration period during May and June, while juvenile pink salmon remained in the Iliamna/Iniskin Estuary into August. Both species were largely gone by September. Juvenile pink salmon were significantly more abundant in Iniskin Bay, while juvenile chum preferred Iliamna Bay. Both species fed heavily on copepods and terrestrial insects, and juvenile chum also fed on small snails. More than one cohort of juvenile sockeye salmon also used the nearshore Iliamna/Iniskin Estuary during the spring and summer, though at much lower abundances than chum and pink. Very few juvenile coho and Chinook salmon were captured in the Iliamna/Iniskin Estuary.

Multiple cohorts of subadult and adult Dolly Varden were moderately abundant over most of the nearshore Iliamna/Iniskin Estuary from spring through late summer, with a distinct preference for beaches in outer Iniskin Bay. Adult chum and pink salmon were present in the Iliamna/Iniskin Estuary principally in July and August, likely in preparation for freshwater spawning migrations. These species spawn in several streams that drain into Iliamna, Cottonwood, or Iniskin bays. No other salmon species are known to spawn in these streams, although coho salmon have been documented in small numbers in Y Valley Creek.

Several other forage-fish species, including surf smelt, longfin smelt, and Pacific sand lance, use nearshore areas of the Iliamna/Iniskin Estuary, but at much lower abundances than juvenile herring or salmonids. Starry flounder were commonly found along shorelines (in beach seine catches) in inner Iliamna Bay.

Bottom-trawl surveys found that demersal fish assemblages farther from shore in the Iliamna/Iniskin Estuary were substantially different from assemblages caught in littoral areas with beach seines. Snake prickleback was the most abundant species identified in the bottom-trawl surveys. Yellowfin sole, juvenile halibut and several other flatfish species, whitespotted greenling, juvenile walleye pollock, and several species of sculpin were also common in bottom-trawl tows. Based on analysis of stomach contents, dietary habits varied among the species: starry flounder fed heavily on bivalves, while yellowfin sole preferred polychaete worms. Whitespotted greenling fed primarily on amphipods and mysids.

Juvenile Pacific herring were also abundant in trawl catches, but only during the fall months and March, providing evidence for an offshore movement during the winter. The diet of Pacific herring was composed of mainly pelagic prey species dominated by mysids and copepods. Many herring had significant parasite loads in their stomachs, reducing useable stomach volumes.

The highest catch rates for fish in the Iliamna/Iniskin Estuary were in inner portions of Iliamna Bay. The dominant fish species included juvenile herring, Pacific staghorn sculpin, longfin smelt, and starry flounder. Abundances were sufficiently high to indicate that this area provides a distinct and valuable habitat for herring and other fish species in the Iliamna/Iniskin Estuary, although comparable sheltered, inner-bay habitats in Iniskin Bay were not sampled.

Three intertidal lagoons were commonly used by juvenile chum, pink, and sockeye salmon early in the outmigration season. Catches in these lagoons were substantial enough to support the conclusion that these lagoons provide important local rearing habitat for juvenile salmonids that differs from many of the other habitats characterized in the Iliamna/Iniskin Estuary. These lagoons provide the three main estuarine habitat functions ecologically important to juvenile salmon—foraging habitat, areas of transition to marine salinities, and areas where predators can be avoided.

Analysis of sampling data also suggests that the portion of outer Iniskin Bay area between North Head and Knoll Head provides valuable nearshore and stream habitats for pink salmon and Dolly Varden. The catch rates for both species were substantially higher in this area than in other portions of the study area. Large pink salmon runs are known to occur in Y Valley Creek, which discharges to this area. The highest catch rates for adult Dolly Varden also were observed near the mouth of Y Valley Creek, suggesting that this may be a natal or overwintering stream for the species as well as a foraging area during summer months.

Macroinvertebrates were abundant in bottom-trawl catches during the entire March through November period that has been sampled over the study years; catches were dominated by a few species of pandalid and crangonid shrimp. Macroinvertebrate densities did not decrease during the fall and winter periods, as demersal fish abundances did, suggesting year-round use of the Iliamna/Iniskin Estuary by macroinvertebrates. Increased sexual maturity of some macroinvertebrates, including shrimp, was observed during the fall and winter months. Juvenile Dungeness and tanner crab were at times moderately abundant in trawl catches in the Iliamna/Iniskin Estuary, especially tanner crab in the fall.

Substantially fewer invertebrate species were observed in the catch from beach seine sets than in deeper demersal samples, with the notable exception of high densities of mysids in the beach seine catch in inner Iliamna Bay. Mysids are an important prey species for juvenile salmonids and several other fish species in the Iliamna/Iniskin Estuary.

The epibenthic macroinvertebrates sampled are important prey for several fish species (as confirmed in the diet analysis) in the Iliamna/Iniskin Estuary, including whitespotted greenling, Dolly Varden, and Pacific staghorn sculpin. Several families of invertebrates (amphipods, pandalid shrimp, and crangonid shrimp), common in samples, comprise a substantial portion of the diet of these fish.

43.3 References

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Threaded sculpin caught in a trawl sample, March 2, 2010.

Herring spawn on *Fucus* spp., May 27, 2010.

Beach seining in Cottonwood Bay, May 27, 2010.

Pulling in a 120-foot beach seine, November 12, 2008.

44. MARINE WILDLIFE

44.1 Introduction

This study examined the distribution and abundance of marine-oriented wildlife (birds and mammals) during surveys conducted by ABR, Inc.—Environmental Research & Services. The following surveys were conducted:

- Boat-based surveys for birds and mammals during four sampling periods (summer, early winter, late winter, and spring) in each of two study years (2004/2005 and 2005/2006).
- Airplane-based surveys of birds during spring and fall migration in 2004 and 2005.
- Airplane-based surveys of harbor seals between April and December 2005, between May and October 2007, and between June and August 2008.
- Helicopter-based surveys for Steller's Eiders and sea otters throughout the year in 2006 through 2008.

The surveys included species listed as threatened or endangered under the Endangered Species Act (Steller's Eider, sea otter, Steller's sea lion, and beluga), species that have been considered for listing under the Endangered Species Act (Kittlitz's Murrelet), and birds and mammals in general (including species breeding here).

Researchers attempted to describe the distribution and abundance of marine birds and marine mammals in the vicinity of Knoll Head (Figure 1-4 in Chapter 1) in 2004 through 2008. The specific objectives of this study were as follows:

- Determine the seasonal distribution and abundance of birds and mammals during several annual cycles.
- Determine the seasonal distribution and abundance of birds during spring and fall migration.
- Determine the distribution of and seasonal patterns of use for harbor seal haulouts.
- Describe the seasonal species composition of the bird and mammal communities.
- Determine and describe the use of the area by rare, threatened, and endangered species.

44.2 Results and Discussion

During the surveys, researchers recorded at least 69 species of marine-oriented birds. The avian community was dominated numerically by waterfowl and seabirds. These two groups together usually represented more than 95 percent of all birds in the study area, although shorebirds were numerically important during a brief 10-day period in early May, when a few tens of thousands occupied the extensive mudflats in this area. Other species-groups (waterbirds, raptors, corvids) represented a minor percentage of the avifaunal community. Species richness varied seasonally, with the most species occurring in the spring and, to a lesser extent, in the fall and with the fewest species generally occurring in mid-winter. Abundance also varied seasonally, with the greatest numbers of birds occurring in the spring, when large numbers of waterfowl, seabirds, and shorebirds used the area, and in the fall, when large numbers of waterfowl and seabirds used the area. Densities of birds generally were highest in the nearshore zone.

Species that were particularly abundant included Mallards; Greater Scaup; Harlequin Ducks; Long-tailed Ducks; Surf, White-winged, and Black scoters; and Mew and Glaucous-winged Gulls. During the shorebird migration in the spring, Western Sandpipers and Dunlins also were particularly abundant. In the 1970s, more than 4,100 birds of eight species were estimated to be breeding in the study area, with Tufted Puffins and Glaucous-winged Gulls together representing 85 percent of all birds nesting in the study area (U.S. Fish and Wildlife Service, n.d.). In June 2004, more than 1,200 birds of 10 species were recorded in the study area, although not all were believed to be breeding; in 2005, more than 1,500 birds of 10 species were recorded in the study area, although not all were believed to be breeding. Hence, substantial declines in numbers of Double-crested Cormorants, Common Eiders, Glaucous-winged Gulls, Pigeon Guillemots, Tufted Puffins, and Horned Puffins have occurred since the 1970s.

Twenty species of birds that are classified as being of conservation concern were recorded during the Pebble Project study or are suspected to occur in the study area. Altogether, these 20 species consist of six species of waterfowl, one waterbird species, two raptor species, eight shorebird species, and three seabird species. Of these 20 species, one (Steller’s Eider) is protected by the U.S. Fish and Wildlife Service as a threatened species under the Endangered Species Act, and one (Kittlitz’s Murrelet) is classified as a candidate species under the Endangered Species Act. (Note that the latter species was not recorded in this study but that the study area is within its range and provides suitable habitat for nesting and foraging.)

During the marine wildlife surveys, researchers recorded six species of marine mammals, saw another one off-transect (gray whale), and had a record of another species from other scientific researchers working in the area (common minke whale). The mammal community was dominated numerically by harbor seals in the summer and sea otters in the winter; together, these two species represented 90 to 99 percent of all marine mammals in the study area. Other species (Steller's sea lion, beluga, and harbor and Dall's porpoise) represented a minor percentage of the mammalian community in the study area. Species richness was difficult to discern because so few species occurred in the study area, but the greatest number of species tended to occur in the spring. Seals were more common in the nearshore zone, whereas sea otters occurred throughout the entire area. Areas occupied by sea otters, Steller's sea lions, and belugas in the spring were similar to those recorded earlier, during Alaska Department of Fish and Game surveys for Pacific herring.

Five of the eight species of marine mammals that either were recorded during the surveys or are known to occur in this area are classified as being of conservation concern. One of the five species is a mustelid (sea otter), two are pinnipeds (Steller's sea lion, harbor seal), and two are cetaceans (gray whale, beluga). Of these species, two (Steller's sea lion and beluga) are protected as endangered species under the Endangered Species Act, one (sea otter) is protected as a threatened species under the Endangered Species Act, and one (gray whale) is classified as a delisted species under the Endangered Species Act..

In general, islands were the most important habitats for harbor seals and sea otters because they are used as haulout locations; the "Iniskin Islands" (those islands off of the eastern side of the mouth of Iniskin Bay) in particular were of importance to these two species. Sea otters generally started moving into the study area from summering areas farther south in Kamishak Bay in large numbers in November; they generally moved out of the study area by late April or early May, with just a few animals remaining to summer there. The maximal count of sea otters was 1,433 animals during helicopter-based surveys in January 2008. Numbers of seals hauled out in the study area tended to peak during the annual molt in late July to mid-August. The peak count of harbor seals in all three years of fixed-wing surveys was 1,410 animals in August 2007; after applying correction factors for Julian date, time of day, and proportion of seals not hauled out, the estimated total number present in the study area was 1,841 ± 96 seals, with a 95 percent confidence interval of 1,652 to 2,029 seals. These numbers are approximately 27 to 35 percent of the total number of harbor seals estimated by the National Marine Fisheries Service to occur in western Cook Inlet.

Belugas were recorded in Iliamna, Iniskin, and Chinitna bays, but only in the fall of 2007 and 2008, and Steller's sea lions generally occur in the area in the spring, presumably because that is when Pacific herring enter the area to spawn.

44.3 References

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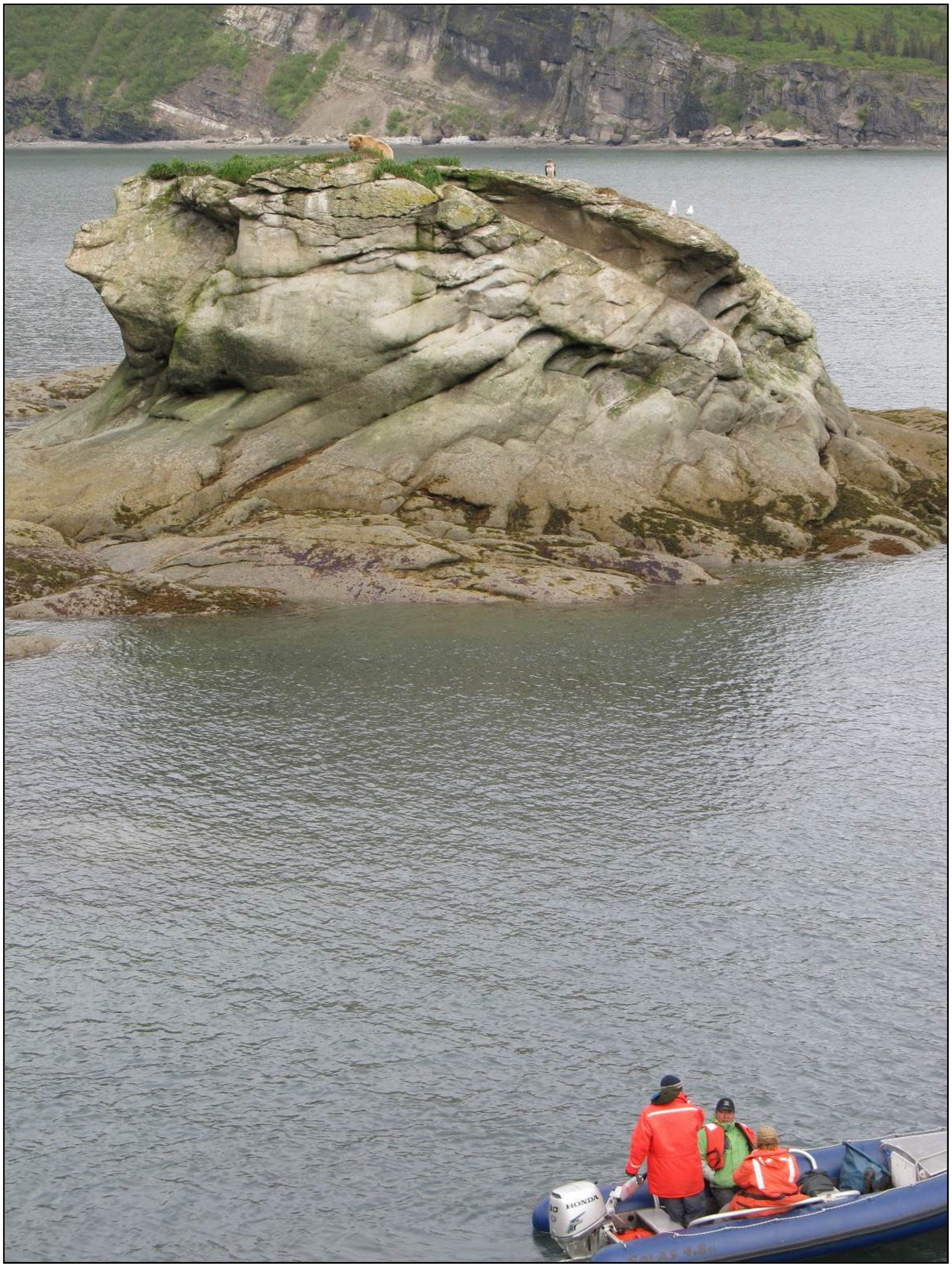
Outer Iniskin Bay in March 2007.

Bob Day conducts boat-based surveys of marine wildlife between Iliamna and Iniskin bays, 2005.

Julie Parrett surveys for Steller's Eiders in Iniskin Bay, 2006.

A flock of Steller's Eiders in Iniskin Bay, 2008.



Skiff driver David Peterson, bear guard Manuel Anelon, and biologist Pam Seiser observe a brown bear eating a seal and digging up puffin burrows on an islet at the mouth of Iniskin Bay, 2010.

45. THREATENED AND ENDANGERED SPECIES AND SPECIES OF CONSERVATION CONCERN

45.1 Introduction

A review of existing information was conducted to derive a list of the threatened or endangered bird and mammal species and species of conservation concern that occur in the Cook Inlet drainages study area (Figure 1-4 in Chapter 1), including adjacent marine waters, and to summarize what is currently known about the conservation status of those species. This work focused on bird and mammal species of conservation concern and did not address other high-profile wildlife species (e.g., bears and moose) that are of concern for subsistence, sport hunting, or ecological reasons, but are not of conservation concern in this part of Alaska. Similarly, another high-profile and federally protected species (Bald Eagle) was not addressed because in Alaska Bald Eagles are abundant and are not considered of conservation concern. In addition to the work on bird and mammal species, an analysis of the potential for a set of rare vascular plant species to occur in the Cook Inlet drainages study area was conducted.

Researchers conducted two activities: a review of data from field surveys and a literature review. Field survey data from 2004 through 2008 (the studies are summarized in Chapter 41 for terrestrial wildlife and Chapter 44 for marine wildlife) were reviewed for species-occurrence information. The literature review was used to assess which species are currently listed as threatened or endangered or of conservation concern and to summarize information on why each of those species is of concern.

To determine which rare vascular plant taxa could potentially occur in the Cook Inlet drainages study area, researchers requested information from the Alaska Natural Heritage Program on those species that have state rankings that indicate rarity (S1, S2, S1S2, or S2S3) and that have been collected in the area. The potential for these species to actually occur in the area was assessed by evaluating the known ranges of the plants, their habitat associations, and the habitats available in the Cook Inlet drainages study area.

45.2 Results and Discussion

One bird species (Steller's Eider) that was recorded in the Cook Inlet marine study area is protected as a threatened species under the Endangered Species Act. Critical habitat for Steller’s Eiders has been designated and includes breeding and staging areas in the Yukon-Kuskokwim Delta region and molting/staging areas on the northern coast of the Alaska Peninsula; no critical habitat for this species was designated in Cook Inlet. Steller's Eiders were recorded regularly in the Cook Inlet marine study area during winter and early spring; they occurred primarily in offshore waters in the middle portions of Iniskin and Iliamna bays and occasionally in nearshore waters.

Kittlitz's Murrelet is a candidate species under the Endangered Species Act and may be present in the Cook Inlet drainages study area (onshore and/or offshore) given the appropriate nesting and wintering habitat in the area. However, to date, there are no records of the species in the region.

Twenty-four bird species that were recorded in the Cook Inlet drainages study area are considered of conservation concern for Alaska. These species were listed as being of concern by at least two of 10 statewide or national-level management agencies or nongovernmental organizations that address bird conservation issues in the state. These species are Trumpeter Swan, King Eider, Common Eider, Surf Scoter, Black Scoter, Long-tailed Duck, Red-throated Loon, Horned Grebe, Red-faced Cormorant, Pelagic Cormorant, Golden Eagle, Peregrine Falcon, Black Oystercatcher, Marbled Godwit, Black Turnstone, Surfbird, Rock Sandpiper, Dunlin, Short-billed Dowitcher, Marbled Murrelet, Olive-sided Flycatcher, Gray-cheeked Thrush, Varied Thrush, and Blackpoll Warbler. Of these 24 species, 20 are of concern primarily because population declines have been documented or are strongly suspected, either in Alaska or in breeding or wintering areas outside the state. These species also are of concern for a variety of additional reasons, which, depending on the species, can include the following issues:

- Sensitivity to disturbance and contaminants.
- Vulnerability to habitat loss and alteration during the breeding, migration, and wintering periods, but especially during migration and on the wintering grounds, which are often outside Alaska.
- Susceptibility to hunting pressure, fisheries bycatch, or heavy natural mortality during migration.
- Naturally small population sizes.
- Restricted breeding and/or wintering ranges.

Three marine mammal species that have been recorded in the Cook Inlet marine study area are protected as threatened or endangered under the Endangered Species Act. In Alaska, the western “distinct population segment” of Steller’s sea lion, which occurs west of 144°W longitude (near Cape Suckling), is listed as endangered. Critical habitat for the western distinct population segment has been designated around known rookery and haulout areas; no critical habitat, however, was designated in lower Cook Inlet in the vicinity of Iniskin and Iliamna bays. Steller's sea lions were recorded during the Pebble Project studies in the Cook Inlet marine study area in small numbers from spring to fall and occurred most often on islands at the mouth of Iniskin Bay and in the open bight between Iliamna and Iniskin bays.

The Cook Inlet population of belugas also is listed as endangered. Critical habitat for belugas within the Cook Inlet marine study area includes all waters within 2 nautical miles of the mean higher high water mark. Belugas have been recorded rarely in the Cook Inlet marine study area, with the most recent observations, in 2007 and 2008, occurring in the fall months; some earlier observations, from 1978 to 2002, occurred during spring and early summer.

Sea otters of the southwestern Alaska population of northern sea otter (listed as threatened) also occur in the Cook Inlet marine study area. The Cook Inlet marine study area is located within designated critical habitat for this population of northern sea otters; most of the critical habitat area in the study area is composed of waters within the 20-meter isobath (depth contour). During the Pebble Project studies, sea otters were recorded in the study area primarily during winter with only scattered individuals recorded during the spring and summer; they occurred broadly throughout the study area, but most otters were found outside Iniskin and Iliamna bays, in offshore habitats and among the islands at the mouths of the bays.

Two additional marine mammal species recorded in the Cook Inlet marine study area are considered of conservation concern for Alaska. The gray whale was delisted as an endangered species under the Endangered Species Act after its population recovered completely, but the species is still considered of conservation concern (ADF&G, 2006; NMFS, 2010). A single gray whale was recorded in the Cook Inlet marine study area in summer 2004.

The harbor seal also is listed as a species of conservation concern for Alaska. Populations of harbor seals in Alaska are not considered to be depleted (NFMS, 2010); however, some populations in the Gulf of Alaska and Prince William Sound experienced significant declines during the 1980s and 1990s (Angliss and Outlaw, 2007). Those declines presumably led to designation of the harbor seal as a species of conservation concern by two management agencies (ADF&G, 1998; BLM, 2005). Harbor seals were recorded in the Cook Inlet marine study area during all seasons and were the most abundant marine mammals encountered during the marine wildlife surveys.

One terrestrial small mammal of conservation concern, the Alaska tiny shrew, may occur in the Cook Inlet drainages study area. The occurrence of this recently described species in the study area has not been confirmed. The tiny shrew is listed as of conservation concern by the Alaska Natural Heritage Program (AKNHP, 2008). The Alaska Natural Heritage Program classified this shrew as vulnerable in the state (ranking S3), presumably because of its apparent rarity and uncertain conservation status. This ranking warrants further scrutiny, however, as more information becomes available, especially in view of the species' cryptic nature, the possibility of misidentification, the difficulty of capture, and the shrew's widespread distribution, as documented by inventory work in various parts of the state in the decade since the species was described.

The wood frog, which has been has been recorded in the mine study area (Chapter 16, Section 16.12) and may occur in the Cook Inlet drainages study area as well, is considered of conservation concern in Alaska (ADF&G, 2006). The wood frog is the only species of amphibian that occurs in Alaska north of the southeastern panhandle of the state (Hodge, 1976). In developed areas in eastern Cook Inlet, the species was found to be abundant and widespread (Gotthardt, 2004). Nevertheless, the species is considered of conservation concern in Alaska, as are amphibians worldwide, because of widespread population declines in all groups of amphibians (McCallum, 2007).

Based on data compiled through 2006 (AKNHP, 2006), 17 rare vascular plant taxa with state rankings that indicate rarity (S1, S2, S1S2, or S2S3) were determined to have some potential to occur in the Cook Inlet drainages study area. These species are *Arabis lemmonii*, *Botrychium alaskense*, *Botrychium multifidum*, *Botrycium virginianum*, *Carex heleonastes*, *Catabrosa aquatica*, *Ceratophyllum demersum*, *Draba lonchocarpa* var. *vestita*, *Eleocharis kamtschatica*, *Eleocharis quinqueflora*, *Eriophorum viridicarinatum*, *Geum aleppicum* var. *strictum*, *Myriophyllum farwellii*, *Potentilla drummondii*, *Primula tschuktschorum*, *Saxifraga adscendens* ssp. *oregonensis*, and *Smelowskia pyriformis*. The conclusion that these species could occur in the Cook Inlet drainages study area is based on the existence of known collections of these taxa within a broad region surrounding and including the study area and the availability of suitable habitats in the study area. Of these 17 rare taxa, six are listed as critically imperiled in Alaska (S1 or S1S2 ranks). These six taxa, however, are ranked as secure globally; they are considered S1 or S1S2 primarily because there are few collection records and/or small populations of these species in Alaska. The remaining 11 taxa are listed as imperiled in Alaska (S2 or S2S3 ranks). Among these 11 taxa, three species (*Botrychium alaskense*, *Primula tschuktschorum*, and *Smelowskia pyriformis*) also are listed as globally imperiled (G2 or G2G3 ranks), primarily because there are few collection records and/or small populations of these species worldwide. All three of these species are endemic to Alaska.

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Black Oystercatcher on its nest, Cook Inlet marine study area, June 2011.

Harbor seals hauled out on rocks, Cook Inlet marine study area, August 2007.

Sea otters resting on ice floes, Cook Inlet marine study area, March 2008.

46. LAND AND WATER USE

46.1 Introduction

The land use baseline study describes the existing ownership, use, and management of land and surface waters in the Cook Inlet drainages study area (except for subsistence uses, which are addressed in Chapter 51).

The regional study area for the land use study in the Cook Inlet drainages encompasses an extensive region on the western Cook Inlet coast and nearby offshore islands and coastal waters. It includes the coastal strip of uplands and tidelands between Lake Clark National Park and Katmai National Park. Within the regional study area, a smaller study area, termed the central study area, was subject to a more detailed examination of the uplands, tidelands, nearby offshore islands, and nearshore waters surrounding Iliamna and Iniskin Bays (the central study area coincides with the Cook Inlet drainages study area depicted on Figure 1-4 in Chapter 1).

The method of study was to review and analyze relevant existing land use studies, plans, management documents, and land records developed by state, federal, and local governments. These sources were supplemented through interviews of people with relevant information about land use in the study area.

46.2 Results and Discussion

The regional study area encompasses approximately 577,280 acres of uplands and approximately 704,000 acres of tidelands and submerged lands within the three-mile offshore limit. The State of Alaska is the largest landowner in the study area, with approximately 344,704 acres of uplands. Most state uplands, approximately 248,320 acres, are managed as the McNeil River State Game Refuge and Sanctuary.

Regional and village Native corporations established under the Alaska Native Claims Settlement Act are the next largest landowners, with patent or interim conveyance to approximately 166,213 acres. Native corporations, in accordance with the Alaska Native Claims Settlement Act, have selected an additional 63,744 acres, the final ownership of which remains to be resolved.

Cook Inlet Region, Inc., Seldovia Native Association, and Tyonek Native Corporation are the primary landowners in the central study area. Lesser private landowners include Alaska Native allotment owners or applicants and other private landowners; these account for approximately 2,444 acres.

Except for McNeil River State Game Refuge and Sanctuary and the Kamishak Special Use Area, the state uplands, tidelands, and submerged lands in the regional study area are managed according to the planning designations and management policies of the Kenai Area

Plan. Most state uplands (approximately 90 percent) are designated as wildlife habitat, with the balance designated for general use, heritage, and forestry. About two-thirds of the state tidelands and submerged lands are designated for Public Recreation and Tourism — Dispersed Use, with most of the balance being designated as habitat.

The Kenai Area Plan planning area is divided into twelve regions, and each region is further divided into management units. Management units within the study area include the following:

- Tidelands and submerged lands near the mouth of Iniskin Bay.
- Tidelands in Iliamna Bay near Williamsport.
- Tidelands and submerged lands near Seal Spit on the north coast of the Iniskin Peninsula.
- Tidelands and submerged lands off the south coast of the Iniskin Peninsula.

These management units are designated, respectively, for habitat, waterfront development, habitat or high-value resource management, and habitat.

The management intent of McNeil River State Game Refuge and Sanctuary (Figure 1-1 in Chapter 1) is to provide permanent protection for brown bear and other wildlife and fish populations and their habitats. Human activities are to be managed in a manner compatible with that purpose. The prime activity in the sanctuary and refuge is wildlife viewing, mainly brown bear viewing.

According to the Alaska Department of Natural Resources, the Kamishak Special Use Area is managed primarily for wildlife habitat and harvest, with public recreation as a secondary value that will be allowed only if compatible with wildlife management objectives.

The state owns all tidelands and a 100-foot-wide right-of-way along the existing Williamsport to Pile Bay Road. The State of Alaska’s preferred possible route for an improved road west from Williamsport partly follows this existing alignment and partly crosses into Native corporation lands to avoid a steep avalanche-prone section of the existing road.

There are several sites suitable for a possible port in the vicinity of Iniskin and Iliamna bays. Cook Inlet Regional, Inc. (CIRI) currently holds title to the surface and subsurface estate of much of the uplands in this area, but the surface estate is open to selection by CIRI’s village corporations.

The prevalent existing land and water uses in the regional study area are wilderness and natural habitats that support a variety of low-intensity recreational activities such as hunting, sportfishing, wildlife viewing, and flight-seeing. Access for recreation is by small plane or boat. There are no improved boat harbors, port facilities, public airports, or public transportation improvements, except the Williamsport barge landing and the Williamsport to Pile Bay Road.

There are no permanent year-round settlements in the central study area, although there are two clusters of Native allotments and homesteads or homesites: one at Seal Spit on the northern coast of the Iniskin Peninsula and another on the coast south of Williamsport near and around Cottonwood Bay.

47. REGIONAL TRANSPORTATION

47.1 Introduction

The objective of the transportation study was to document existing and proposed overland, water, and air transportation facilities and services in the Cook Inlet drainages study area.

The Cook Inlet drainages study area for the transportation study is the coastal strip on the west side of Cook Inlet between Lake Clark National Park and Katmai National Park. Because of Homer's possible role as a marine support center, its port facilities are included.

The methods for this study relied on a review of existing transportation studies, plans, and documents for relevant information. This information was supplemented with interviews of several providers of transportation services.

47.2 Results and Discussion

The Cook Inlet drainages study area can be generally characterized as a remote area with a rugged coastline and often harsh weather and sea conditions. It has minimal local transportation improvements. Most of the uplands in the study area are state-owned lands designated for habitat and low-intensity recreational use. Private lands are owned mostly by Alaska Native corporations. There are a few dozen Native allotments and homesites, but no permanent year-round settlements. The primary human uses are wilderness recreation, wildlife viewing, and flightseeing.

The state-owned, 15.03-mile-long, unpaved Williamsport-Pile Bay Road is the only publicly maintained road in the study area. This road is also partially in the Bristol Bay drainages study area (Chapter 19). It is open for use only seasonally, between June and November. The road is mainly used to transfer commercial fishing vessels and gear between Cook Inlet and Bristol Bay communities. Approximately 50 fishing boats are transported between Cook Inlet and Pile Bay yearly. The state made some improvements to the road in 2009.

The only marine-transportation improvement in the study area is the privately-owned barge landing and small-boat haulout at Williamsport. Channel conditions limit barge delivery opportunities to 4 or 5 days a month. Until 2009, Homer-based Alaska Coastal Freight made most barge deliveries to Williamsport, approximately 10 to 12 annually. In 2009, Iliamna Development Corporation started a combination barge-road-barge service to ship fuel and freight from Homer to Iliamna Lake communities. This service shipped 22 loads in 2009.

There are no public airport facilities, rail facilities, or non-local pipelines in the study area.

The Port of Homer has two deep-draft docks and is equipped to support general-cargo vessels, roll-on/roll-off trailer ships, and petroleum tankers. The port has 35 acres of upland open storage. The City of Homer is pursuing a multi-year, $26 million project to upgrade its deepwater dock facilities, enlarge its upland marine staging area, and improve road access to the staging area and dock facilities.

New major transportation infrastructure is likely to be driven by new large-scale resource development projects. The State of Alaska's *Southwest Alaska Transportation Plan* (PB Consult Inc., 2004) proposes Williamsport navigation improvements and a dock facility, and roadway improvements for the Williamsport-Pile Bay Road. A third project, the Pile Bay public dock and boat-launch facility (in the Bristol Bay drainages study area), is closely linked to the two improvements in the Cook Inlet drainages. These three proposed port- and road-improvement projects are generally regarded as a set of complementary projects that comprise an integrated transportation system. The estimated cost of the improvements is $27,307,000. The cost-benefit analysis estimates the capital and maintenance costs at $2,786,800 annually in 2020 and the freight-cost savings at $3,848,400, for an estimated net savings of more than $1,000,000 annually. These improvements are the first leg of a Cook Inlet to Bristol Bay corridor proposed in the *Southwest Alaska Transportation Plan* that might eventually provide a road link between western Cook Inlet and the community of Iliamna.

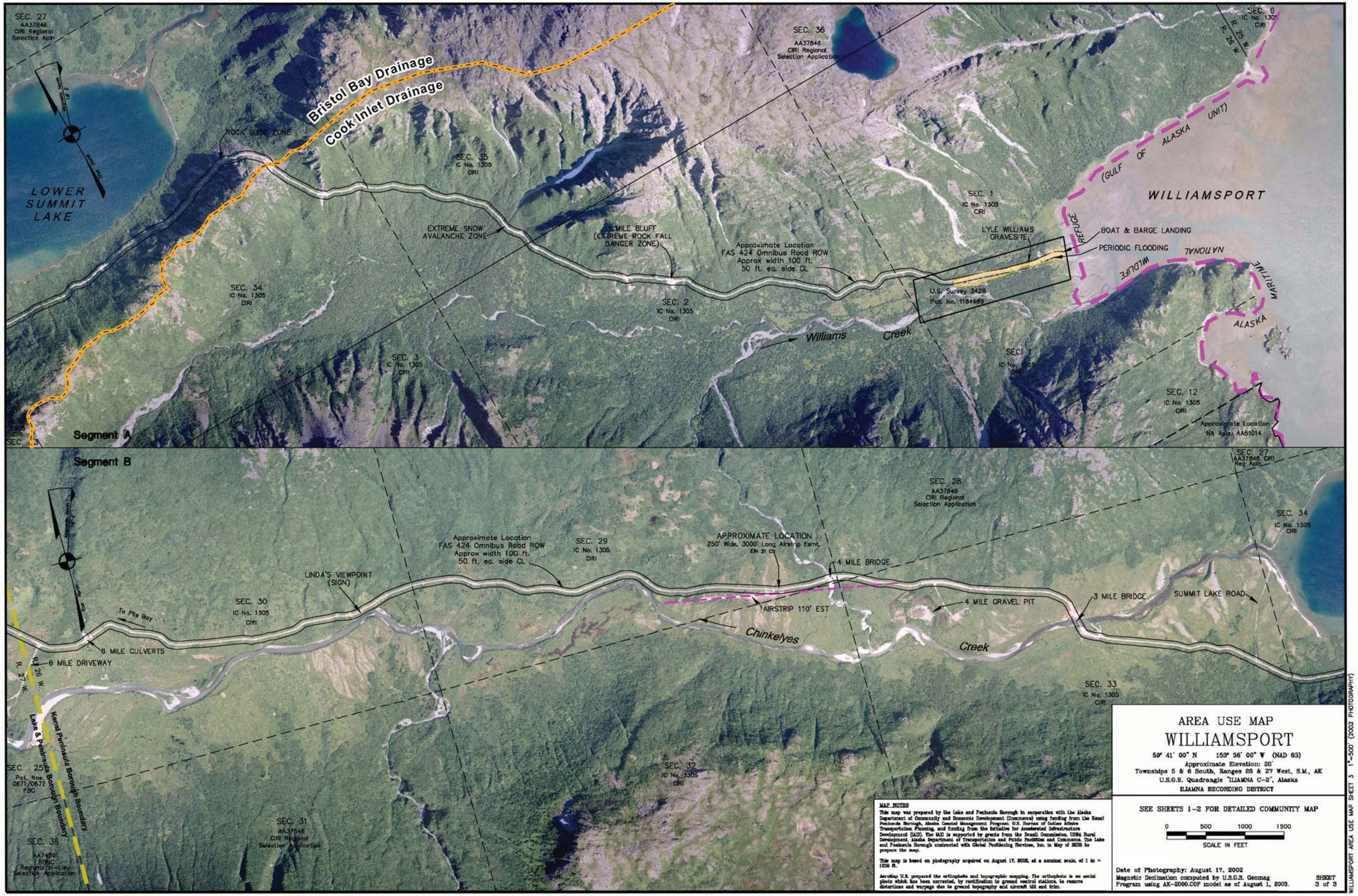
As part of its Industrial Roads Program, the State of Alaska completed the *Iliamna Regional Transportation Corridor Analysis* (PND et al., 2007) to evaluate alternatives for a deep-water port site and a road corridor between Cook Inlet near Williamsport and the Pebble Deposit northwest of Iliamna. The state-preferred port site is located on a privately owned tract near the mouth of Iniskin Bay. The state-preferred road corridor generally follows the Cook Inlet to Bristol Bay corridor identified in the *Southwest Alaska Transportation Plan* (PB Consult Inc., 2004).

47.3 References

Lake and Peninsula Borough (L&PB) and Alaska Department of Commerce, Community and Economic Development (ADCCED). 2005. Williamsport Community Maps. Obtained from http://www.dced.state.ak.us/dca/profiles/profile-maps.htm.

PB Consult Inc. 2004. Revised Southwest Alaska Transportation Plan. Prepared for the Alaska Department of Transportation and Public Facilities, Central Region.

PND Engineers, Inc. (PND), in association with AES Lynx Enterprises, Inc., and RA Krieg & Associates. 2007. Iliamna Regional Transportation Corridor Analysis (IRTCA), Volume 1. Prepared for the Alaska Department of Transportation and Public Facilities, Central Region Planning, Anchorage, AK.



AREA USE MAP

WILLIAMSPORT

59° 41' 00" N 153° 36' 00" W (NAD 83)
Approximate Elevation: 20'
Townships 5 & 6 South, Ranges 26 & 27 West, S.M., AK
U.S.G.S. Quadrangle "ILIAMNA C-2", Alaska
ILIAMNA RECORDING DISTRICT

SEE SHEETS 1-2 FOR DETAILED COMMUNITY MAP

Date of Photography: August 17, 2002
Magnetic Declination computed by U.S.G.S. Geomag Program using AK-2000.COF model as of August 1, 2003.

SHEET
3 of 3

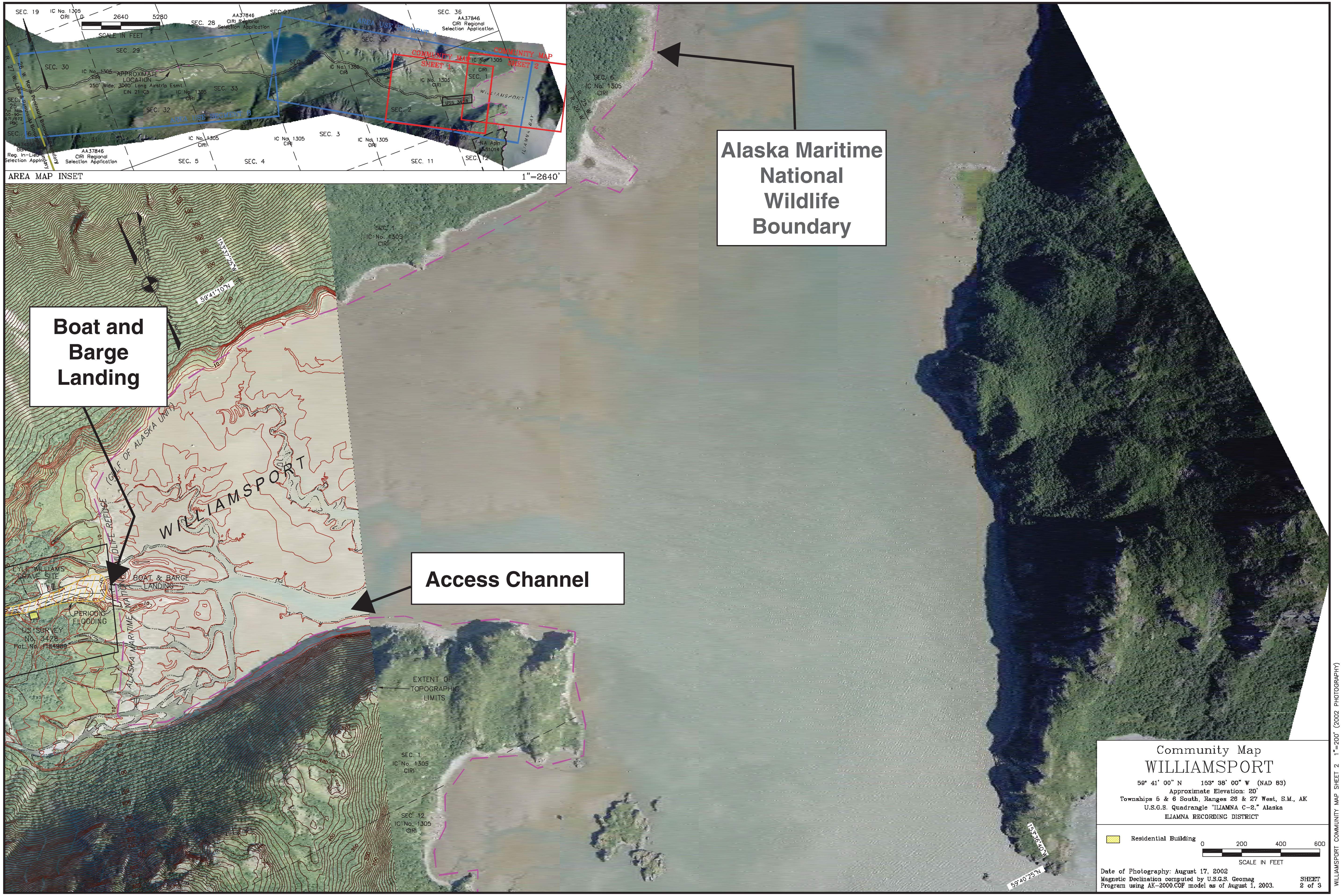
MAP NOTES

This map was prepared by the Lake and Peninsula Borough in cooperation with the Alaska Department of Community and Economic Development (Commerce) using funding from the Kenai Peninsula Borough, Alaska Coastal Management Program, U.S. Bureau of Indian Affairs Transportation Planning, and funding from the Initiative for Accelerated Infrastructure Development (IAID). The IAID is supported by grants from the Denali Commission, USDA Rural Development, Alaska Department of Transportation and Public Facilities and Commerce. The Lake and Peninsula Borough contracted with Global Positioning Services, Inc. in May of 2003 to prepare the map.

This map is based on photography acquired on August 17, 2002, at a nominal scale, of 1 in = 1000 ft.

AeroMap U.S. prepared the orthophoto and topographic mapping. The orthophoto is an aerial photo which has been corrected, by rectification to ground control stations, to remove distortions and warpage due to ground topography and aircraft tilt and trim.

Williamsport-Pile Bay Road Corridor, Williamsport End (Map source: L&PB and ADCCED, 2005, drainage boundary label added).



Williamsport Barge Landing (Map source: L&PB and ADCCED, 2005, labels added).

48. POWER

48.1 Introduction

The existing energy infrastructure in the Cook Inlet drainages study area (Figure 1-4 in Chapter 1) was documented. The study objective was to describe existing facilities for supply of electrical power and petroleum fuels. The study involved reviewing maps, land records, and other public agency data sources.

48.2 Results and Discussion

No permanent, year-round settlements exist on the western Cook Inlet coast between Cape Douglas and Tuxedni Bay. There are two clusters of seasonally occupied Native allotments and homesites: one at Cottonwood Bay south of Williamsport, and another near Seal Spit in Chinitna Bay. Otherwise, only a few scattered allotments and homesites exist. There are no public or large private energy facilities in the study area.

49. SOCIOECONOMICS

49.1 Introduction

The socioeconomic baseline study was undertaken to collect borough-level information on the demographics and economy in the Cook Inlet drainages study area. This study area includes the Kenai Peninsula Borough, Matanuska-Susitna Borough, and the Municipality of Anchorage. Demographic information researched includes population, age, and race. The discussion of the economy includes personal income, employment, earnings, and unemployment.

The socioeconomic baseline description includes the most recent demographic and economic data available publically at the time of writing. Commonly used sources include the Alaska Department of Labor and Workforce Development, and the federal Bureau of Economic Analysis. Long-term historical trend analysis relies on 1990 and 2000 U.S. census data. Data-specific references are provided in the full-length chapter of the environmental baseline document. Please note that some data are for years more recent than the standard 2004 through 2008 study period.

49.2 Results and Discussion

The Kenai Peninsula Borough is a second-class borough covering approximately 16,000 square miles of land. The borough is bordered on the east by Prince William Sound. To the west, the borough straddles Cook Inlet.

The 2009 population of the Kenai Peninsula Borough was 53,578 people. Approximately half of the borough's population resides in the greater Kenai/Soldotna area, while 20 percent resides in the greater Homer area. The 2008 population of the Kenai Peninsula Borough was mostly white, while 10 percent of the population was Alaska Native or American Indian. In 2009, 72 percent of the population of the borough was age 20 or older. The 2000 median age in the borough was 36.3 years.

Personal income earned by residents of the Kenai Peninsula Borough totaled $1.9 billion in 2007, and per capita income was $35,415. Average monthly employment in the borough in 2008 was 18,663 jobs, with a total annual payroll of $725.1 million; the average monthly wage and salary income of workers in the borough was $3,238. The 2009 average unemployment rate in the Kenai Peninsula Borough was 10.1 percent.

The Matanuska-Susitna Borough is a second-class borough that encompasses 24,700 square miles of land. The borough is bordered by the Denali Borough to the north, the Valdez-Cordova Census Area to the east, and the Kenai Peninsula Borough and the Municipality of Anchorage to the south.

The population of the Matanuska-Susitna Borough totaled 84,314 residents in 2009. The borough has been one of the fastest-growing areas of the state. Between 2000 and 2009, the area's population increased by 24,992 residents, or 42 percent. In 2008, 85 percent of the population of the borough identified themselves as white, and just over 9 percent of the population was identified as Alaska Native or American Indian. In 2009, roughly one quarter of the population was under the age of 15, approximately one third was age 15 through 39, another approximate quarter of the population was between the ages of 39 and 55, and 19 percent of the population was 55 or older. The median age in the Matanuska-Susitna Borough in 2000 was 34.0 years.

Personal income earned by Matanuska-Susitna Borough residents totaled $2.8 billion in 2007, and per capita income was $34,341. Monthly employment in the borough in 2008 averaged 18,648 jobs, with a total annual payroll of $659.5 million; the average monthly wage and salary income of workers in the borough was $2,942. The 2009 average unemployment rate in Matanuska-Susitna Borough was 9.3 percent.

The Municipality of Anchorage covers roughly 1,700 square miles at the northeastern end of Cook Inlet. The population of Anchorage in 2009 totaled 290,588 residents. Approximately 42 percent of Alaska's population resides in the Municipality of Anchorage. In 2008, whites compromised 75 percent of the population, Alaska Native or American Indians comprised 11 percent, and the combination of black, Asian, and Pacific Islander made up the remaining 14 percent of the population. The median age of residents of the municipality in 2000 was 32.4 years. In 2009, approximately one quarter of the population was under the age of 15, over one third was 15 through 39 years old, roughly another quarter of the population was 40 through 54, and 18 percent of the population was 55 or older.

Personal income earned by Anchorage residents totaled $12.8 billion in 2007. Anchorage accounts for 47 percent of all personal income earned by Alaska residents. Per capita income for Anchorage residents in 2007 was $46,243.

The Anchorage economy is broadly diversified. Anchorage is Alaska's service, supply, and financial center. The military, oil, transportation, tourism, health care, education, and government sectors all play significant roles in the municipality's economy. Monthly employment in the Municipality of Anchorage averaged 150,133 jobs in 2008. Income from wage and salary jobs in 2008 totaled over $7.2 billion, and monthly wage and salary income in Anchorage averaged $4,011. The 2009 average unemployment rate in the municipality was 6.6 percent.

50. CULTURAL RESOURCES

50.1 Introduction

The purpose of the cultural resources study was to characterize the existing cultural resources in the Cook Inlet drainages on lands generally surrounding Iliamna and Iniskin Bays. The Cook Inlet drainages study area is shown on Figure 1-4 in Chapter 1. Cultural resources may include historic buildings, structures, and landscapes; prehistoric and historic surface and subsurface sites; and traditional- and religious-use areas. The objectives of the cultural resources field surveys, research, and interviews were to locate, identify, and describe documented and previously undocumented archaeological, historic, and ethnographic cultural resources in the Cook Inlet drainages study area.

Cultural resources research and field work were conducted in 2005 and 2007. To characterize the cultural resources in the Cook Inlet drainages study area, researchers reviewed the Alaska Heritage Resources Survey database, literature, and archival data; conducted cultural resource interviews and consultations; and conducted field surveys. The review of existing data regarding cultural resources in the study area and the effort to identify previously undocumented cultural resources through interviews, consultations, and field surveys helped to inform researchers as to where and what manner of cultural resources were likely to be found in the study area.

During the 2005 and 2007 field seasons, survey efforts for cultural resources were focused around Iliamna and Iniskin bays, as well as in areas with a high probability of containing previously undocumented cultural resources

50.2 Results and Discussion

Prehistoric cultural resources have been found in areas near the study area, including Pedro Bay, Kamishak Bay, Chinitna Bay, and Tuxedni Bay. During the late prehistoric through the historic periods, Dena’ina, Aluttiq, and possibly Yup’ik people have used portions of the Cook Inlet study area. The Cook Inlet drainages were an important part of historic economic activity in this region, with the route of the current Williamsport-Pile Bay Road serving as a traditional portage used for Dena’ina seal and bear hunting and as an historic trade route used by Russians trading in the Iliamna Lake area. American explorers and entrepreneurs also used this route to access the area. Cultural resources from late 18th century Russian and later American exploration and development in the region are present in the study area.

Based on information from the Alaska Heritage Resource Survey database and a review of available literature, four previously documented cultural resource sites are located in the vicinity of Iliamna and Iniskin bays. One of the previously documented cultural resources—the Williamsport to Pile Bay Road (Alaska Heritage Resource Survey code ILI-00132) has been determined eligible for the National Register of Historic Places. The remaining three previously documented cultural resources have not been evaluated for eligibility for the National Register of Historic Places. These sites include Dutton (ILI-00005, a historic mining camp), an oil exploration site near Oil Bay (ILI-00038), and AC Point (ILI-00052, the site of an early 1900s Alaska Commercial Company warehouse.

The Cook Inlet drainages study area is located in territory where Dena'ina Athabascan, specifically Iliamna Dena'ina, is spoken. The existing published sources indicate that 24 place names, all of which are Dena'ina in origin, are located in the Cook Inlet drainages study area. Eleven place names are located throughout the area of Iliamna and Cottonwood bays, and others are scattered around Iniskin Bay, Chinitna Bay, and throughout the study area. One cultural resource, the Williamsport to Pile Bay Road (also called the Iliamna Portage Route and the Williamsport to Pile Bay Portage), was reported in the Cook Inlet drainages study area during the cultural resources interviews. The remaining two cultural resource sites in the study area, which were identified during the subsistence and traditional knowledge interviews, are historic camps.

Pedestrian surveys and subsurface testing in the Knoll Head area was conducted in 2005 and 2007. Field surveys in 2005 uncovered two archaeological sites: a rock shelter (ILI-00185) and a hearth (ILI-00186). The Knoll Head area may hold more archaeological sites undiscovered during the reconnaissance survey. No cultural resources were identified during the 2007 surveys.

Archaeologist documenting sediment stratigraphy of a shovel test in the Knoll Head area.

Shovel test showing evidence (the gray ash and black charcoal layers near the base of the pit) of a possible hearth near Iniskin Bay.

Archaeologist examining a rock shelter site near Iniskin Bay.

51. SUBSISTENCE USES AND TRADITIONAL KNOWLEDGE

This study has not yet been conducted. Results will be published as an independent document upon study completion.

52. VISUAL RESOURCES

52.1 Introduction

The visual analysis was done to analyze the existing landscape character and quality in potentially viewed areas in the Cook Inlet drainages study area (Figure 1-4 in Chapter 1).

Based on landform patterns, hydrology, vegetation, and cultural elements, four landscape units were identified in the study area: Williams Creek Valley, Coastline, Y Valley, and the Iniskin Peninsula. The landscape units were divided into subunits based on distance zones.

Landscape visibility and scenic attractiveness, and their derivative scenic classes, are used to assess existing visual condition. Mapping for the scenic inventory takes into account the landscape visibility, the concern levels of users and residents, scenic attractiveness, scenic class, and scenic integrity. Scenic attractiveness measures the scenic importance of a landscape based on human perceptions, and scenic integrity is a measure of the completeness of a landscape.

The research was done in summer 2004 using the methodology outlined in the U.S. Forest Service document *Landscape Aesthetics, A Handbook for Scenery Management* (USFS, 1995). Researchers traveled by helicopter to document landscape character and views.

52.2 Results and Discussion

The landscape setting of the study area is characterized by mountains of varying topographic relief, fast-flowing rivers, tundra, marshy lowlands, and ponds. Depending on elevation and location, most of this land is covered by alpine tundra, low or tall shrubs, or areas of mixed broadleaf and spruce trees.

Viewers comprise seasonal residents of Williamsport or Camp Point, hunters and fishermen (including subsistence users), recreational visitors to Lake Clark National Park and Preserve, and travelers by boat and air. Though limited in number, these viewers are expected to have a high level of concern with regard to visual characteristics and to changes to the landscape; however, based on observations, most of this study area is visible only from the air and only as background views.

Scenic attractiveness is categorized into three classes: Class A—distinctive, Class B—common, and Class C—indistinctive. The landscape in the study area is of distinctive (Class A) scenic attractiveness and is almost fully intact, with a few exceptions, providing very high scenic integrity.

Scenic class is a measure of the value of scenery using a scale of 1 to 7, with 1 being the highest value. Scenic class considers scenic attractiveness, landscape visibility, and public concern level. The entire study area has a rating of Class 1.

52.3 References

U.S. Forest Service (USFS). 1995. Landscape Aesthetics: A Handbook for Scenery Management.

Unit 1, Williams Creek: View of Williams Creek Valley.

Unit 2, Cook Inlet Coastline: View of Iliamna Bay.

Unit 3, Y Valley.

Unit 4, Iniskin Peninsula: View near the Head of Chinitna Bay.

53. RECREATION

53.1 Introduction

The recreation study inventoried, described, quantified, and mapped the outdoor recreational resources and activities in the Cook Inlet drainages study area. The study had two objectives:

- Describe the location, use, and management status of important recreational resources in the study area.
- Describe, quantify, and map important recreational activities and their locations.

The regional study area for the recreation study in the Cook Inlet drainages comprises three overlapping study areas: the land use study area, the sportfishing study area, and the big game hunting study area (Figure 53-1). For practical reasons the regional study area's northern and southern boundaries were flexibly defined to fit the recreational resources, activities, and related databases:

- The land use study area includes the coastal strip of uplands bounded on the west by the Bristol Bay/Cook Inlet drainages boundary, on the east by Cook Inlet, on the north by Lake Clark National Park, and on the south by Katmai National Park. (The parks straddle the drainages boundary; however, because most of their recreational use occurs west of the boundary, the parks are discussed in their entirety in Chapter 25, Recreation—Bristol Bay Drainages.) The land use study area includes the islands, tidelands, and submerged lands south of Redoubt Bay to Cape Douglas.
- The sportfishing study area is based on the Alaska Department of Fish and Game's (ADF&G's) sportfishing management areas and includes the 3,044 square miles of uplands in management Area N (West Cook Inlet-West Susitna River drainages), parts of which are in national parks. It also includes all of Area N's marine waters from the west coast to the middle of Cook Inlet and from the mouth of the Susitna River on the north to Cape Douglas, south of Kamishak Bay.
- The study area for big game hunting includes ADF&G's game management unit 9A and a portion of unit 9C, which stretch along the west coast of Cook Inlet and inland to cover 4,305 square miles. Parts of this study area are within national park boundaries.

Within the regional study area is the smaller central study area, which encompasses a coastal area surrounding Iliamna and Iniskin bays and extending westward to the boundary between the Cook Inlet and Bristol Bay drainages. The central study area coincides with the Cook Inlet drainages study area depicted on Figure 1-4 in Chapter 1.

Research was conducted using the Kenai Area Plan, ADF&G resource and management reports and documents, and unpublished data records, supplemented by personal interviews, web searches, and other unpublished sources. Unless otherwise noted, sportfishing data are from 1999 through 2005 and hunting data are from 2000 through 2006.

53.2 Results and Discussion

The regional study area is remote, unpopulated, and lacks transportation improvements. It consists of coastal uplands and extensive tidelands and submerged lands. Wildlife includes fish, otters, seals, sea lions, whales, several species of birds, brown bears, and moose. Under the Kenai Area Plan, the primary use designation for most state uplands in the land use study area is habitat management, while most tidelands and submerged lands are designated for recreation (ADNR, 2001). The main recreation activities are fresh and saltwater sportfishing, big game hunting, and wildlife viewing. Other recreational uses of state and private lands in this region—for example, backcountry camping and hiking, wildlife viewing, and flight-seeing—are not counted in any systematic way and may go unnoticed.

The ownership of the lands in the land use study area is a mix of state, federal, Alaska Native Claims Settlement Act Native corporation, Alaska Native allotment, and private ownership. All these lands are primarily undeveloped wilderness. There are four active recreational lodges in the study area, all near freshwater sportfishing locations. Two lodges feature primarily wildlife viewing. There are no other developed recreational facilities in the land use study area.

ADF&G's Sport Fish Division manages Alaska's sport fisheries. Freshwater sportfishing in the sportfishing study area was light. For example, ADF&G reported no activity or catch for Iliamna Bay. The average annual number of sportfishing days in the study area during 1999 through 2005 was 2,126 and the average annual catch totaled 13,325 fish; an annual average of 883 fish were harvested. The primary species caught were coho salmon, Dolly Varden, and chum salmon, with a minor catch of king salmon and rainbow trout. No clear freshwater sportfishing trends were established other than the erratic return of salmon species.

The sportfishing study area's marine waters support modest saltwater sportfishing. There are no developed small-boat facilities, and distances from developed facilities range between 32 and 95 miles. The primary saltwater species is Pacific halibut. In lower Cook Inlet, the average annual days fished during 1999 through 2005 were 779, average number of anglers was 526 per year, and average number of trips was 448 per year, with an average annual harvest of 801 fish. In upper Cook Inlet, the annual averages were 947 angler days, 735 anglers, and 632 trips, with an average annual harvest of 1,016 fish. Western Cook Inlet is one of the state's two major razor clam sport-harvest areas. The average annual harvest for the sportfishing study area was 20,597 during the study period. There is some harvest of hard-shell clams from bays in study area.

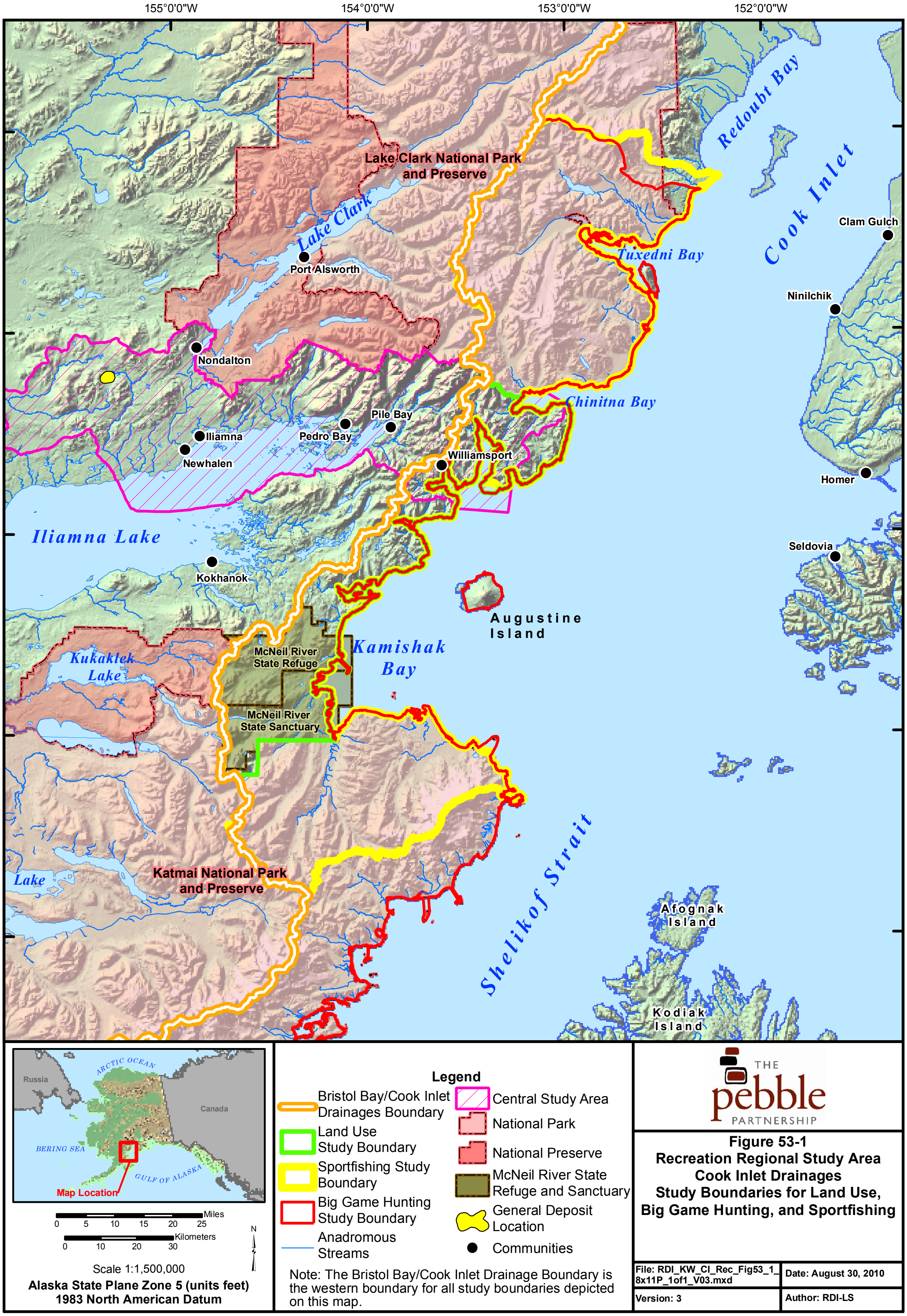
ADF&G's Division of Wildlife Conservation manages and regulates big game hunting in Alaska. The primary target species in the hunting study area are brown bear, moose, and caribou. Most hunters travel to hunting locations by aircraft. For management purposes, the brown bear hunt is open only in odd-numbered regulatory years. Guided hunts accounted for the majority of the bear harvest in the study area, and nonresident hunters took the majority. One hundred sixtyfour brown bears were harvested in the study area in 2000 through 2005, and annual figures were relatively stable.

From 2000 through 2005, 105 moose hunters visited the hunting study area, and 36 moose were harvested, almost exclusively in September. Approximately two-thirds of hunters were nonresidents, and many employed guide services. Annual figures suggest a downward trend in moose hunting and harvest. The study area is outside the range of the primary regional caribou herds, so caribou hunting was light. From 2000 through 2005, 28 hunters reported a harvest of 13. Hunting activity was too low to permit analysis of any trend.

There are several destinations in the regional study area for wildlife viewing and photography, particularly of brown bears; the most important is the McNeil River State Game Sanctuary and Refuge. Public access to the sanctuary is limited and is obtained through a lottery system. In 2006, 183 lottery winners spent 970 days in the sanctuary. Visits to other bear-viewing locations are increasing, as are guided bear-viewing and photography trips and flights. The regional study area's rugged terrain limits opportunities for river sports. Because of the study area's remoteness, sport hunting for waterfowl is not popular.

53.3 References

Alaska Department of Natural Resources (ADNR). 2001. Kenai Area Plan. Division of Mining, Land, and Water, Anchorage, AK.



Note: The Bristol Bay/Cook Inlet Drainage Boundary is the western boundary for all study boundaries depicted on this map.

THE pebble PARTNERSHIP

Figure 53-1
Recreation Regional Study Area
Cook Inlet Drainages
Study Boundaries for Land Use, Big Game Hunting, and Sportfishing

File: RDI_KW_CI_Rec_Fig53_1_8x11P_1of1_V03.mxd	Date: August 30, 2010
Version: 3	Author: RDI-LS

Pebble Project Environmental Baseline Studies
2004-2008
Technical Summary

APPENDIX A.
Analytical Quality Assurance/Quality Control Review

TABLE OF CONTENTS

TABLE OF CONTENTS .... A-i

ACRONYMS AND ABBREVIATIONS .... A-ii

A.1 Introduction A-1

A.2 Results and Discussion A-1

- A.2.1 Surface Water Quality A-2
- A.2.2 Groundwater A-2
- A.2.3 Trace Elements A-3
- A.2.4 Marine A-3

TABLE .... following Section A.2.4

PHOTOGRAPHS .... following table

ACRONYMS AND ABBREVIATIONS

DQO	data-quality objective
QA	quality assurance
QC	quality control

APPENDIX A. ANALYTICAL QUALITY ASSURANCE/QUALITY CONTROL REVIEW

A.1 Introduction

The analytical quality assurance (QA)/quality control (QC) program was developed to ensure that field procedures, laboratory analyses, and data deliverables for the Pebble Project met technical and quality requirements stipulated by regulatory agencies and the Pebble Partnership. The primary objective of the program is to ensure that the quality of the analytical data is consistent among consultants collecting samples in the field and among laboratories performing the testing and that the data meet specified data-quality objectives (DQOs) and are legally defensible. The program accomplishes this objective by providing sample-collection oversight, laboratory-services management, data verification, data validation, and data management. These services were performed for the data collected from the April 2004 through December 2008 for the surface water quality (including seeps), groundwater quality, trace elements, and marine studies. The study areas for the Pebble Project studies are depicted on Figure 1-4 in Chapter 1 of the technical summary for the environmental baseline studies.

Oversight of sample collection involved reviewing field sampling plans for adherence to industry-accepted standards and the quality assurance project plans, and consistency between sampling teams for select aspects of the sampling process common in similar studies. Compliance to the field sampling plans was monitored through field audits performed at least once each year during the summer and, for studies for which samples were collected in winter, a second time during a winter month.

Oversight continued with receiving samples from the field teams and executing documentation and chain-of-custody protocols for controlled transfer of samples to the laboratories for testing. Post-collection procedures (e.g., filtering water for dissolved metals, dissecting fish), when required, also were monitored for compliance to the field sampling plans.

Management of the laboratories and monitoring of their testing and reporting regimens was also within the purview of the QA/QC program.

A.2 Results and Discussion

The usability of data was assessed by data validation using the key indicators of precision, accuracy, representativeness, comparability, completeness, and sensitivity compared against specified DQOs. Total versus dissolved metals and cation/anion balance also have specific DQOs for surface water and groundwater. Table A-1 explains how each key indicator is assessed and to which studies they apply.

A.2.1 Surface Water Quality

The surface water quality program study includes samples from streams, ponds, and lakes in the mine study area, the transportation-corridor study area, and the Cook Inlet drainages study area, and from Iliamna Lake as well. Overall, the precision for this program was excellent. The most variability was seen in manganese, nickel, silver, thallium, and tin in terms of laboratory testing and field sampling. Improvements for nickel were observed during the 2007 field season. Accuracy controls within the laboratory were stable. Sulfate showed variability in precision and accuracy measurements. Seasonal variations were observed in the sulfate concentrations and should be considered when using the data. Performance-evaluation sample results in 2006 and 2007 showed high biases for a small number of analytes, but these outliers are not considered to be a significant cause for concern in terms of data usability. Improvement was seen in the 2008 performance-evaluation samples with no biases observed. The data set for the surface water quality program was considered representative and comparable. The completeness goal for surface water was met. Sensitivity goals were met for a majority of the data, with sensitivity improving over time and most exceedences being minor and including only a few metals. Comparisons of total versus dissolved metals results that did not meet data-validation criteria largely involved the metals barium, chromium, cobalt, copper, nickel, and zinc. Investigations into the sample procedures and data and a subsequent elevation of laboratory method reporting limits reduced total versus dissolved metals failures. The cation/anion balances for a vast majority of surface water data met the criteria.

The surface water quality program also includes surface water samples from seeps. Excellent precision was demonstrated in the seeps data. Exceptions existed, for example, in the cases of mercury and selenium where a limited number of detections resulted in a limited number of pairs for field duplicates and triplicates. Data assessment for accuracy demonstrated that the accuracy controls were stable within the laboratory. The data set for the seeps program was considered representative and comparable. The completeness goal for seeps was met. Sensitivity goals were met for a majority of the data with exceedences being minor and including only a few metals.

A.2.2 Groundwater

The groundwater quality program includes samples from monitoring wells in the mine study area and from drinking water wells in the transportation-corridor study area.

Data quality indicators reflected a high level of data acceptance and usability. The intra- and inter-laboratory statistics demonstrated variability for alkalinity, chloride, lead, molybdenum, nickel, and sulfate. Concentrations for those parameters should be used with some measure of uncertainty. Laboratory results for sulfate showed seasonal variability. The data set for the groundwater quality program was considered representative and comparable. The completeness goal for groundwater was met. Sensitivity goals were met for a majority of the data, with sensitivity improving over time and most exceedences being minor and including only a few metals. Comparisons of total versus dissolved metals results that did not meet data-validation criteria largely involved lead, molybdenum, and nickel. The raised laboratory reporting limits affecting surface water metals were applied to all terrestrial water quality programs, including groundwater. The cation/anion balances for a vast majority of groundwater data met the criteria.

A.2.3 Trace Elements

The trace elements study includes sediment, vegetation, soil, fish tissue, and bivalve tissue samples from streams, ponds, and lakes including Iliamna Lake. All study areas are included.

The data quality for sediment, vegetation, soil, fish and bivalve tissue was excellent, as indicated by the assessment of the key data quality indicators. Aluminum and potassium results for sediments and nitrogen results for soils in 2007 may have had a high bias, indicated by the high result reported by the primary lab for the performance-evaluation sample that year. All trace elements data were considered valid as qualified and are acceptable for use.

A.2.4 Marine

The marine program includes samples of marine water, marine sediment, and marine fish and bivalve tissue from Cook Inlet and incorporates water quality and trace elements studies.

The data quality for marine sediment, marine water, and marine tissues was acceptable as indicated by the assessment of the key data quality indicators of precision, accuracy, completeness, and sensitivity; however, marine water data for 2004 from the primary laboratory were considered not representative of ambient concentrations of select metals (arsenic, copper, nickel, and selenium). Marine water data for 2008, all marine sediment data, and all marine tissue data were considered valid as qualified (as applicable) and are acceptable for use.

TABLE A-1
Key Indicators of Data Usability

Key Indicator	Assessed By	Applies To
Precision	Relative standard deviation calculated from results for laboratory control, laboratory duplicate, and field duplicate samples.	All studies
Accuracy	Percent recovery calculated from results for laboratory control and performance evaluation samples.	All studies
Representativeness	Use of field blanks, field duplicates, and laboratory blanks to monitor potential transport contamination and variation in sampling techniques.	All studies
Comparability	Use of field sampling methods and laboratory analytical methods that are comparable and consistent throughout the baseline environmental studies.	All studies
Completeness	The amount of data determined valid divided by the total amount of data acquired.	All studies
Sensitivity	Comparison of laboratory detection and reporting limits to baseline goals established in the quality assurance project plans.	All studies
Total vs. dissolved metals	Comparison of total metals to dissolved metals, specifically drawing attention to situations where the dissolved metal result is greater than the total metal result and whether subsequent qualification is warranted.	Surface water and groundwater
Cation/anion balance	Separately summing the total cations and the total anions and comparing the sums to method criteria.	Surface water and groundwater

Field auditors, along with a seeps sampler and a bear guard.

Fish are dissected following protocols documented in the sampling plan.

Pebble Project Environmental Baseline Studies
2004-2008
Technical Summary

APPENDIX B.
Iliamna Lake Study

TABLE OF CONTENTS

TABLE OF CONTENTS .... B-i
B.1 Introduction B-1
B.2 Results and Discussion B-1
PHOTOGRAPHS .... following Section B.2

APPENDIX B. ILIAMNA LAKE STUDY

B.1 Introduction

The objectives of the Iliamna Lake study were to describe existing water quality, sediment, mussel tissue, and zooplankton conditions in the Iliamna Lake study area (Figure 1-4 in Chapter 1).

Mussel tissue samples and sediment samples were collected at four nearshore sampling sites for analysis of laboratory parameters twice during 2005 and once during 2006 at Finn Bay, Flat Island, Bucket Lake and Whistlewing Bay. Five deeper-water sites were selected for sampling of water quality, sediments, zooplankton, and field parameters. Those sites are located in Pile Bay, Knutson Bay, Northeast Bay (just east of the Iliamna boat dock), Roadhouse Bay, and at the mouth of Upper Talarik Creek. From May through October 2005 and 2007, the study team collected data monthly at the five deeper-water sampling sites. Water-quality samples were collected using a Niskin sampler and were submitted for laboratory analysis of trace elements. Sediment samples were collected using grab sampling technique and submitted for laboratory analysis of trace elements. Zooplankton samples were collected using a tow net and were analyzed for taxa identification.

Ambient water-quality measurements were collected at all 9 study sites using handheld meters,

B.2 Results and Discussion

Evaluation of the data from Iliamna Lake for water quality, mussel tissue, and sediment indicates that Iliamna Lake is an oligotrophic, dimictic lake with water-quality conditions similar to the natural conditions of other regional lakes. Only a few analytical parameters (e.g., copper, lead, aluminum, iron, manganese, and alkalinity) had results outside of the criteria established by the Alaska Department of Environmental Conservation for freshwater. The concentrations are likely a result of geological influences and are consistent with previous studies conducted at Iliamna Lake and other area watersheds. Field parameters were within normal ranges, with the exception of a few slightly low pH measurements at Pile Bay, and are considered suitable for lake biota.

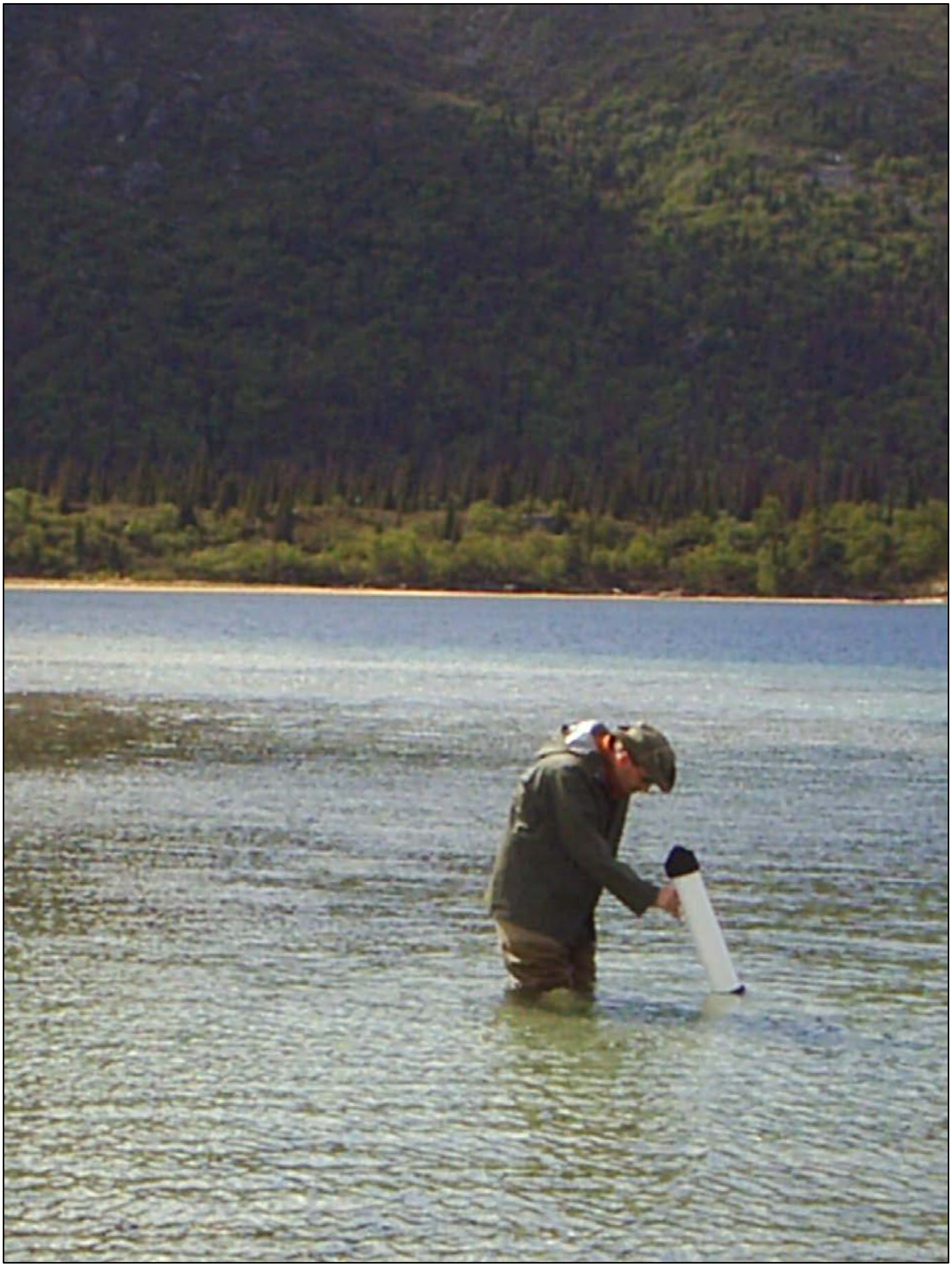
Concentrations of nutrients and major ions found during the 2005 through 2007 Iliamna Lake study were similar to concentrations from a study conducted at Iliamna Lake nearly 40 years before; the one exception was sodium, which was present at nearly twice the concentration found by the earlier study. Cation and anion dominance in Iliamna Lake were generally characteristic of temperate lakes. Sodium was more abundant than magnesium, however, which suggests a contribution from igneous rocks in the region. Depth was not found to have an effect on the concentrations of major ions, and this finding indicates that waters at the study sites were well mixed. Concentrations of several major ions and total dissolved solids were lower earlier in the summers, peaked in September, and declined again in October. The temporary increases may be associated with the influence of precipitation and inflow from streams.

Temporal and spatial variations were evident in concentrations of some of the water-quality analytes. Pile Bay and Knutson Bay tended to exhibit similar concentrations, which were often different (usually higher) than concentrations for the other three deeper-water sites. Zinc reached peak concentrations in June and July. Copper, lead, zinc, and aluminum were found to be periodically above the chronic aquatic life criteria (CALC) or drinking water standards. Alkalinity was almost always below the minimum criteria, indicating that the lake system may not be able to buffer substantial changes in pH. Mercury, cyanide, and organics were rarely found to be above the method reporting limit during the study.

Iliamna Lake zooplankton communities were dominated by copepods and rotifers during many of the sampling events. Copepod abundance in 2005 generally was higher earlier in the summer and declined in later months; however, in 2007 copepods increased in relative abundance from May to October (with the exception of July). In both 2005 and 2007, relative abundance for cladocerans was low in the early spring and summer, but increased in late summer and fall. Previous studies suggest that low numbers of cladocerans and a decrease in copepods throughout the summer may result from predation by juvenile sockeye salmon, and this trend is a typical occurrence in sockeye-rearing lakes.

Although evaluation of the data from this study provide insight into potential trends and baseline conditions of Iliamna Lake, it is important to note that all findings are based on relatively small sample sizes and must be considered preliminary and indicative only.

Water sampling using the Niskin sampler.



Locating freshwater mussels in Iliamna Lake.

Sampling for freshwater mussels in Finn Bay.

Freshwater seal haulout in Iliamna Lake.

THE pebble PARTNERSHIP

Pebble Project Environmental Baseline Studies
2004-2008
Technical Summary

APPENDIX C.
Data Management and Geographic Information System

TABLE OF CONTENTS

TABLE OF CONTENTS .... C-i
ACRONYMS AND ABBREVIATIONS .... **Error! Bookmark not defined.**
C.1 Introduction C-1
C.2 Results and Discussion C-1
TABLE .... following Section C-2

APPENDIX C. DATA MANAGEMENT AND GEOGRAPHIC INFORMATION SYSTEM

C.1 Introduction

The Data Management and Geographic Information System were created to store scientific data from Pebble Project studies in a secure centralized location with standardized data formats, analysis, and reporting. The goal is to support environmental baseline study teams and maintain the data through the life of the project.

Work on the geographic information system includes managing all mapping data including spatial study data and base maps, analyzing mapping data, supporting the wetlands study, distributing data to the investigators, and creating and cataloging cartographic map products. Data management tasks include building a database and a website for data entry, data loading, analysis, document management, reporting, and long-term secure archival storage.

The geographic information system uses ArcGIS 9.3 for map production, Environmental Systems Research Institute shapefiles as a standard vector format, Geotiff and other raster formats, and an Environmental Systems Research Institute File Geodatabase. The standard map projection is Alaska State Plane Zone 5 Feet using North American Datum 1983 (NAD 83).

For data management, Oracle 10g is the current database management system. Web programming uses Microsoft .NET 3.5 in C#.NET with Microsoft Internet Information Server. The production hardware is a Dell PowerEdge R710 with Windows Server 2008 as the operating system.

The Pebble Project server is maintained in a secure environment in compliance with the Sorbanes-Oxley Act of 2002. Both production and test systems are maintained with the ability for fail-over to the test system. Backups are done daily to a removable RAID backup disk in a separate location. Dual backup disks are kept and are swapped to a third-party off-site storage site each month.

The Data Management and Geographic Information System for Pebble Project has been in operation at Resource Data Inc. since 2004 and is expected to continue for the life of the project.

C.2 Results and Discussion

The Data Management and Geographic Information System provides data management and analytical, programming, and mapping support for the environmental investigators. This data management and support spans all disciplines, study areas, and project phases.

The geographic information system includes the following elements:

- Basemaps in vector and orthophotographic form.
- Environmental data including those for fish, habitats, vegetation, soils, and surficial geology.
- Quality assurance and quality control, field maps, and photo reports for wetlands.
- Cartographic services.

The data management system is an integrated website and database that provides the following features:

- Secure site with varying levels of role-based user access.
- Real-time meteorological data for the mine study area.
- Document repository.
- Contacts list for study teams and project teams.
- Wetlands pages to enter, verify, review, and report wetlands plot information.
- Analytical data for loading, extracting, editing, and reporting sample data.

The Data Management and Geographic Information System is routinely populated by investigators, Pebble staff, and other project team members. Table C-1 is a recent summary of the data for Pebble Project.

TABLE C-1
Summary of Data for Pebble Project, March 2010

Data Category	Data Instances	Recent Count
Analytical Sample Data	Laboratory Sample Results	396,146
	Laboratory Sample Parameters	12 - 72
	Distinct Sample Locations	1,133
Wetlands	Plots	19,512
	Field Photographs	50,069
	Distinct Plant Species Identified by Crews	1,575
	Parameters Identified for each Plot	164
Geographic Information System	Layers	1737
	Archived Layers	555
	Total Layers	2,292
	Unique Maps Produced	949

THE pebble PARTNERSHIP

Pebble Project Environmental Baseline Studies
2004-2008
Technical Summary

APPENDIX D.
Chemical Abbreviations

APPENDIX D. CHEMICAL ABBREVIATIONS

The purpose of Appendix D to the 2004 through 2008 environmental baseline document for Pebble Project is to provide definitions for the chemical abbreviations used in that document. All chemical abbreviations used in the environmental baseline document are defined in the appendix, with a few possible exceptions that are defined only in the chapter where they are used. The abbreviations listed in Appendix D may or may not be defined in the individual chapters where they are used, but in most cases they are not included in the acronyms lists provided in the individual chapters. Not all chapters of the environmental baseline document include chemical abbreviations.

THE
pebble
PARTNERSHIP

Pebble Project Environmental Baseline Studies
2004-2008
Technical Summary

APPENDIX E.
Consolidated Study Plans

TABLE OF CONTENTS

TABLE OF CONTENTS .... E-i
E.1 Purpose E-1
E.2 Goals and Objectives E-1
E.3 Project Study Area E-1
E.4 Approach E-1
TABLES .... following Section E.4

APPENDIX E. CONSOLIDATED STUDY PROGRAM

E.1 Purpose

The purpose of the consolidated study program is to summarize the study plans for the baseline studies for The Pebble Partnership's Pebble Project. It is separated into 19 parts, one for the introduction and one for each of 18 disciplines of study. The study program encompasses proposed and completed work for these disciplines for 2004 through 2008. Each section of the consolidated study program is a compilation of the annual study plans that were developed for each year of study for a given discipline during the years 2004 through 2008. Certain chapters in the environmental baseline document present data from 2009 and 2010; therefore, the consolidated study programs for those disciplines also include 2009 and 2010.

E.2 Goals and Objectives

The primary goal of the study plans is to describe The Pebble Partnership's baseline study program for characterizing the natural environment. The specific objectives of the consolidated study program are as follows:

- Summarize the annual study plans for characterizing baseline environmental conditions.
- Define the objectives of each environmental component of the baseline studies.
- Define the methods and approach for data gathering and analysis.

E.3 Study Areas

The environmental baseline studies center on four study areas: the mine study area immediately around the general deposit location, the transportation-corridor study area between the mine study area and the Bristol Bay/Cook Inlet drainages boundary, the Iliamna Lake study area in the northeastern extent of the lake, and the Cook Inlet study area surrounding Iliamna and Iniskin Bays on Cook Inlet (Figure 1-4 in Chapter 1 of the technical summary for the Pebble Project environmental baseline document). For many of the study disciplines, the study areas evolved over time as data were collected. For example, in 2004/2005, the mine study area was centered on the Pebble Deposit as it was then delineated. By 2006/2007, the mine study area for some disciplines had been expanded considerably to encompass the area surrounding the newly delineated eastern deposit.

E.4 Approach

Several environmental aspects (including physical, chemical, biological, and human) in the study areas require consideration by experts from a variety of disciplines. The disciplines (and the associated consultants) required to characterize the environmental baseline conditions for the Pebble Project are listed in Table E-1. The overall approach of the environmental baseline studies is to collect information on all these aspects and integrate the studies across scientific disciplines to characterize baseline conditions. Depending on the methods used in a given study, not all disciplines require study plans. For example, certain studies that are based on desktop research of existing literature and other available information sources may not have study plans. The study disciplines included in the consolidated study program are listed in Table E-2.

The individual study approach varies widely depending on the study discipline. Researchers studying the chemical environment, for example, collect samples of water, sediment, biological tissue, etc. for laboratory analysis and then evaluate the resulting data. Studies for other disciplines, such as hydrology and meteorology, install instruments on site to measure and record data for subsequent evaluation. Research for biological disciplines such as wildlife may include field counts to acquire data used to determine species distribution and abundance. Studies of the human-related disciplines, for example subsistence, may involve interviewing knowledgeable local residents. The approaches used for individual studies are described in detail in the study program for the respective discipline.

Appendix E is a product of The Pebble Partnership and is a consolidation of the annual study plans provided by the consultants who conducted the studies.

TABLE E-1
Baseline Study Disciplines and Associated Consultants

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

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

TABLE E-2
Consolidated Study Program Elements

No.	Study Discipline
1	Introduction
2	Meteorology
3	Noise
4	Surface Hydrology
5	Groundwater Hydrology
6	Water Quality
7	Trace Elements
8	Geochemical Characterization and Metal Leaching/Acid Rock Drainage
9	Terrestrial Wildlife and Habitat
10	Wetlands
11	Fish and Aquatic Habitat
12	Marine
13	Subsistence
14	Cultural Resources
15	Recreation
16	Land Use
17	Visual Aesthetics
18	Socioeconomics
19	Data Management and Geographic Information System

Pebble Project Environmental Baseline Studies
2004-2008
Technical Summary

APPENDIX F.
Field Sampling Plans

APPENDIX F. FIELD SAMPLING PLANS

Appendix F of the Pebble Project environmental baseline document contains the field sampling plans developed by individual consultants for their respective study disciplines from 2005 through 2008. The purpose of field sampling plans is to describe in detail the procedures and protocols researchers will use to gather physical samples in the field for analysis. The sampling plans serve as instructions for use in the field to ensure that proper techniques are used and to ensure adequate documentation for reviewers of the data.

Not all disciplines have field sampling plans because many do not require collection of physical samples for analysis. Field sampling plans were not necessarily developed each year for any given discipline because once a refined plan existed that plan was used in subsequent years.

The 26 field sampling plans provided in Appendix F of the environmental baseline document are organized under seven general headings (listed below) that contain related individual annual plans. The titles of sampling plans vary between years in some cases, and the organization of the appendix generally groups the plans for similar disciplines together.

- Fish and Aquatic Resources.
- Iliamna Lake Study.
- Marine Studies.
- Metal Leaching and Acid Rock Drainage Characterization.
- Trace Elements and Other Naturally Occurring Constituents.
- Groundwater Quality and Hydrology.
- Surface Water Quality and Hydrology.

THE pebble PARTNERSHIP

Pebble Project Environmental Baseline Studies
2004-2008
Technical Summary

APPENDIX G.
Quality Assurance Project Plans

APPENDIX G. QUALITY ASSURANCE PROJECT PLANS

The annual quality assurance project plans for Pebble Project are provided in Appendix G of the environmental baseline document for Pebble Project. The quality assurance project plans were designed to document the people and procedures by which the Pebble Partnership (and its predecessor Northern Dynasty Mines Inc.) has ensured that the baseline studies for chemical characterization meet rigid quality standards for sample handling and laboratory analysis. The plans address topics such as data-quality parameters (e.g., precision, representativeness), sample preservation and handling, documentation and chain-of-custody, and analytical methods.

The five quality assurance project plans in Appendix G are for the consecutive years 2004 through 2008. The large majority of any variation between years is due to differences in the types of studies undertaken each year during this period.