Pebble Project
Environmental Baseline Document
Physiography and Soils

Agency Meetings, January 31 – February 3, 2012
Anchorage, Alaska
Craig Nistor, P.Geo.

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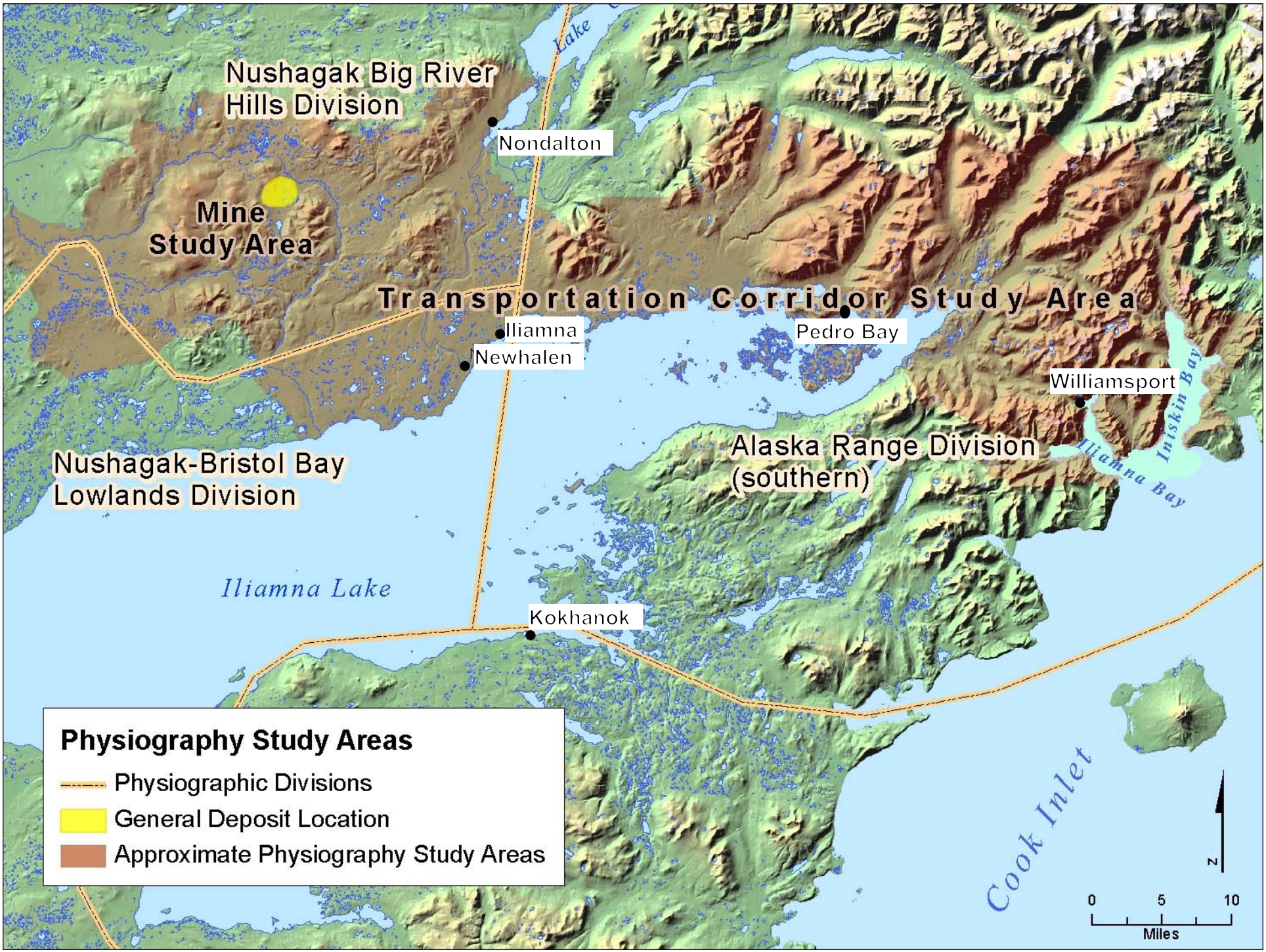
Presentation Outline

1) Physiography
   - Mine Study Area
   - Transportation Corridor Study Area
   - General Physiography

2) Soils
   - Area Overview
   - Mine Study Area
   - Transportation Corridor Study Area

3) Permafrost

Physiography


Nushagak Big River
Hills Division
Nondalton
Mine
Study Area
Transportation Corridor Study Area
Iliamna
Newhalen
Pedro Bay
Williamsport
Iniskin Bay
Iliamna Bay
Alaska Range Division
(southern)
Nushagak-Bristol Bay
Lowlands Division
Iliamna Lake
Kokhanok
Cook Inlet
Physiography Study Areas
Physiographic Divisions
General Deposit Location
Approximate Physiography Study Areas
N
0
5
10
Miles

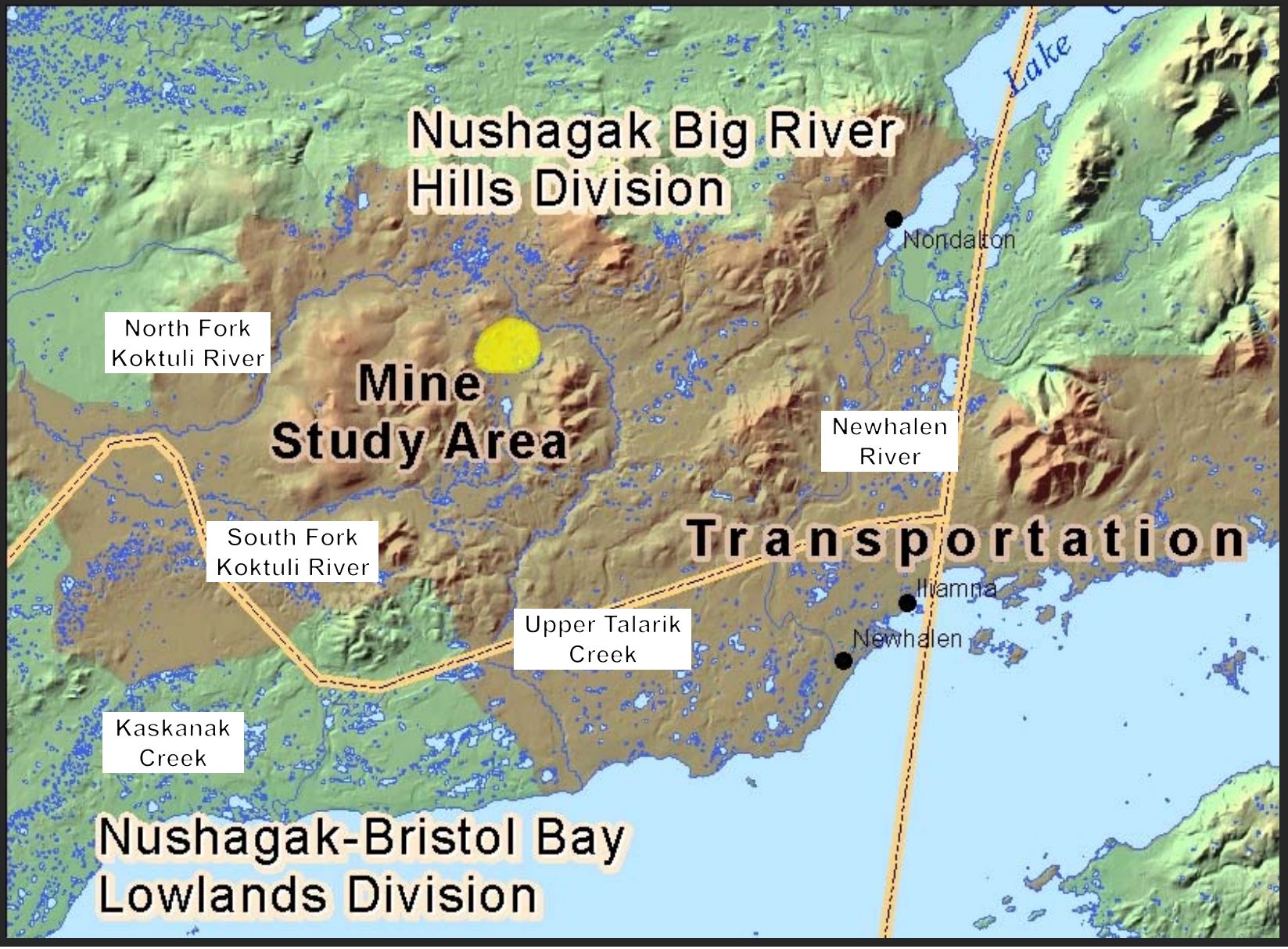
Physiography: **Overview**

Overview

- Mine Study Area
  - Nushagak – Big River Hills
  - Nushagak – Bristol Bay Lowlands

- Transportation Corridor Study Area
  - Nushagak – Big River Hills
  - Nushagak – Bristol Bay Lowlands
  - Southern part of the Alaska Range division

Physiography: Mine Study Area



Physiography: Mine Study Area

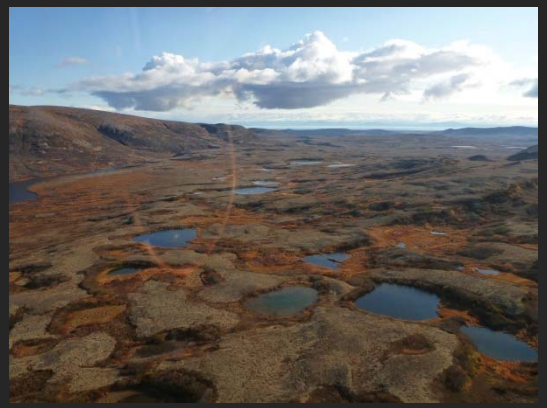
Nushagak – Big River Hills division

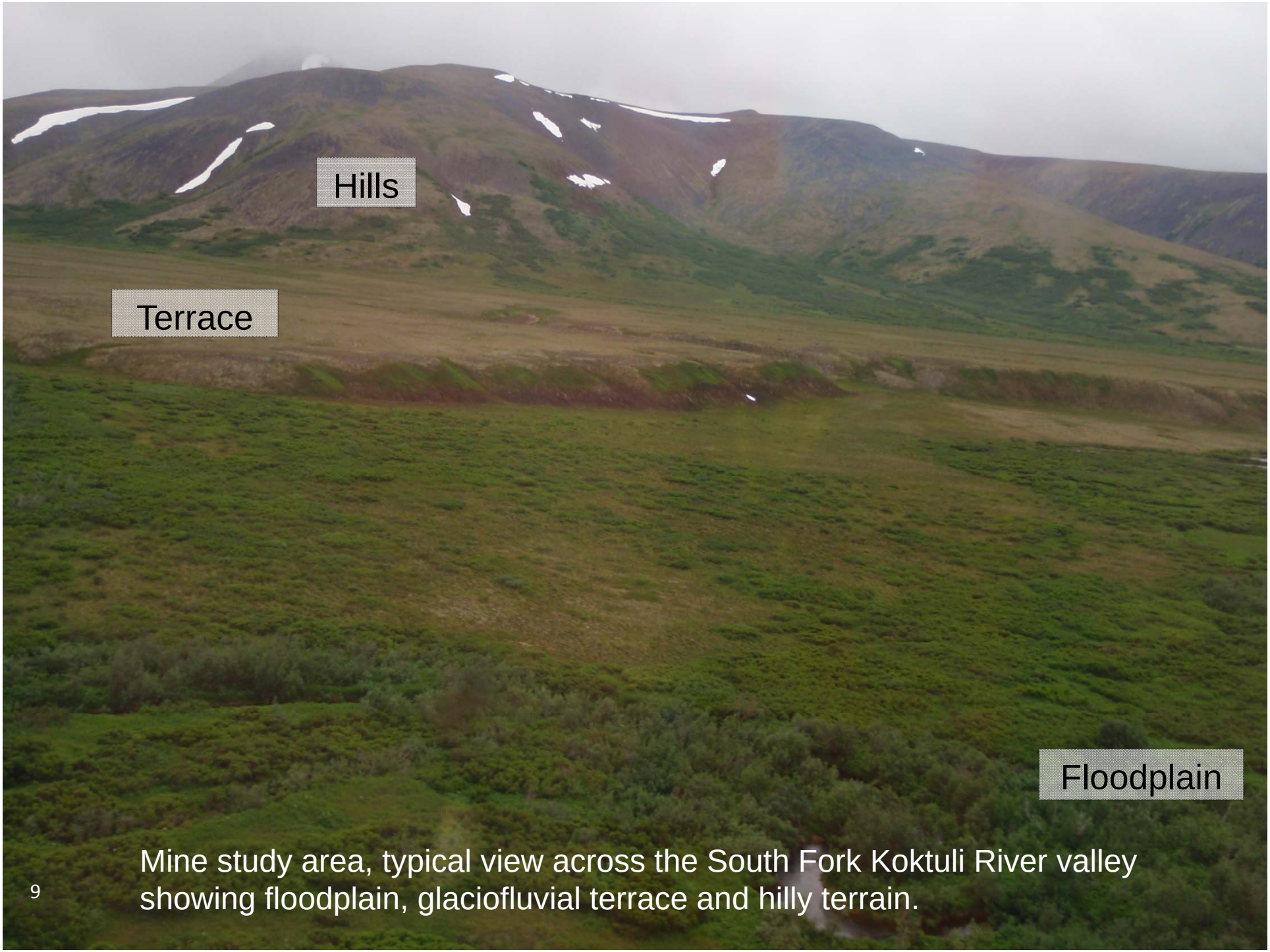
- General characteristics:
  - Low, rolling hills and small mountains
  - Wide, shallow valleys
  - Sinuous drainage channels
  - Below 1,400 ft: Glacial and fluvial sediments
  - Above 1,400 ft: mostly exposed bedrock
- Elevation
  - 584 ft (at Koktuli River) to 3,074 ft (Groundhog Mtn)

Physiography: Mine Study Area

Nushagak – Big River Hills division (2)

- Topographic features due to glacial history:
  - Glaciofluvial/outwash terraces
  - Glaciolacustrine deposits in upper valleys
  - Glacial drift deposits
  - Residual waterbodies
    - Frying Pan Lake in glaciolacustrine basin
    - Kettle lakes in undulating glacial drift





Mine study area, typical view across the South Fork Koktuli River valley showing floodplain, glaciofluvial terrace and hilly terrain.

Mine study area, view to the south toward Frying Pan Lake.

Physiography: Mine Study Area

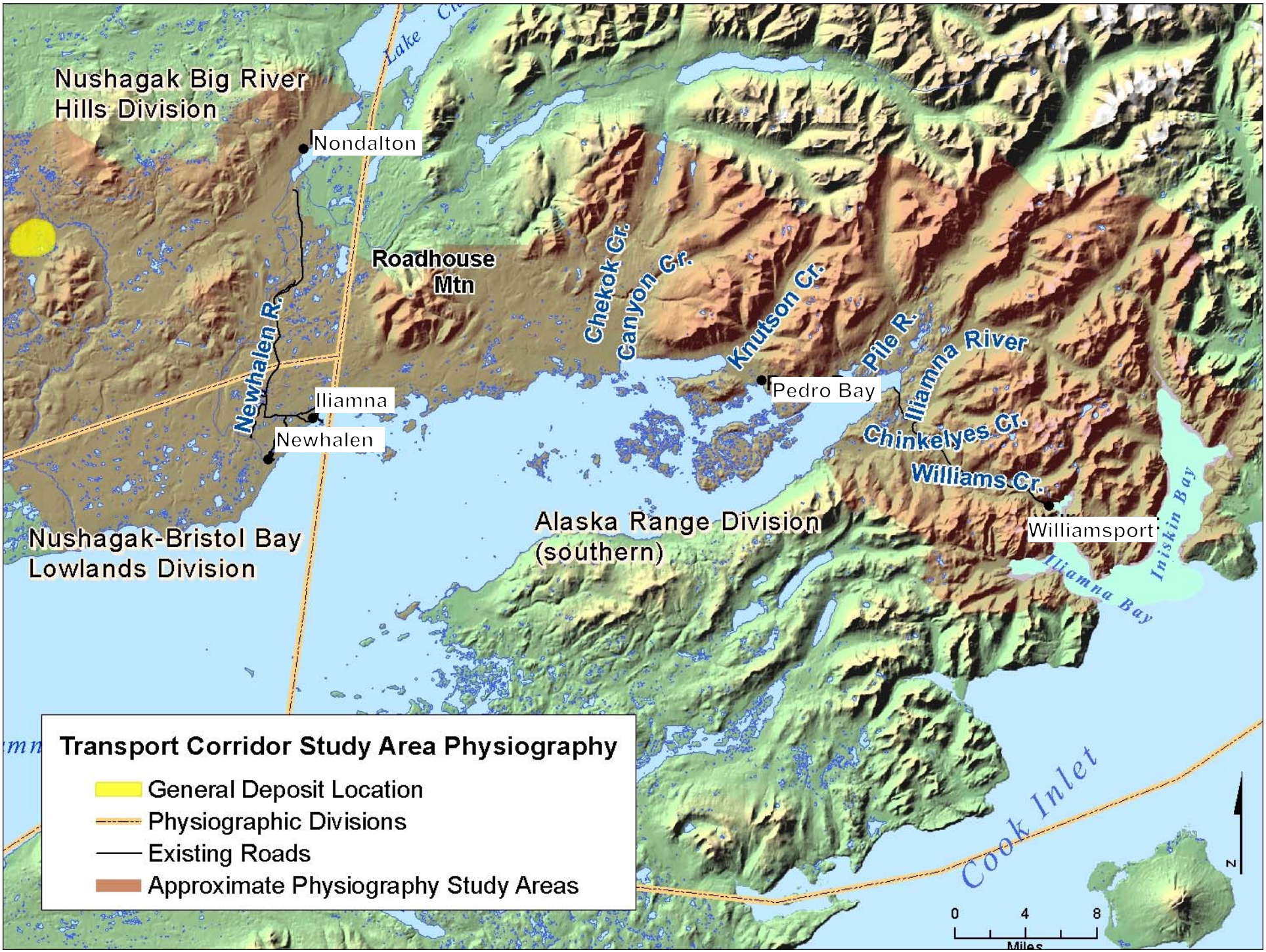
Nushagak – Bristol Bay Lowlands

- South and Southeast of Mine Study Area
  - Along north shore of Lake Iliamna

- General characteristics:
  - Relatively low, flat topography
  - Abundant wetlands and ponds

Low, flat terrain, Nushagak – Bristol Bay Lowlands division

Low, flat terrain, Nushagak – Bristol Bay Lowlands division


Nushagak Big River Hills Division
Nondalton
Roadhouse Mtn
Chekok Cr.
Canyon Cr.
Knutson Cr.
Pile R.
Iliamna River
Pedro Bay
Newhalen R.
Iliamna
Newhalen
Chinkelyes Cr.
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4
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Miles

Transportation Corridor Study Area

Hills Lowlands Mountains Ocean

Mine Study Area

Transportation Corridor Study Area

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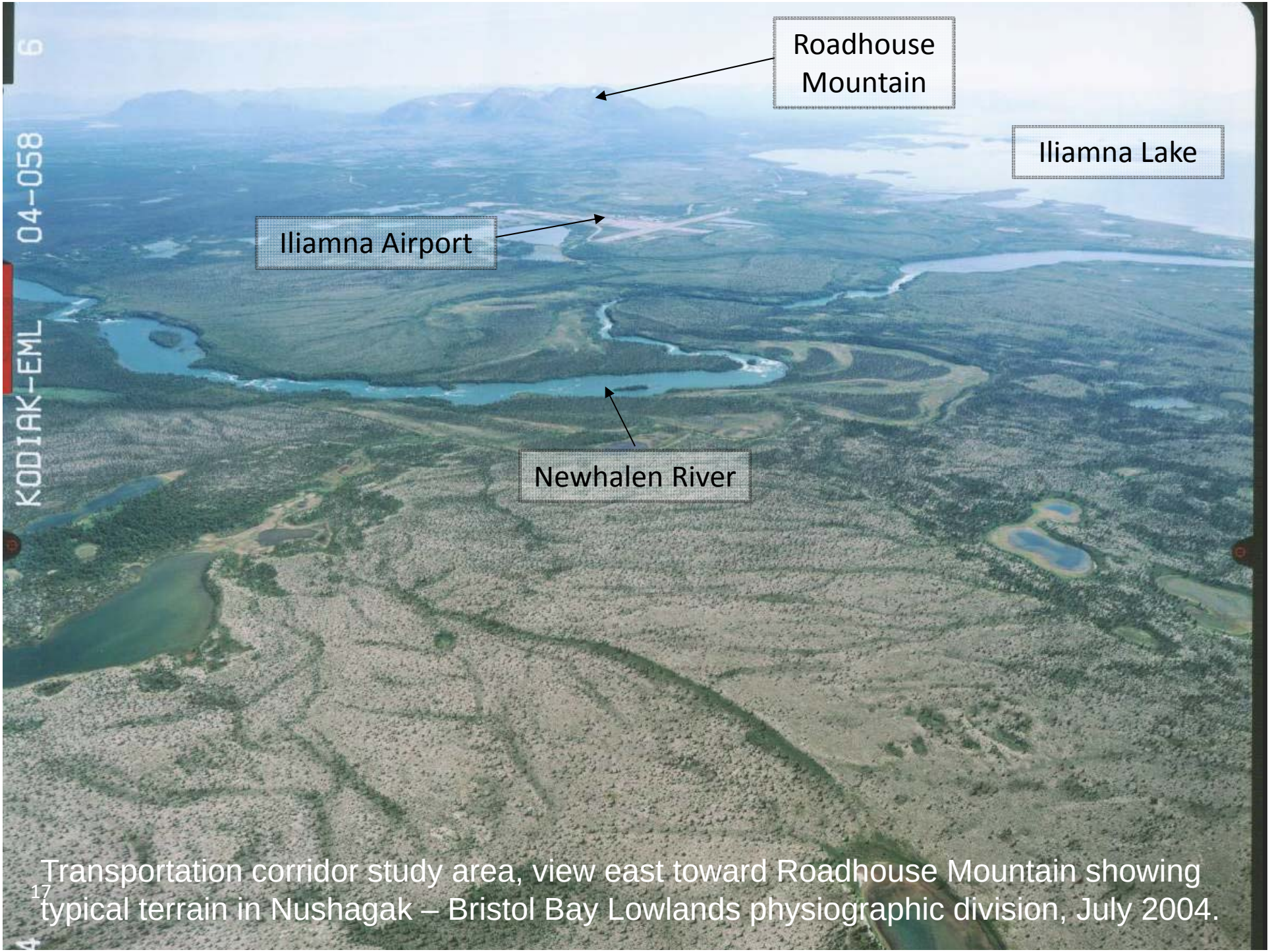
Physiography: Transportation Corridor Study Area

Corridor physiography heading east (1)

- Mine Study Area to Roadhouse Mtn
  - Flat to moderately undulating
- Roadhouse Mtn to Canyon Creek
  - Along the shore of Iliamna Lake
  - Flat to gently sloping

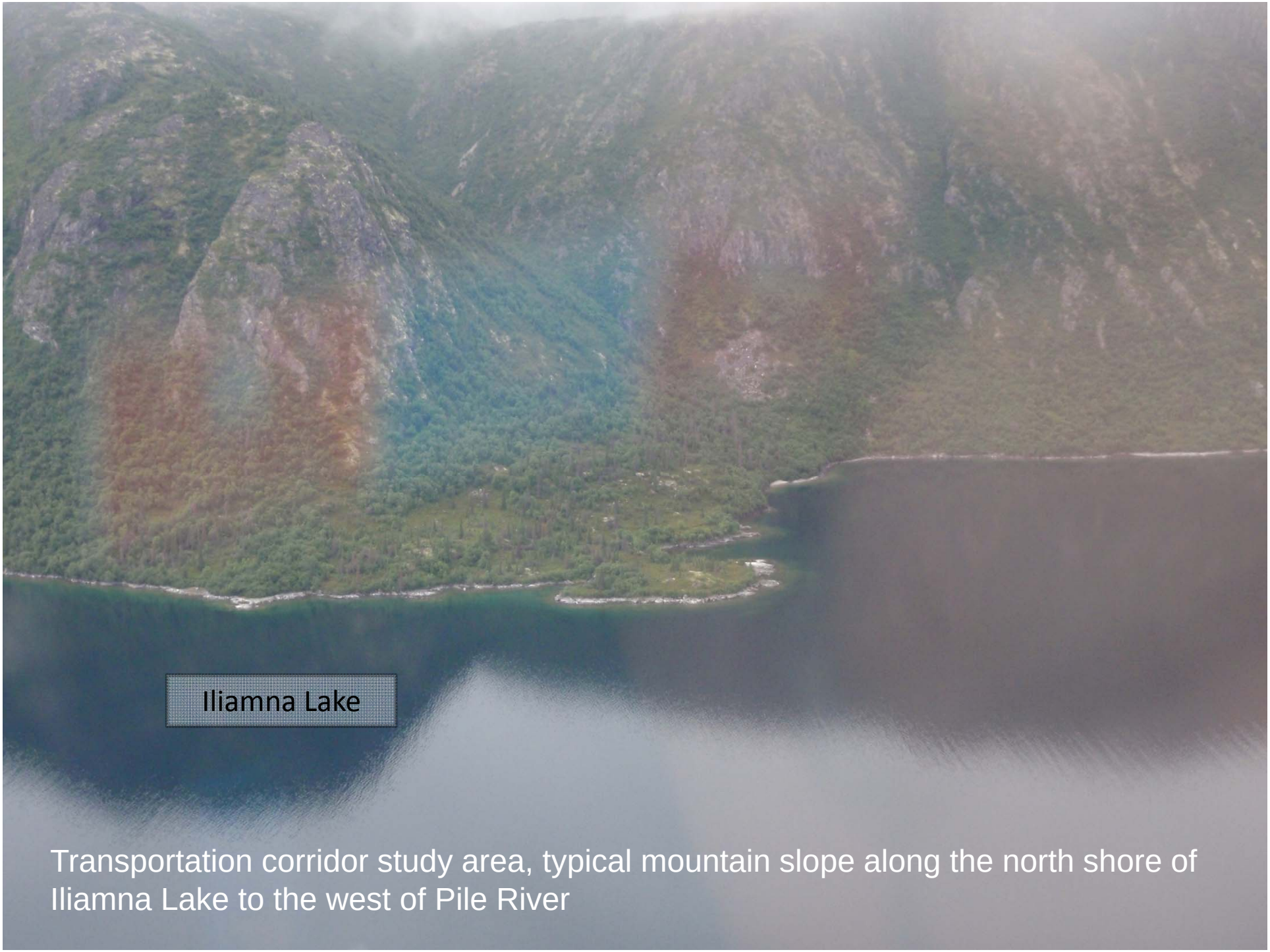


Transportation corridor study area, view east toward Roadhouse Mountain showing typical terrain in Nushagak – Bristol Bay Lowlands physiographic division, July 2004.

Physiography: Transportation Corridor Study Area

Corridor physiography heading east (2)

- Canyon Creek to Pile River
  - Mountain slopes and colluvial terrain

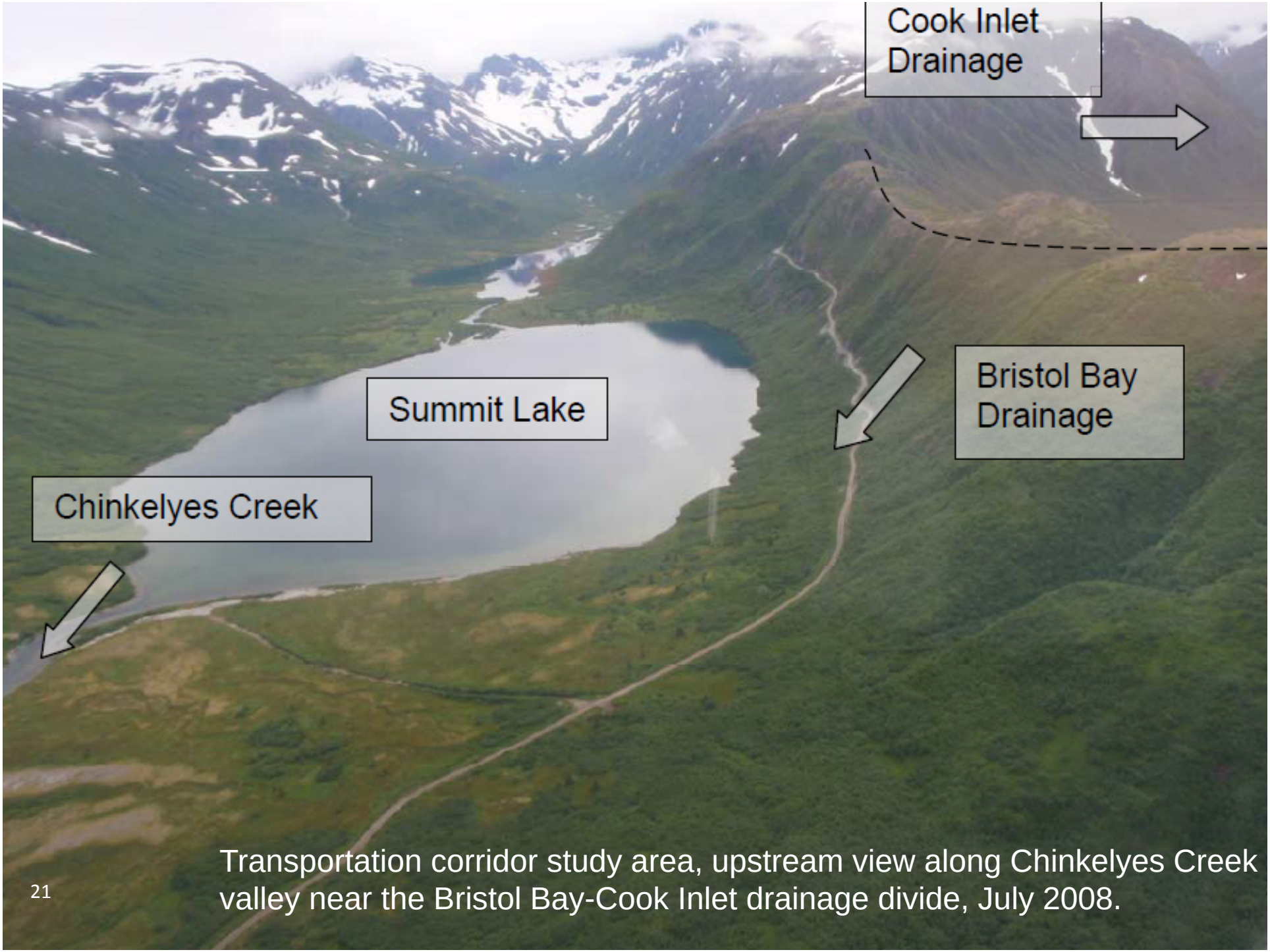


Transportation corridor study area, typical mountain slope along the north shore of Iliamna Lake to the west of Pile River

Physiography: Transportation Corridor Study Area

Corridor physiography heading east (3)

- Chinkelyes Creek Valley
  - Narrow valley and mountain slopes



Transportation corridor study area, upstream view along Chinkelyes Creek valley near the Bristol Bay-Cook Inlet drainage divide, July 2008.

Physiography: Transportation Corridor Study Area

Corridor physiography heading east (4)

- Cook Inlet drainage basin
  - Rugged mountains
  - Glacially carved valleys
  - Fjord inlets
- Coastal shore
  - Steep and rocky along fjord sides
  - Broad tidal mud flats at fjord heads

Physiography: Transportation Corridor Study Area

Corridor physiography heading east (5)

- Iliamna Bay near Williamsport
  - Very shallow
- Iniskin Bay channel off Knoll Head
  - Max depth 80 feet


Canyon Cr.
Knutson Cr.
Pile R.
Iliamna River
Pedro Bay
Chinkelyes Cr.
Williams Cr.
Range Division
ern)
Williamsport
Iliamna Bay
Iniskin Bay

View to the southeast along the eastern coast of Iliamna Bay, July 2008.

Iliamna Bay, Cook Inlet, July 2004.

Physiography: Transportation Corridor Study Area

Stream Crossings:

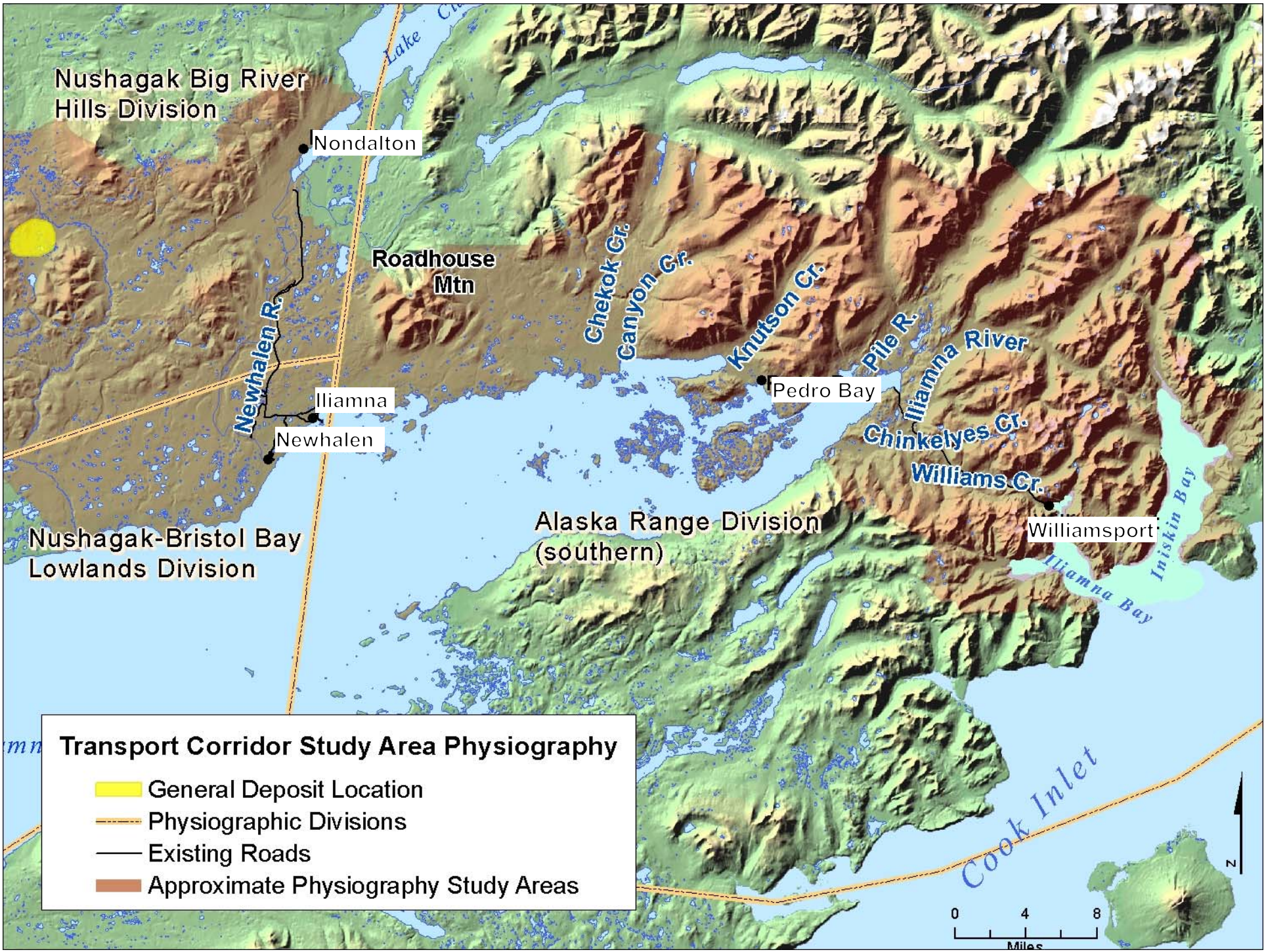
- Newhalen River
- Chekok Creek

Relatively stable, entrenched channels

- Canyon Creek
- Knutson Creek
- Pile River
- Iliamna River

Braided or meandering channels, actively eroding floodplains

- Chinkelyes Creek - - - - - Stable, lake outlet
- Williams Creek - - - - - Braided channel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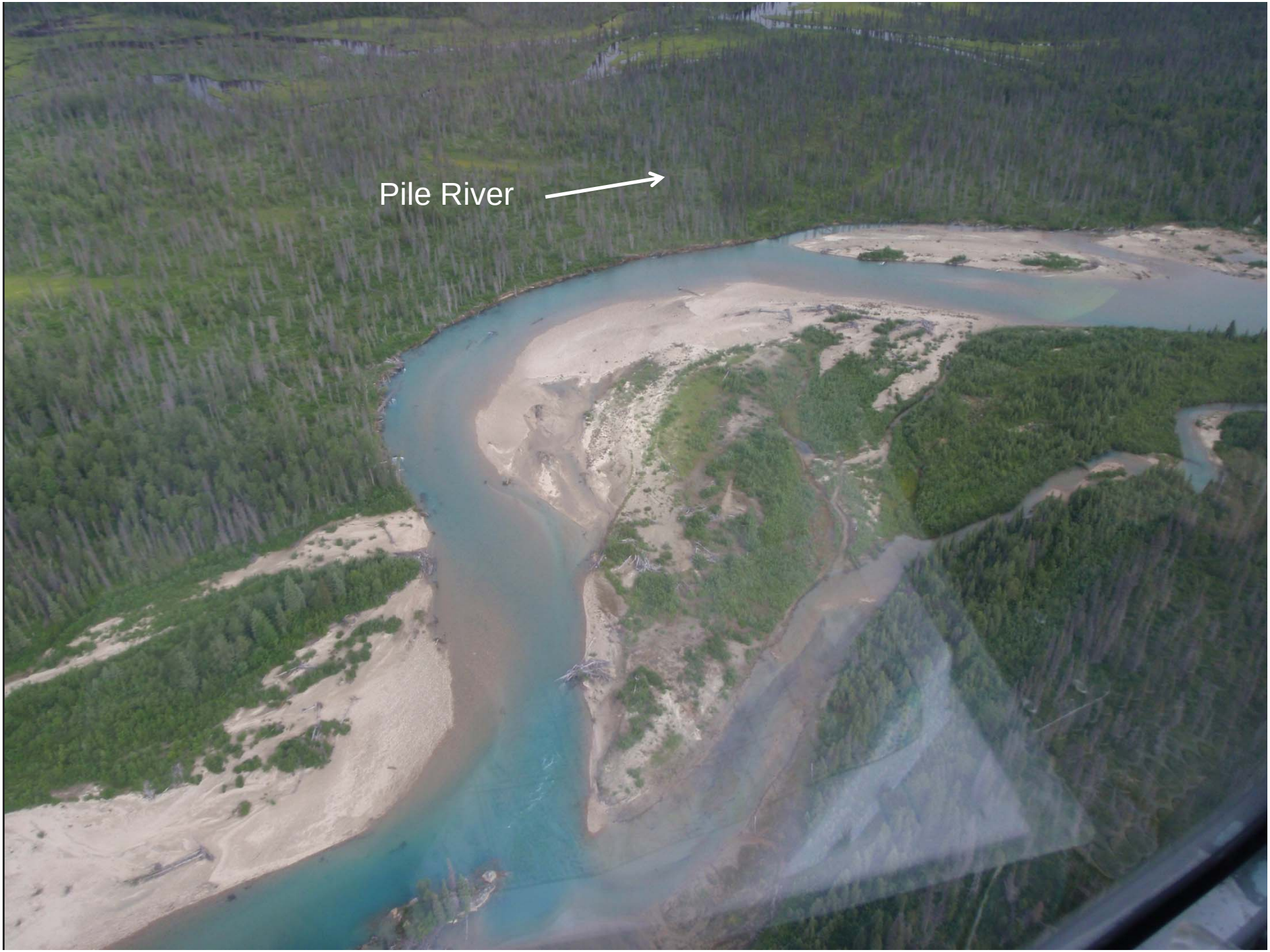
Newhalen River


Knutson Creek

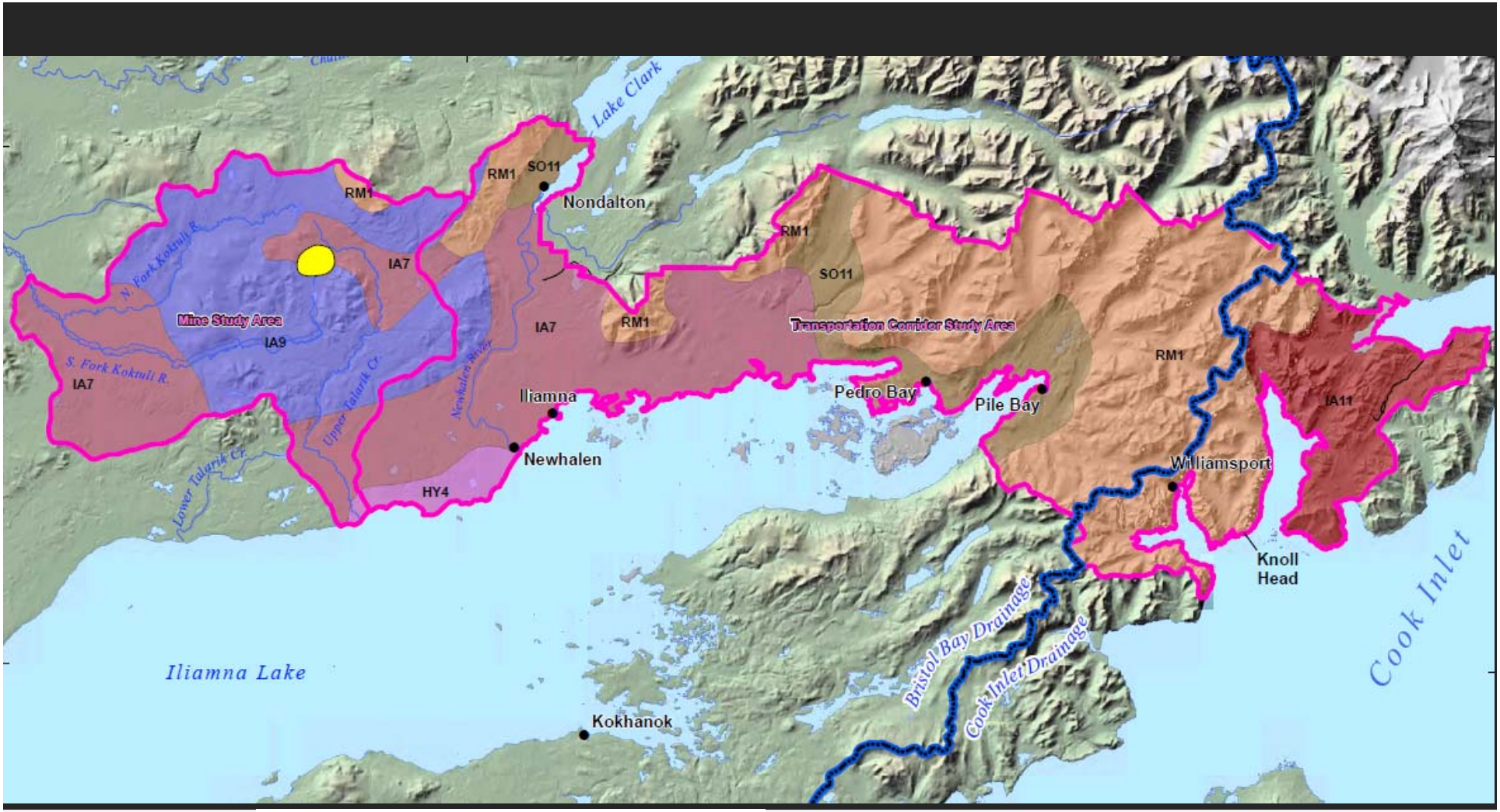

Pile River


Iliamna River


Chinkelyes Creek


Williams Creek

Soils



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.

Soils: Overview

Area Overview

- Glaciated during Pleistocene
- Active volcanoes in region
  - Nearest is Augustine Volcano,
    60 miles from Mine Study Area
- Result is areas of fine textured soil
  - Mix of glacial loess & volcanic ash

Soils: Mine Study Area

Overview:

- Areas with no soil: exposed bedrock/felsenmeer
- Typical soil depths of 1 to 2 ft
- Frying Pan Lake area ranges up to 15ft
- Peat in swampy areas

Soils: Mine Study Area

Mine Area Soil Units (decreasing order of %):

- *IA9 Typic Cryandepts* (58% of mine study area)
  - Very gravelly, hilly to steep
  - Formed in volcanic material
  - Well drained, strongly acidic
  - Thin surface of decomposed plant litter
  - Vegetation: alder, grasses, or low shrubs

Soils: Mine Study Area

Soil Units (2):

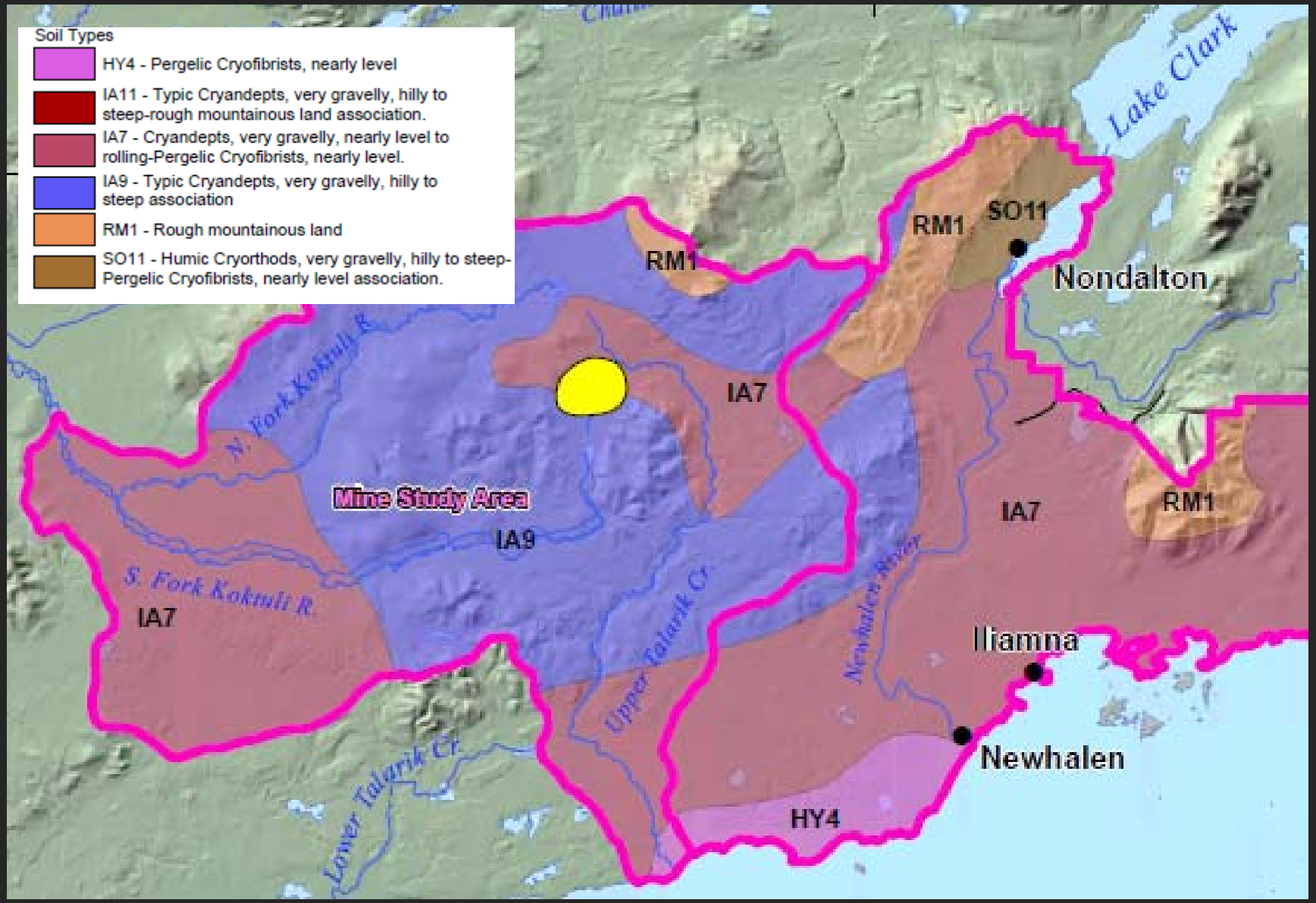
- *IA7 Typic Cryandepts* (40%)
  - Formed in volcanic ash over gravelly material
  - Level to rolling terrain
  - Well-drained, acidic soils
  - On moraines, outwash plains, old beach ridges
  - Vegetation: low tundra species, some white spruce, paper birch

Soils: Mine Study Area

Soil Units (3):

- *RM1 Rough mountainous land* (1%)
  - Steep rocky slopes
  - Thin soils overlying bedrock, stones/boulders
  - Sparse vegetation
- *HY4 Pergelic Cryofibrists* (<1%)
  - Very poorly drained, muskegs
  - Perennially frozen peat soils (below 10~30”)
  - Wet, soft, spongy in summer
  - Vegetation: sedges, mosses, low shrubs

Soils: Mine Study Area



Soils: Transportation Corridor Study Area

Transportation Corridor Soil Units (decreasing %):

- *RM1 Rough mountainous land* (49%)
  - Dominates eastern portion (Canyon Creek to Iniskin Bay)
- *IA7 Typic Cryandepts* (23%)
  - Found in Newhalen River basin and Iliamna shore
- *IA11 Typic Cryandepts* (11%)
  - Typic Cryandepts, steep mountainous terrain (East of Iniskin Bay)

Soils: Transportation Corridor Study Area

Soil Units (2)

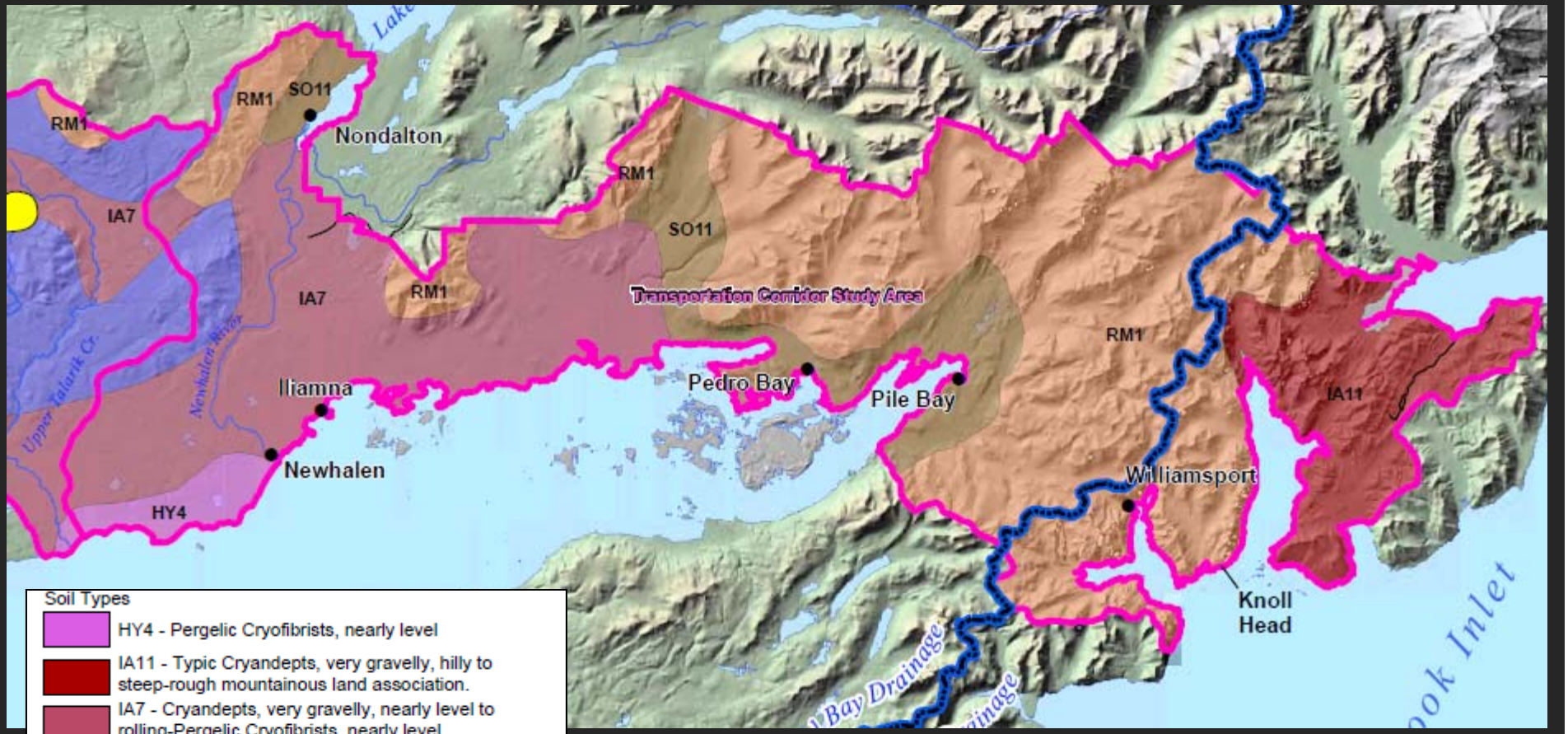
- *SO11 Humic Cryorthods & Pergelic Cryofibrists* (11%)
  - *Humic Cryorthods*
    - Very gravelly, well drained-soils
    - On footslopes, moraines,
    - Vegetation: white spruce/birch forests on steeper slopes, black spruce on gentle slopes
  - *Pergelic Cryofibrists*
    - Perennially frozen, poorly-drained soils
    - Develop in level areas, valleys, depressions

Soils: Transportation Corridor Study Area

Soil Units (3)

- *IA9 Typic Cryandepts (3%)*
  - In Newhalen River drainage
- *HY4 Pergelic Cryofibrists* (2%)
  - Along north shore of Iliamna Lake

Soils: Transportation Corridor Study Area



Soils

Conclusion

- Existing literature highlights influence of volcanic ash in area soils

- The three main soil types present were:
  - *Typic Cryandepts*
  - *Rough Mountainous Land*
  - *Humic Cryorthods / Pergelic Cryofibrists*

Permafrost

Permafrost: Overview

- Mine and Transportation Corridor Study Areas: Zone of sporadic permafrost (Ferrians, 1965)
  - Patchy, complex
  - Relict from previous glaciation
  - Climate does not support permafrost aggradation
  - Relict permafrost may be present beneath organic accumulation areas (pergelic soils)

Permafrost: Mine Study Area

- Geotechnical site investigations: Relict ice lenses and seasonal ice, but no permafrost
- Thaw ponds and patterned ground: thawing of relict permafrost in the past (Hamilton & Klieforth, 2010)

Questions