Permafrost-Influenced Geomorphic Processes

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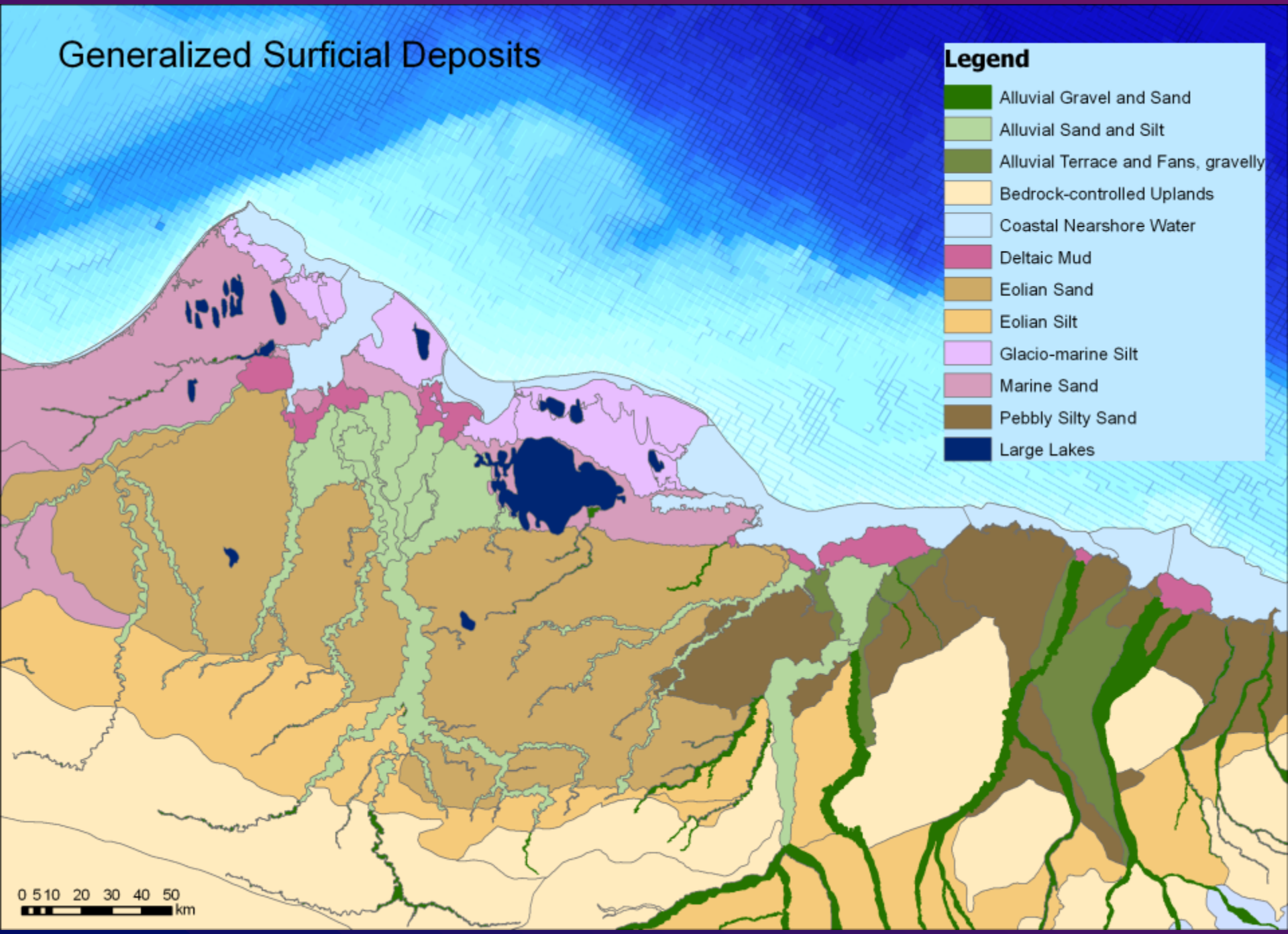
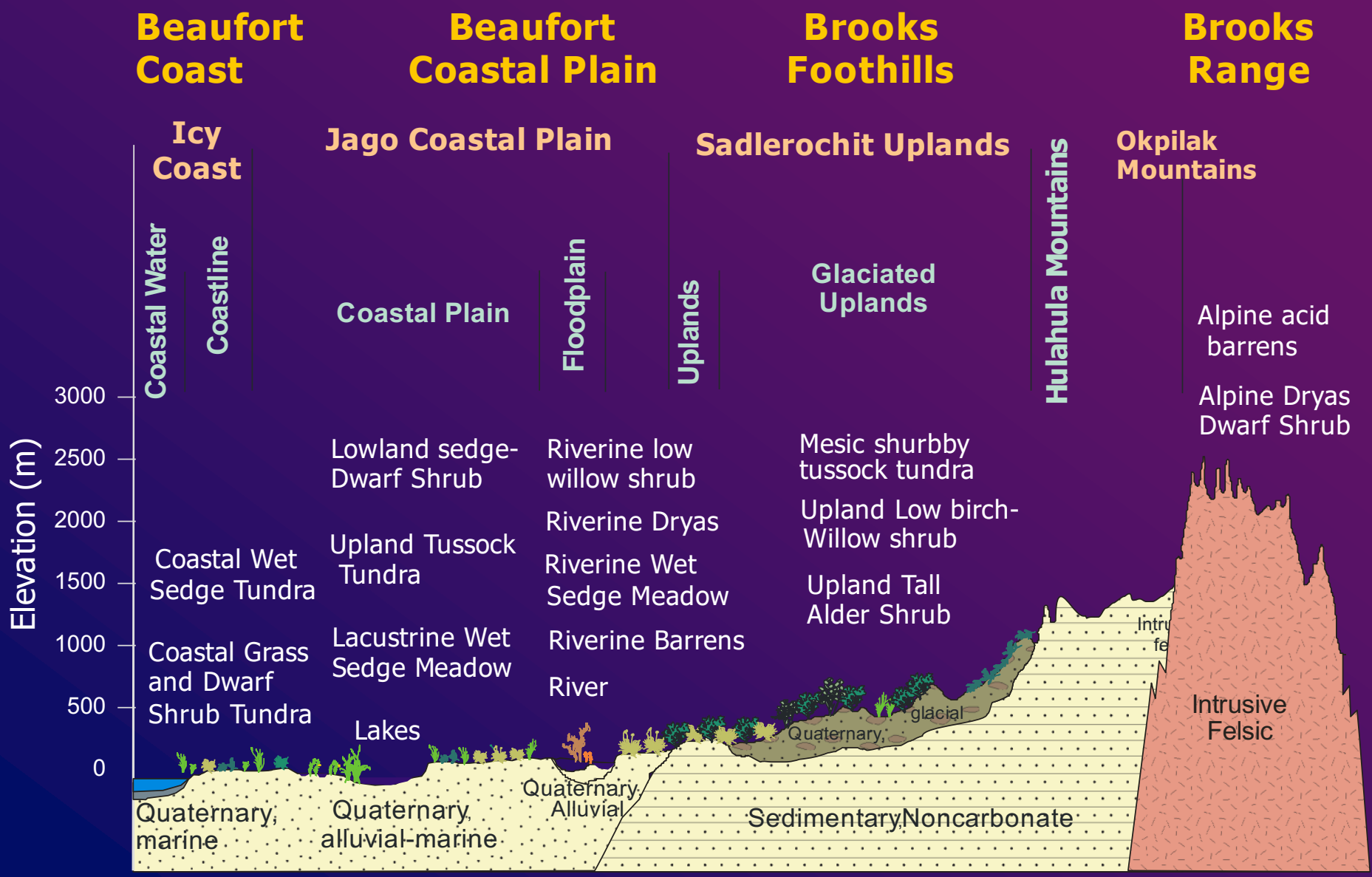
Overview of Geomorphic Processes

- Coasts
  - Storm surges, sedimentation, salinization, permafrost degradation
- Floodplains
  - Changing flooding, sedimentation,
  - Channel migration
- Coastal Plain-Lowlands
  - Thermokarst lakes, waterbody creation
  - Lake expansion and shrinkage
  - Paludification, organic matter accumulation
  - Ice-wedge Degradation
- Uplands
  - Loss of permafrost aquatard, drainage
  - Thaw slumps
  - Thermokarst Lakes in Extremely ice-rich loess (yedoma)
- Mountains
  - Slope Failure


Generalized Surficial Deposits
Legend
Alluvial Gravel and Sand
Alluvial Sand and Silt
Alluvial Terrace and Fans, gravelly
Bedrock-controlled Uplands
Coastal Nearshore Water
Deltaic Mud
Eolian Sand
Eolian Silt
Glacio-marine Silt
Marine Sand
Pebbly Silty Sand
Large Lakes
0 5 10 20 30 40 50
km

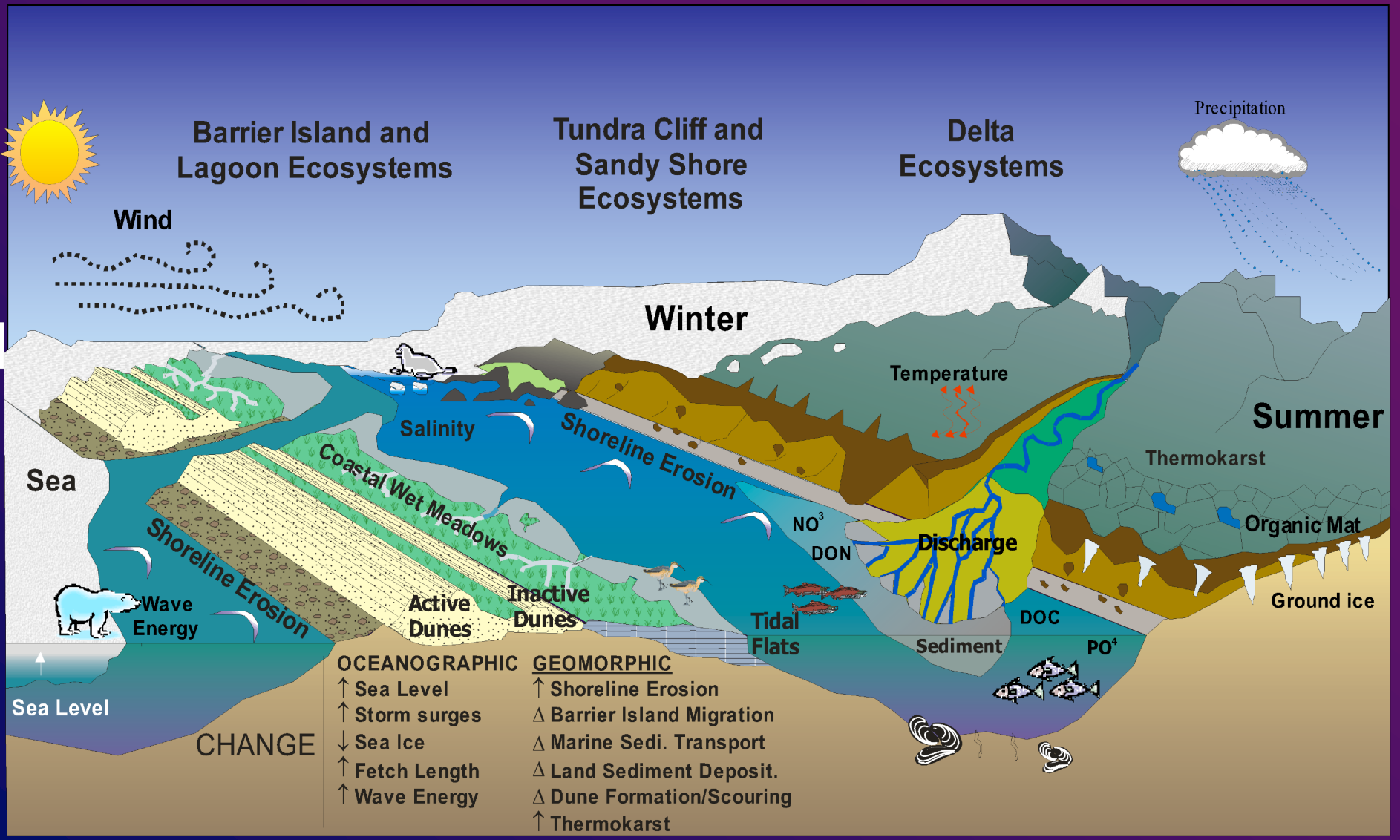
North Slope Ecological Profile



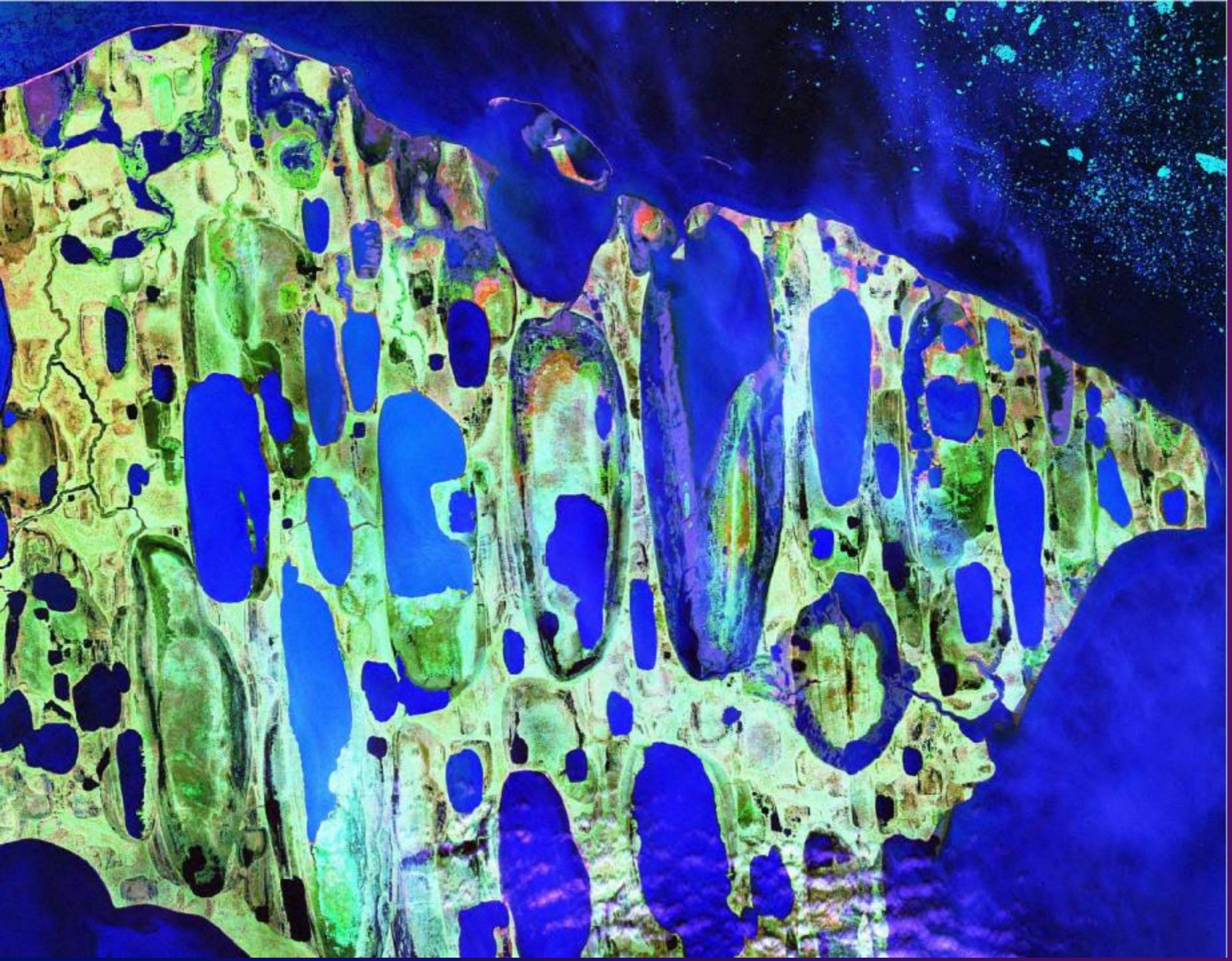
Coastal Ecosystems

- Sedimentation (up to 10 cm in big year)
- Storm Surges (1970 to 2 m)
- Salinization (up to 15 km inland)
- Sea Level Rise (3 mm/yr)

Coastal Geomorphic Processes

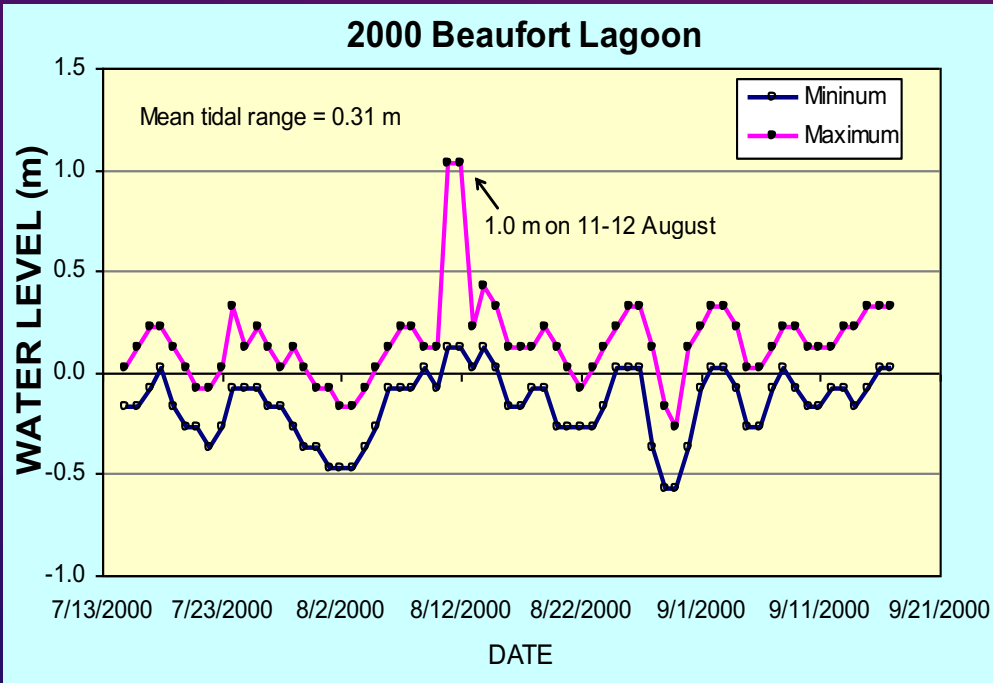


Produced for ARCN-NPS by M. T. Jorgenson and D. M. Sanzone



Storm Surges

October 2002
Storm at Barrow

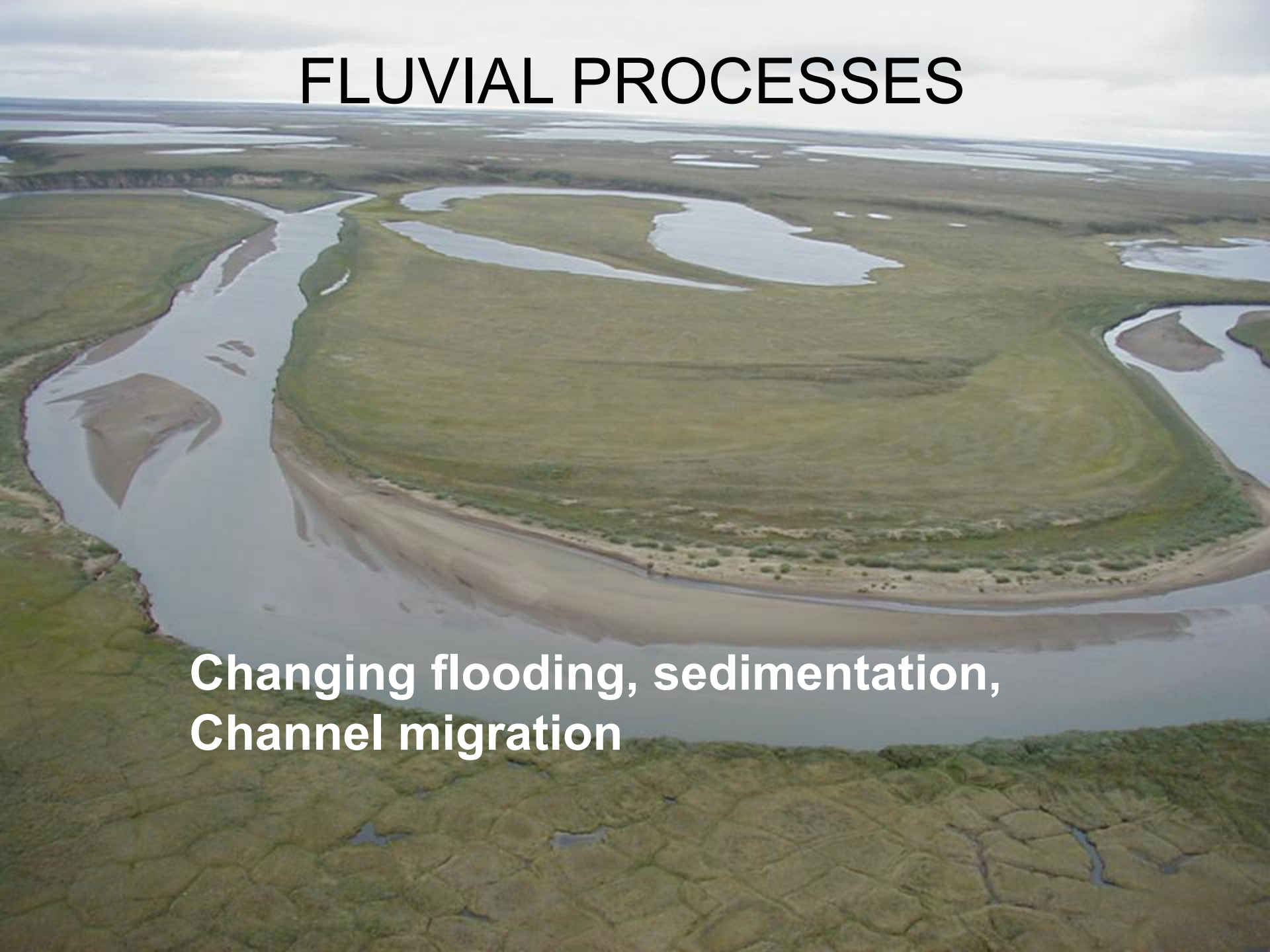


Coastal Erosion

Deltaic Environments

Salinization: Salt-killed tundra

FLUVIAL PROCESSES



Changing flooding, sedimentation,
Channel migration

GEOMORPHIC PROCESSES ON RIVER FLOODPLAINS

Changes over Time:

Increasing height,

Decreasing flooding frequency,

Decreasing sedimentation,

Increasing organics,

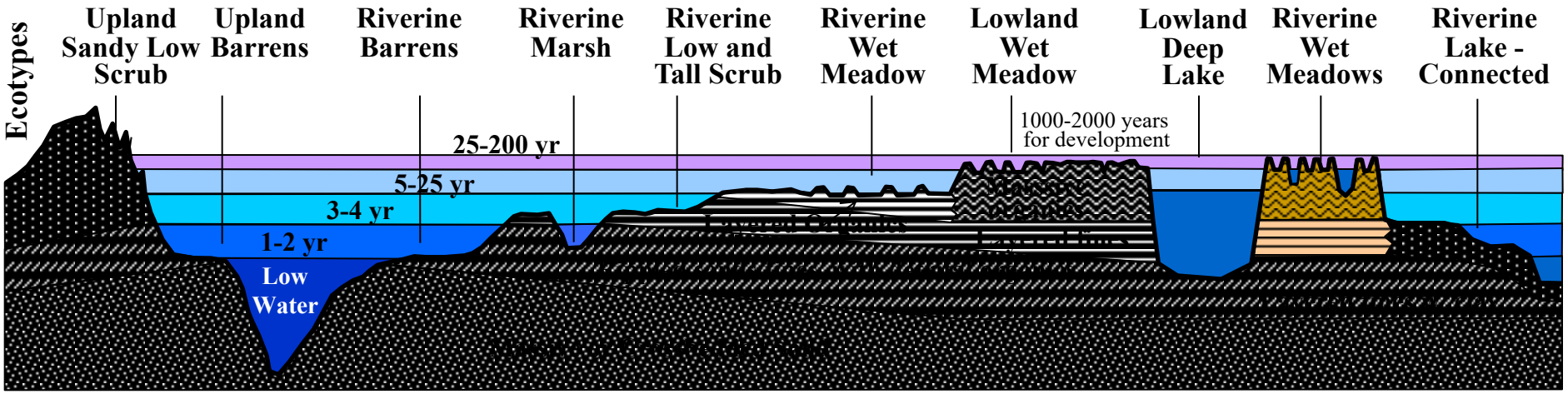
Decreasing thaw depths,

Decreasing water depths

Decreasing pH

Increasing ground ice,

Increasing susceptibility to thermokarst,



Decreasing Flooding and Sedimentation

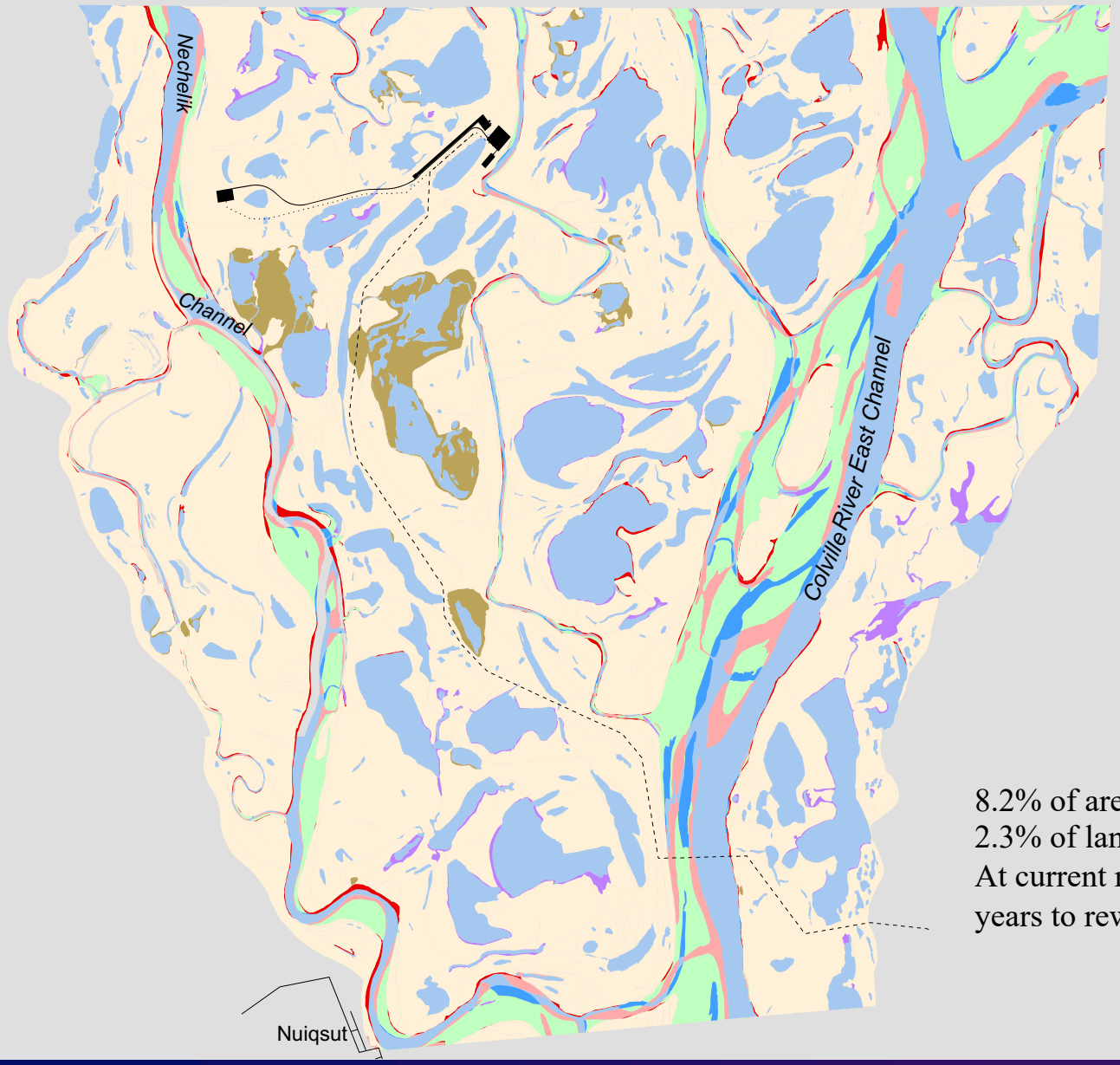
Riverbed/ Riverbars

Active-floodplain Cover Deposit

Inactive-floodplain Cover Deposit

Abandoned-floodplain

Erosion and Deposition



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SCALE IN MILES

0 1 2

Areas of Erosion and Deposition

	Area (%)
Eroded Riverbed/Sandbar	1.3
Riverbed/Sandbar Deposition	2.6
Unchanged Riverbed/Sandbar	7.6
Thaw Basin Drainage/Deposition	1.8
Other Eroded Terrain	1.0
Unchanged Terrain	58.8
Lake-level Change	0.9
Unchanged Water	26.1

Proposed Project

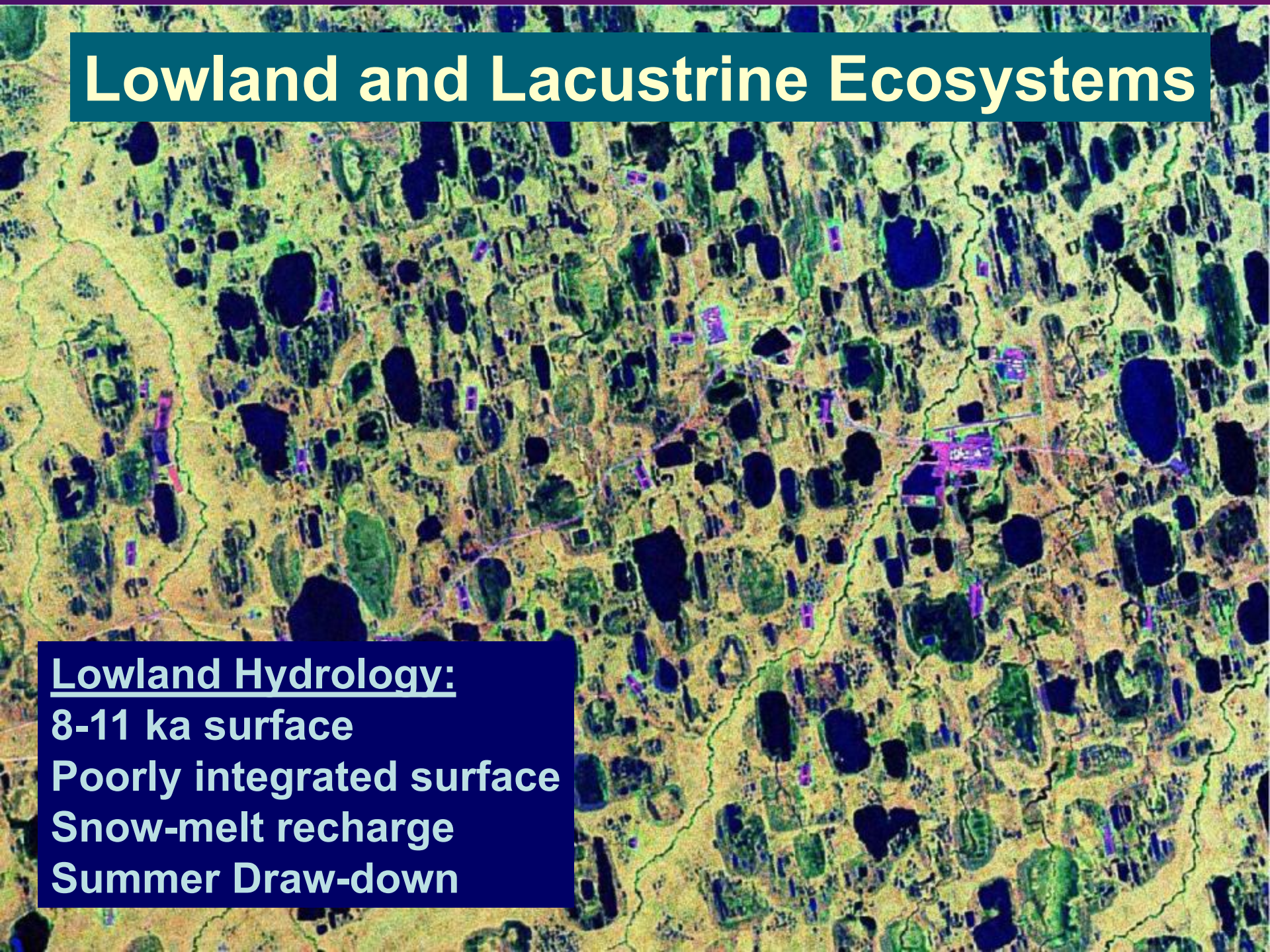
In-field Facilities

Pipelines

8.2% of area changed over 37 yr
2.3% of land eroded
At current rate it would take about 1700 years to rework entire delta

Landscape Change from 1955 to 1992, Central Colville River Delta

Lowland and Lacustrine Ecosystems



Lowland Hydrology:

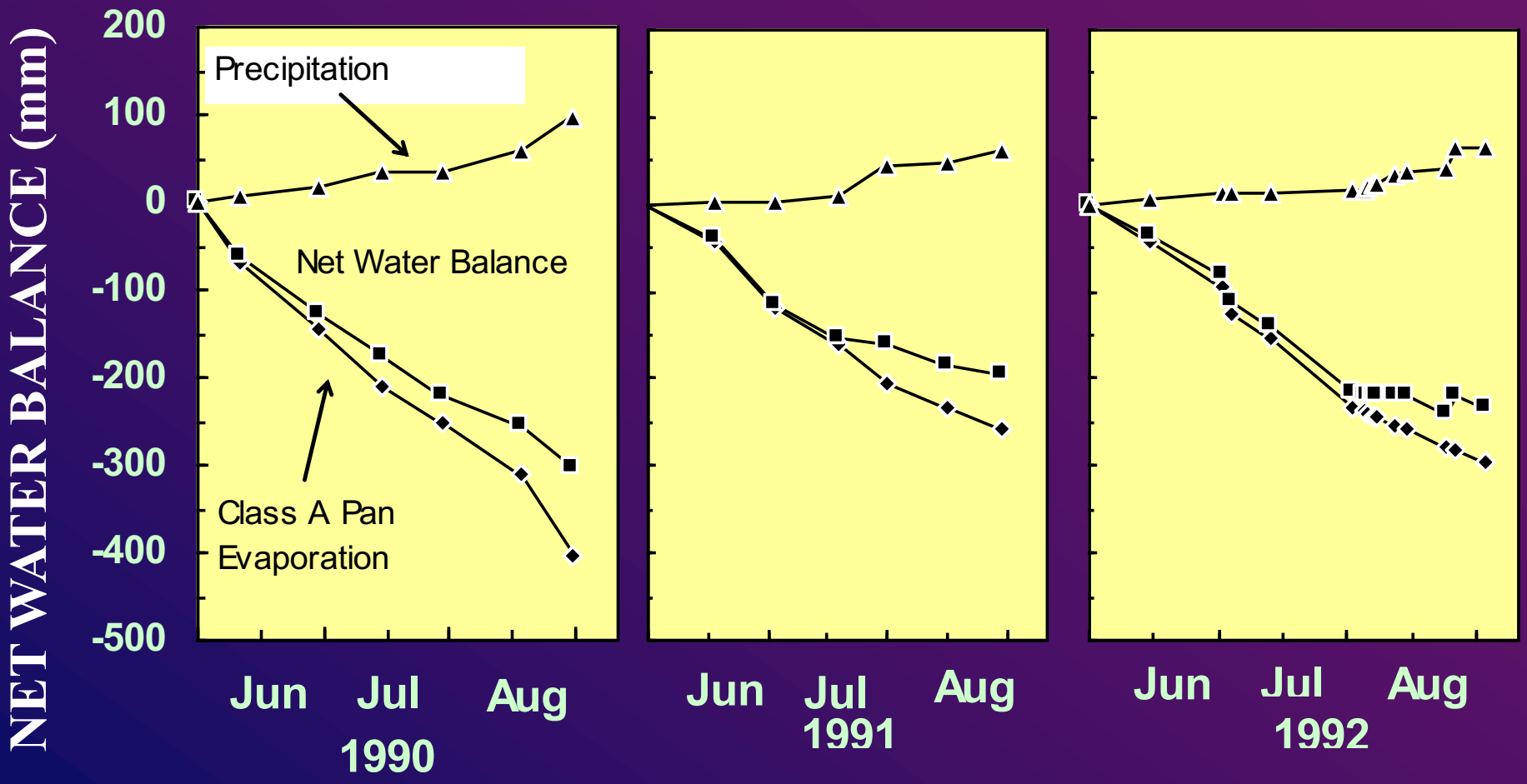
8-11 ka surface

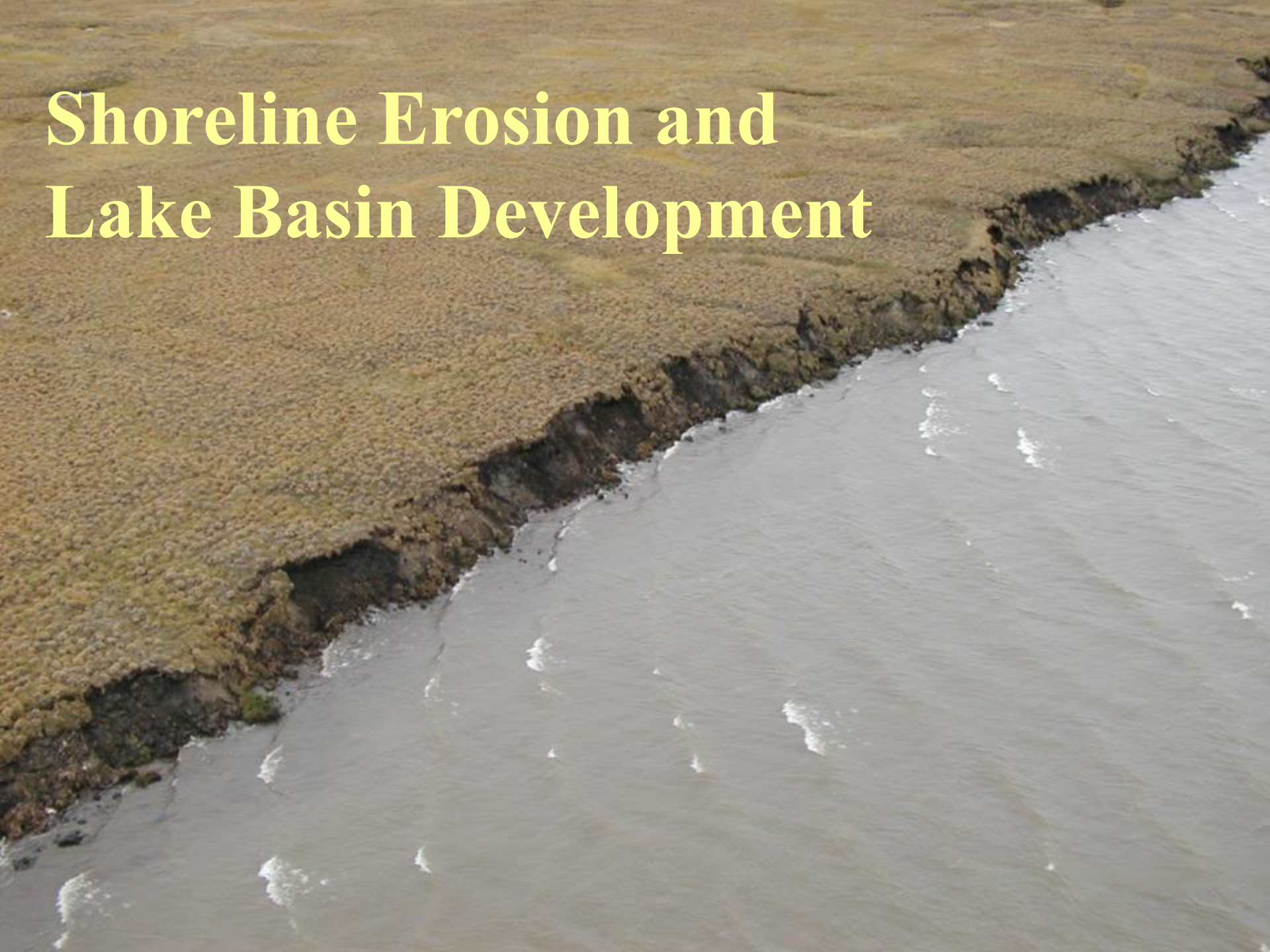
Poorly integrated surface

Snow-melt recharge

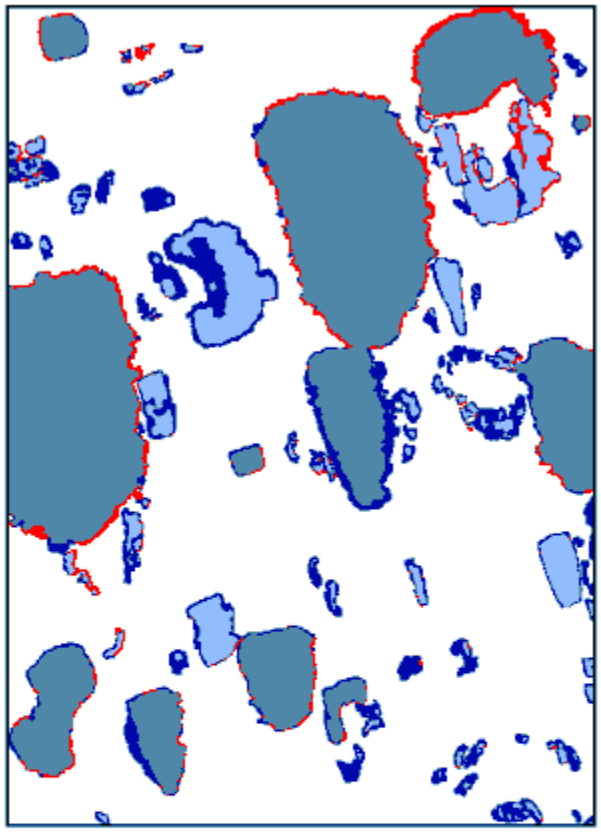
Summer Draw-down

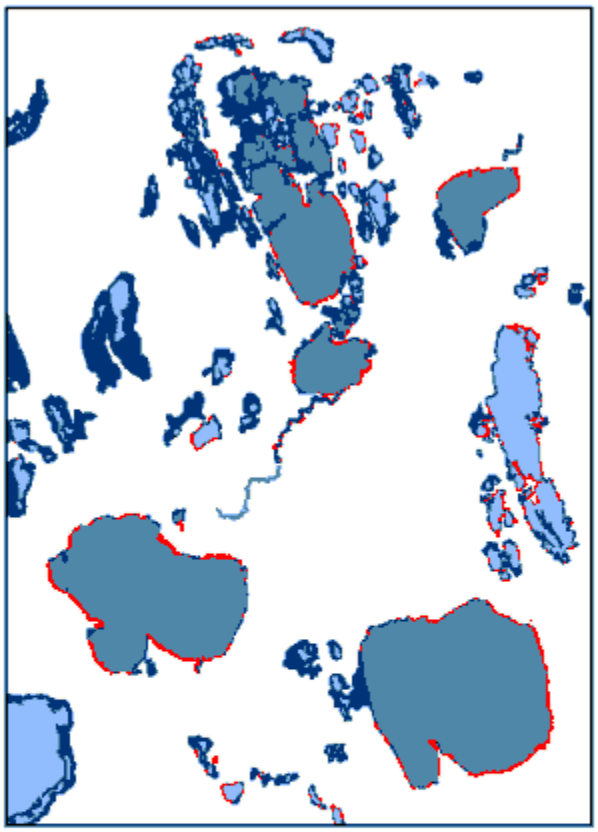
Coastal Plain Geomorphic Model

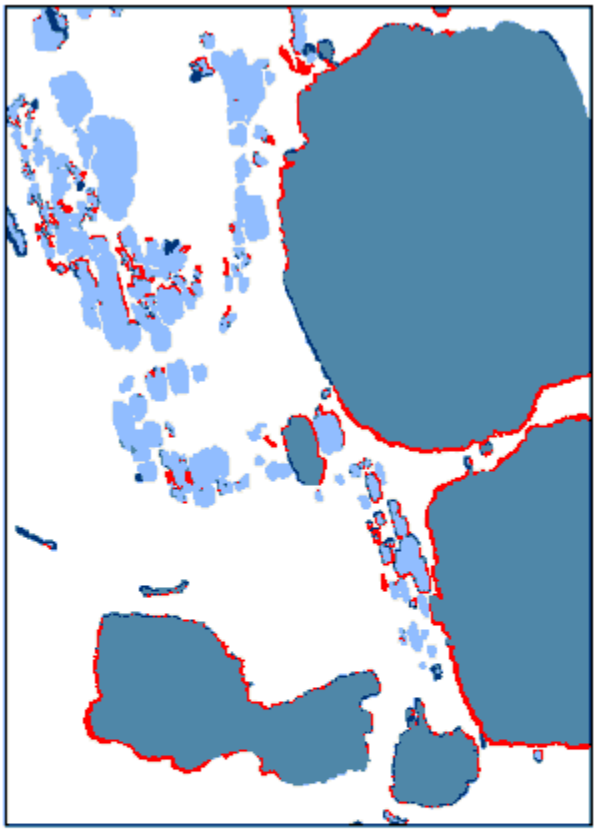

NET WATER BALANCE (mm)
200
100
0
-100
-200
-300
-400
-500
Precipitation
Net Water Balance
Class A Pan
Evaporation
Jun
Jul
Aug
1990
Jun
Jul
Aug
1991
Jun
Jul
Aug
1992



Shoreline Erosion and Lake Basin Development





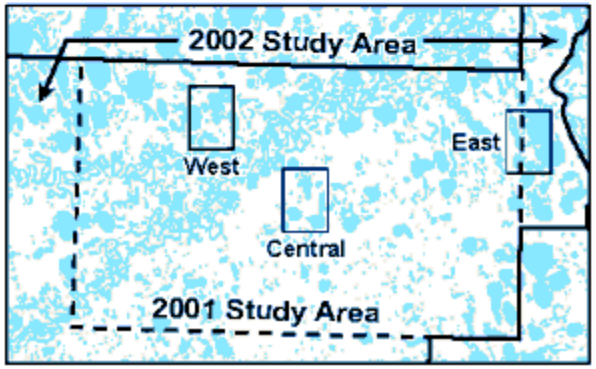


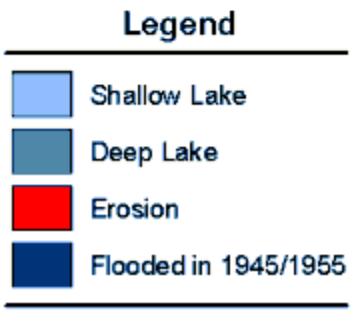
Approximate Scale = 1:46,000

0.25 0 0.25 0.5 0.75 1 Miles

0.5 0 0.5 1 1.5 Kilometers

2001 Color Orthophoto Mosaic acquired 14–15 July; 1945 (4 July) and 1955 (24 July) Black and White Air Photos registered to 2001 Mosaic.
Projection: Alaska State Plane Zone 4, NAD83 as expressed in feet.
ABR file: Landscape_change_02-165.mxd, 10 April 2003



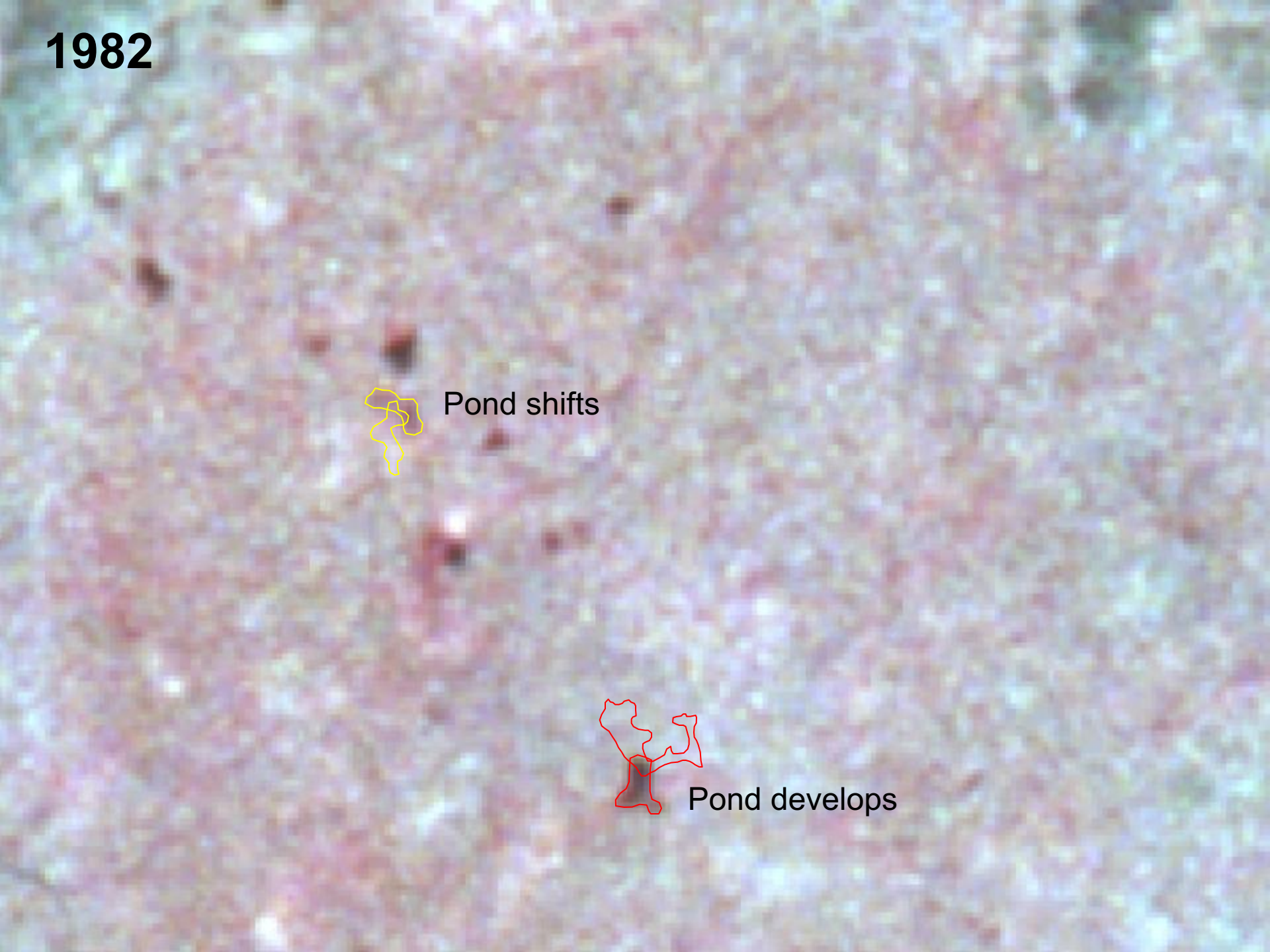


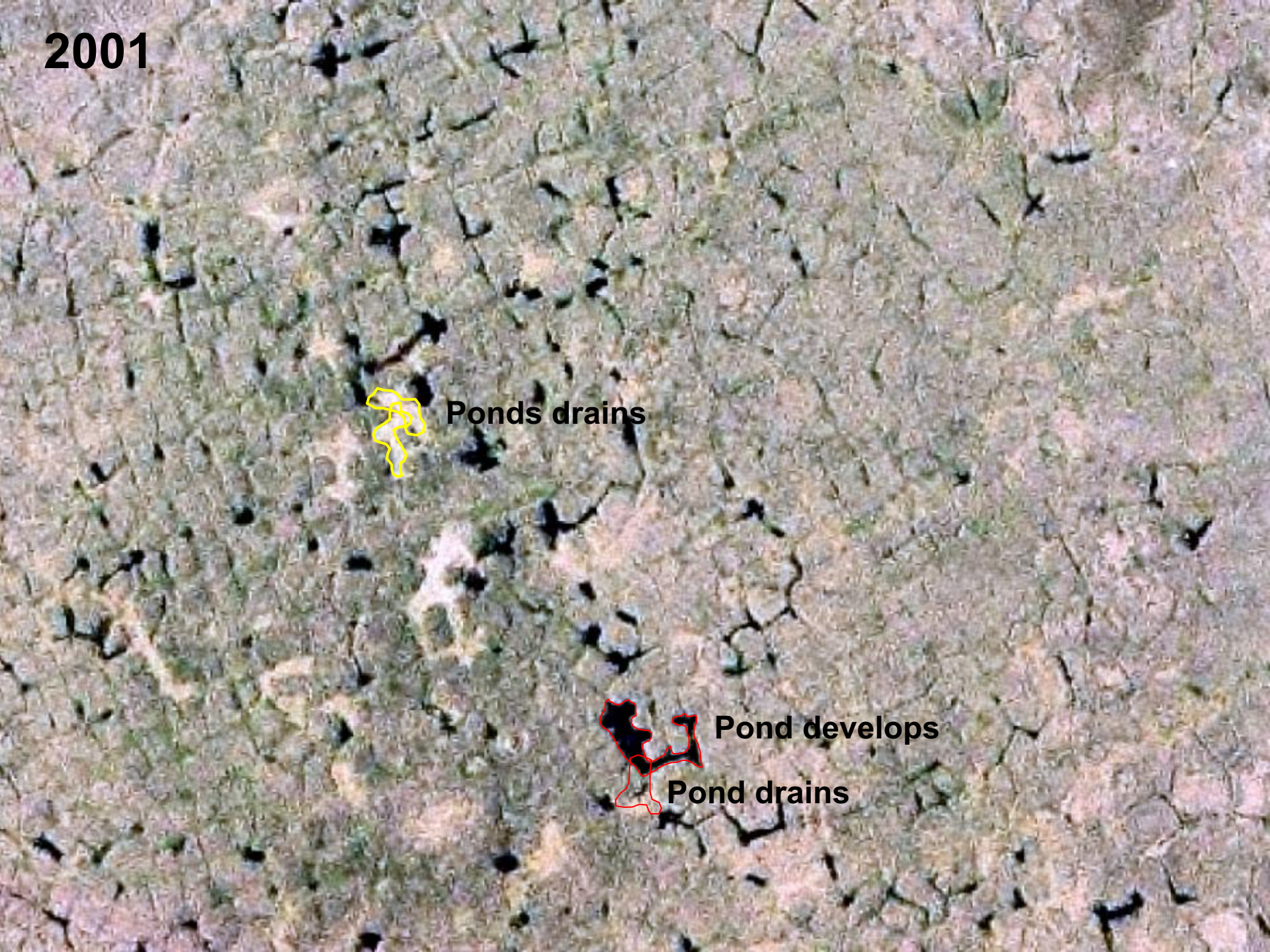
0.7% of land was eroded over 45-56 year period, 0.01%/yr

At this rate it would take 8400 years to rework the surface.

In-filling of Lake Margins


1945
Time Series: Beaufort Coastal Plain
Drying location
Wetting location

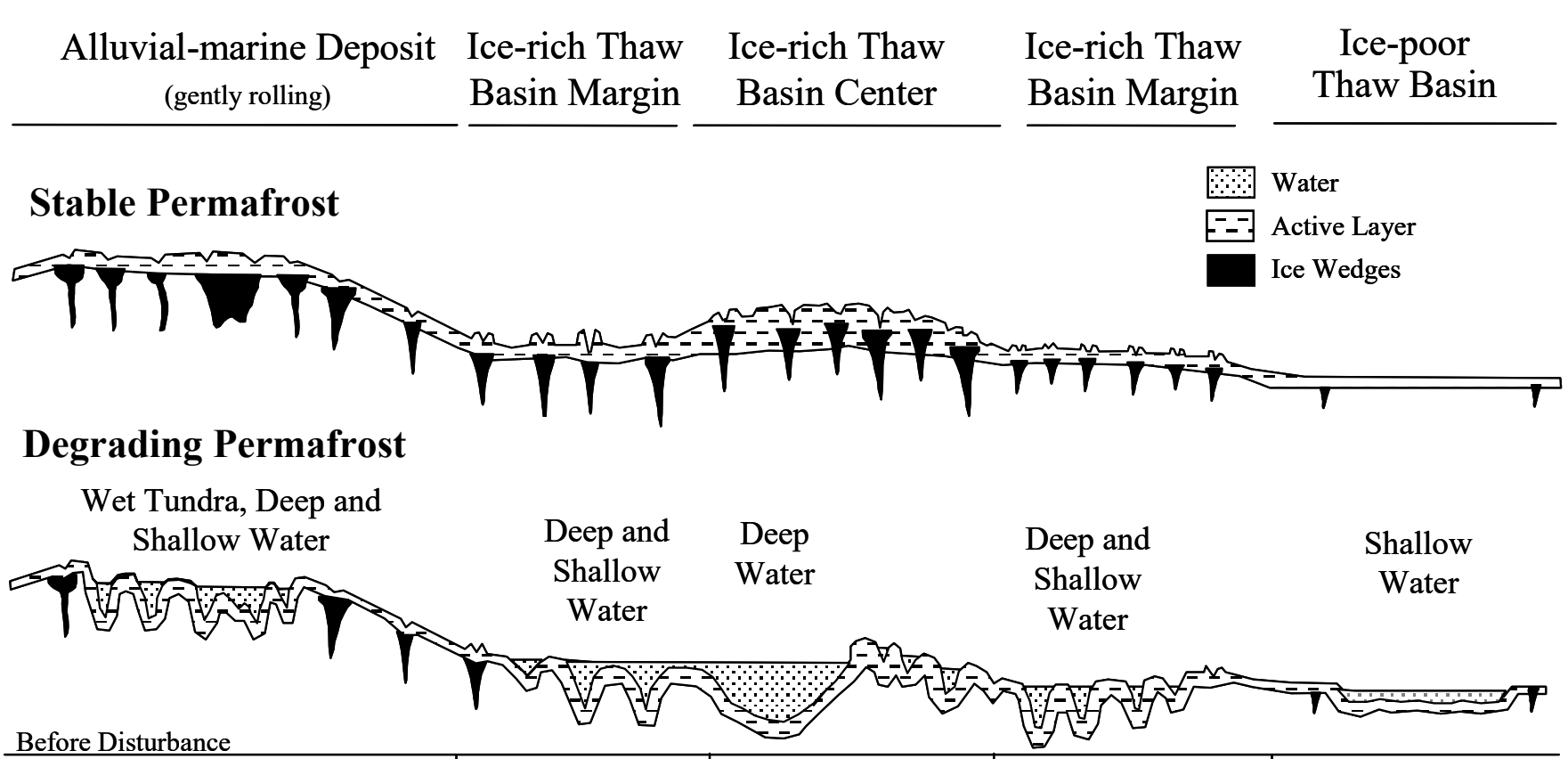

1982
Pond shifts
Pond develops


2001
Ponds drains
Pond develops
Pond drains


1982

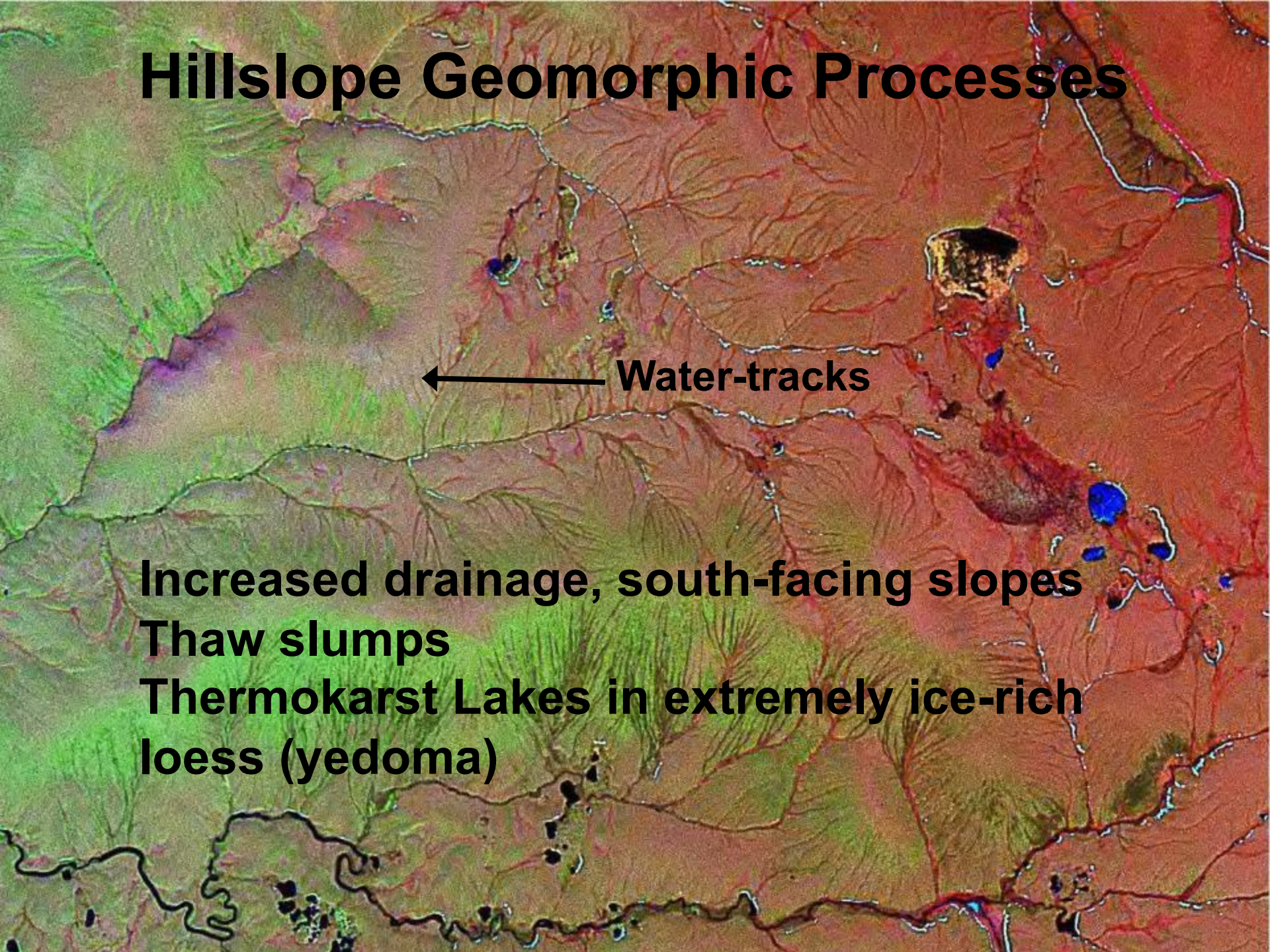

2001

Micro-topographic Effects of Ice-wedge Degradation



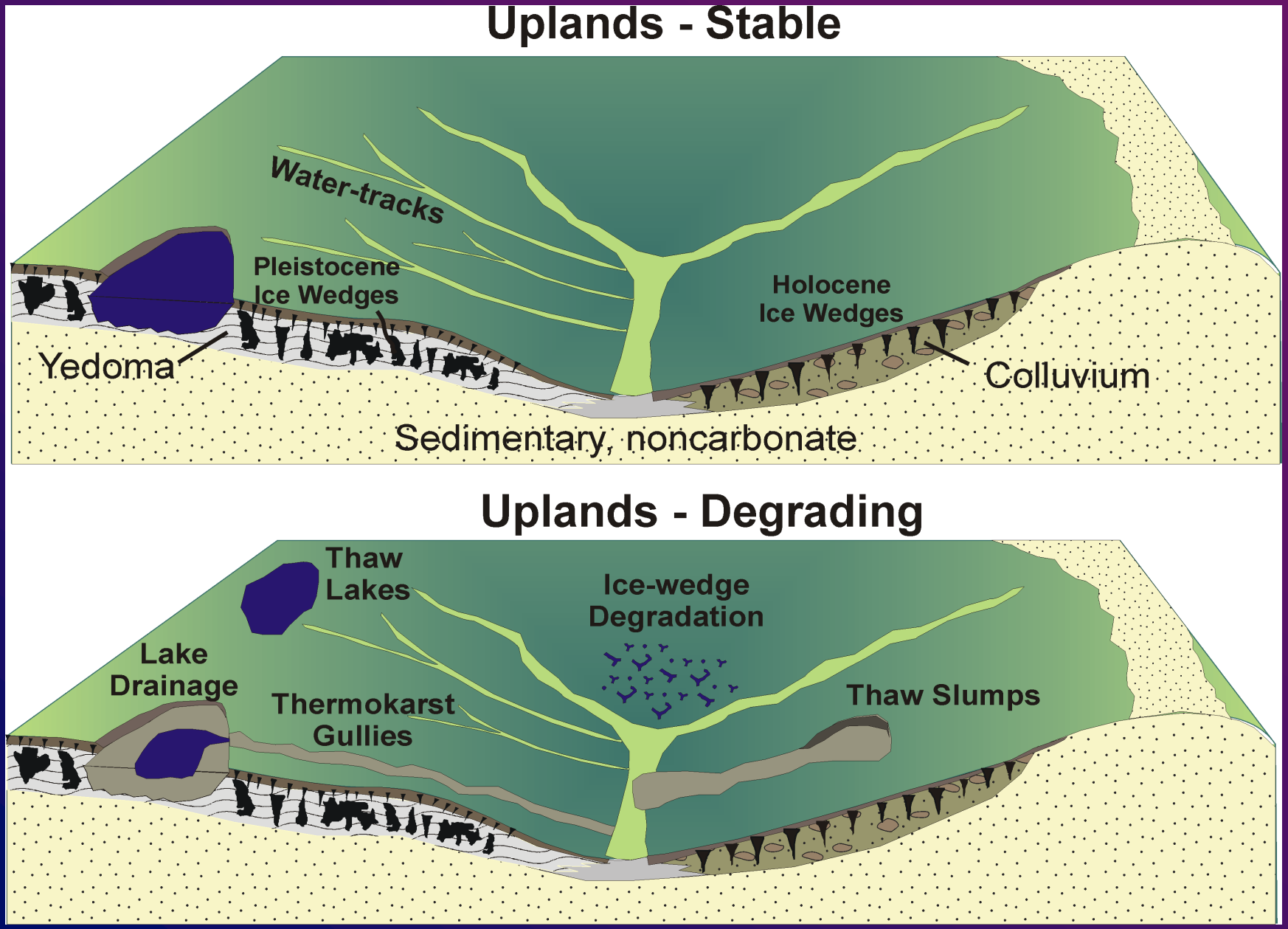
Before Disturbance					
Active Layer (m)	0.3	0.4	0.3	0.4	0.4
Segregated Ice (% vol)	71	64	64	64	60
Wedge ice(% vol)	20	15	20	15	0
After Disturbance					
Active Layer (%)	0.8	0.8	0.8	0.8	0.8
Mound Settlement (m)	0.6±0.3	0.4±0.3	0.3±0.1	0.4±0.3	0.4±0.3
Trough Settement (m)	1-2	1-2	1-3	1-2	0
Drainage	partial	none	none/partial	none	none

Hillslope Geomorphic Processes

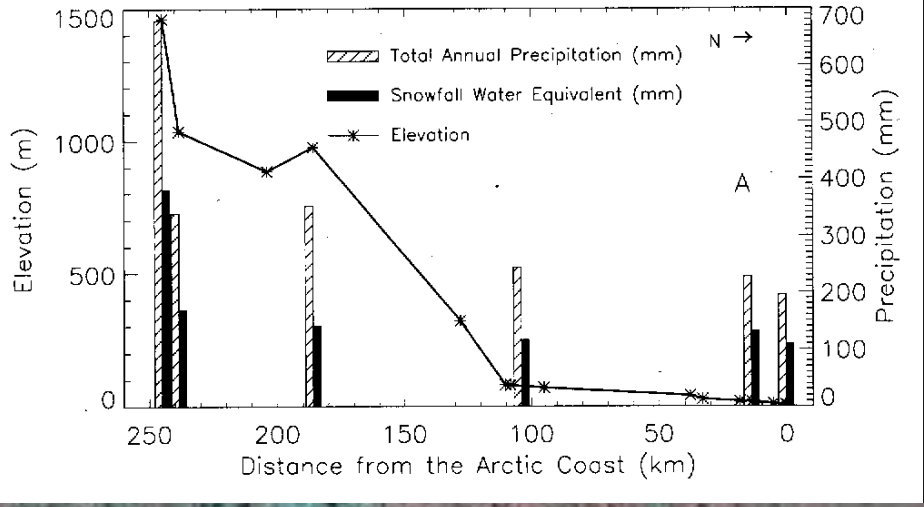


Increased drainage, south-facing slopes
Thaw slumps
Thermokarst Lakes in extremely ice-rich loess (yedoma)

Foothills Model



Precipitation-Leaching Gradient




Spring
Snow Phenology


Fall

Thermokarst Gullies and Water Tracks, Healy

Thaw Slumps

Photo by Andrew Balser

Deep Thermokarst Lakes


Seward Peninsula

CONCLUSIONS

- Regional Factors
  - Cold climate leading to permafrost development
- Coastal Processes (16% of Coastal Plain including Lagoons, 5% land)
  - Sediment deposition, salinization, thermokarst
  - Spread of halophytic vegetation, salt-killed tundra
- Fluvial Processes (9% of area)
  - Flooding leading to sediment deposition
  - Channel migration, erosion, and thaw lakes
  - Feedback from ice aggradation of flooding regime
  - Willow thickets, legumes, productive wet sedge

CONCLUSIONS

Lacustrine Processes
- **(14% areas in lakes, 39% in basins)**
- **Differential sediment deposition**
- **Shoreline Erosion (0.1%/yr)**
- **Lake Drainage (3% of landscape over 100's yrs)**
- **Carbonate inputs, strong pH gradients**

Thermokarst
- **Ice Wedge Degradation (>3%, up to 20%)**
- **Tussock loss, wet sedge increase, redistribution of water**

Hillside Processes
- **Deeper Drainage,**
- **Gully formation,**
- **Thaw slumps**
- **Deep Thermokarst Lakes**