



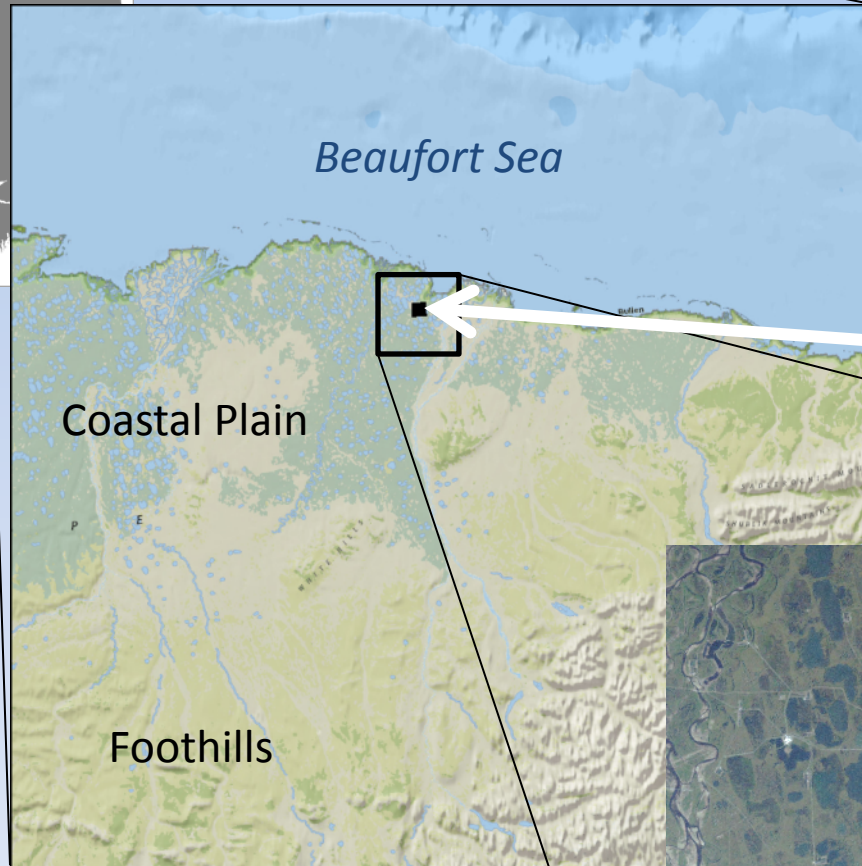
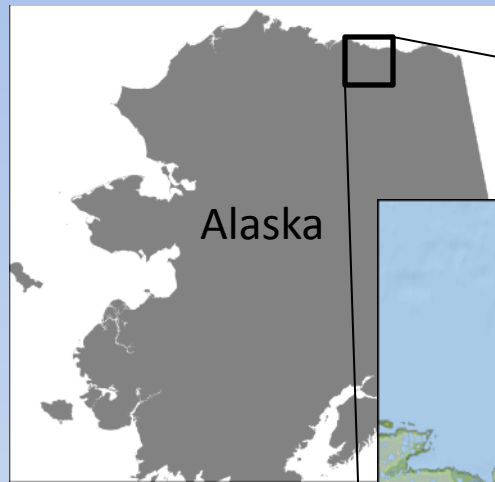
Sixty years of landscape change within an Arctic Oilfield, Prudhoe Bay, Alaska

Martha Raynolds, Donald A. Walker, Gary
P. Kofinas, Ken J. Ambrosius

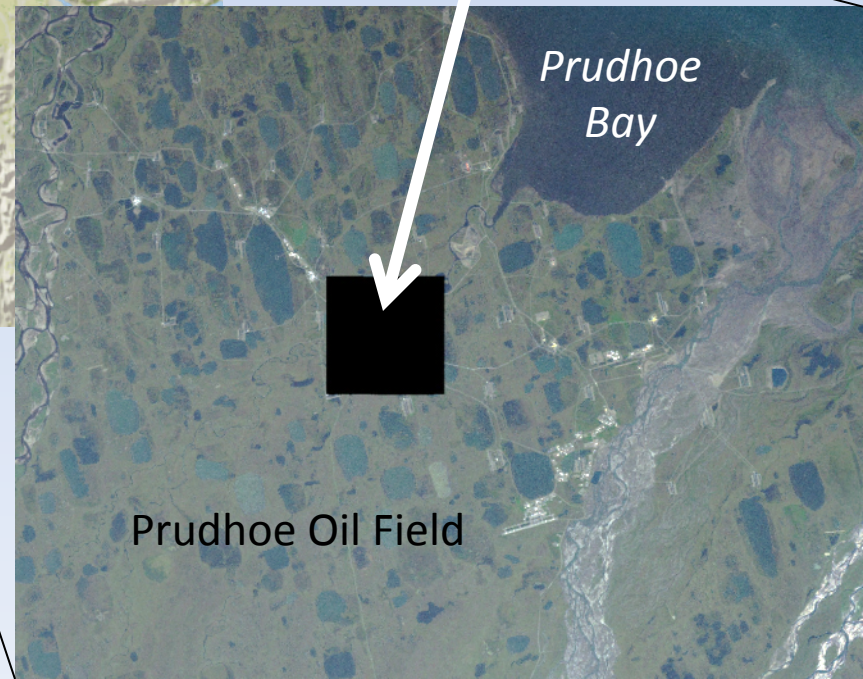


Land Cover Land Use Mapping Workshop
Rovaniemi, Finland
20 May 2012





Study area
within the
Prudhoe
Bay Oilfield
2092 ha.

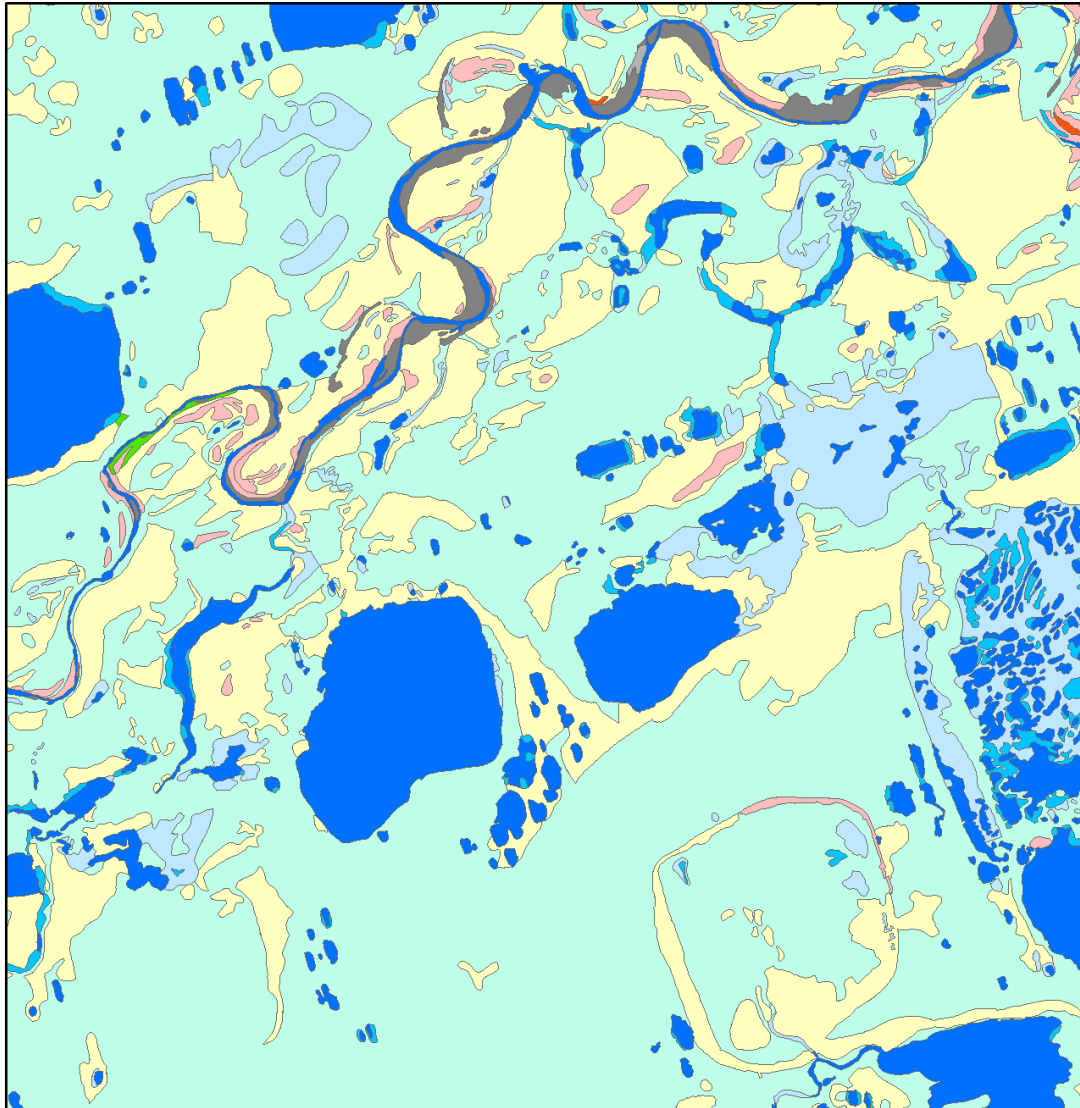


Geobotanical Atlas of the Prudhoe Bay Region, Alaska



Walker, D.A., Everett, K.R., Webber, P.J., Brown, J. 1980. *Geobotanical atlas of the Prudhoe Bay Region, Alaska*. CRREL Report 80-14. 69 pp.

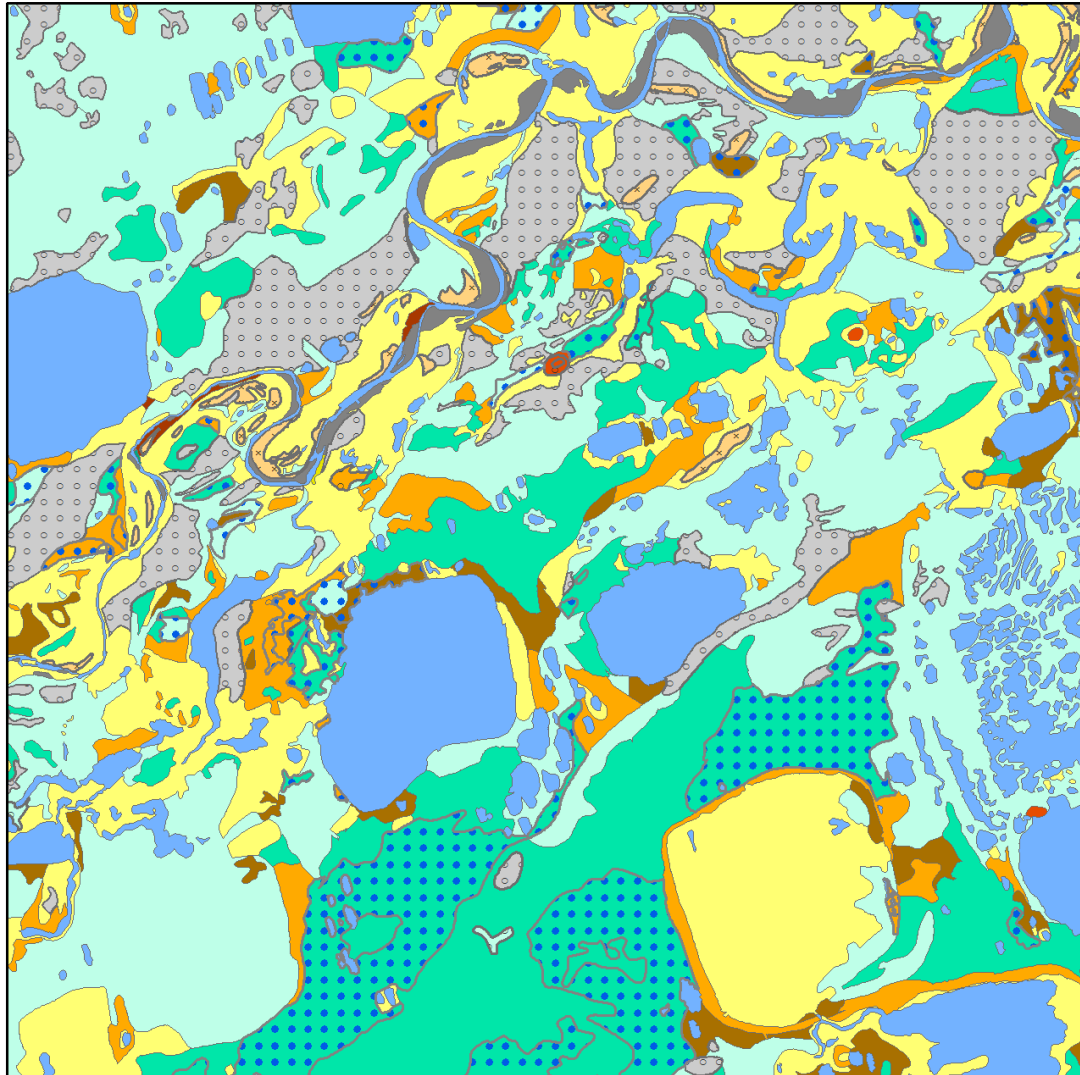
Mapping of geobotanical attributes before development



Primary Vegetation

- Water
- Aquatic grass marsh
- Aquatic sedge marsh
- Wet sedge, moss tundra
- Moist nontussock-sedge, dwarf-shrub moss tundra
- Moist low shrubland
- Dry prostrate dwarf-shrub, lichen tundra
- Dry prostrate dwarf-shrub, forb, grass tundra
- Barren

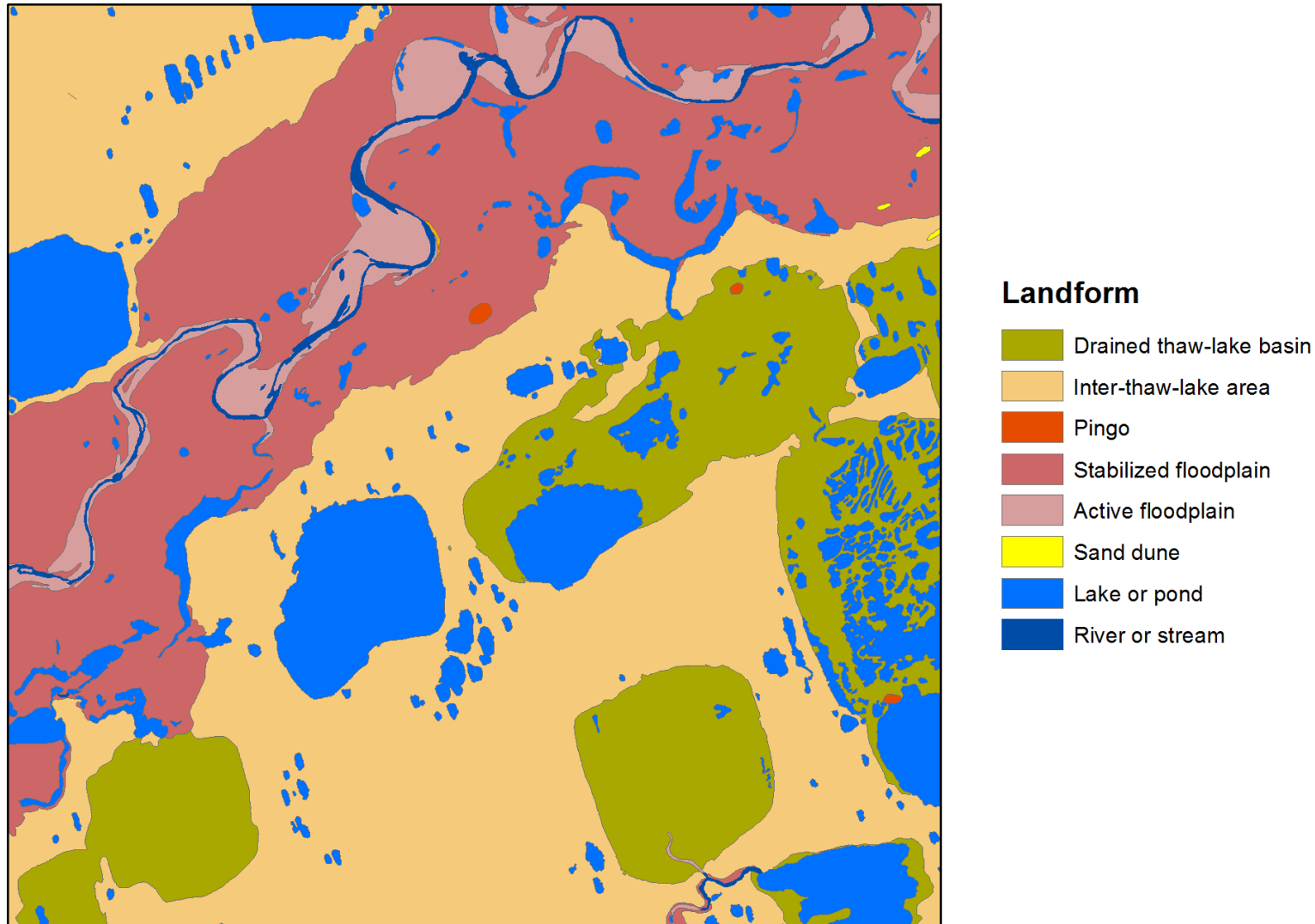
Mapping of geobotanical attributes before development



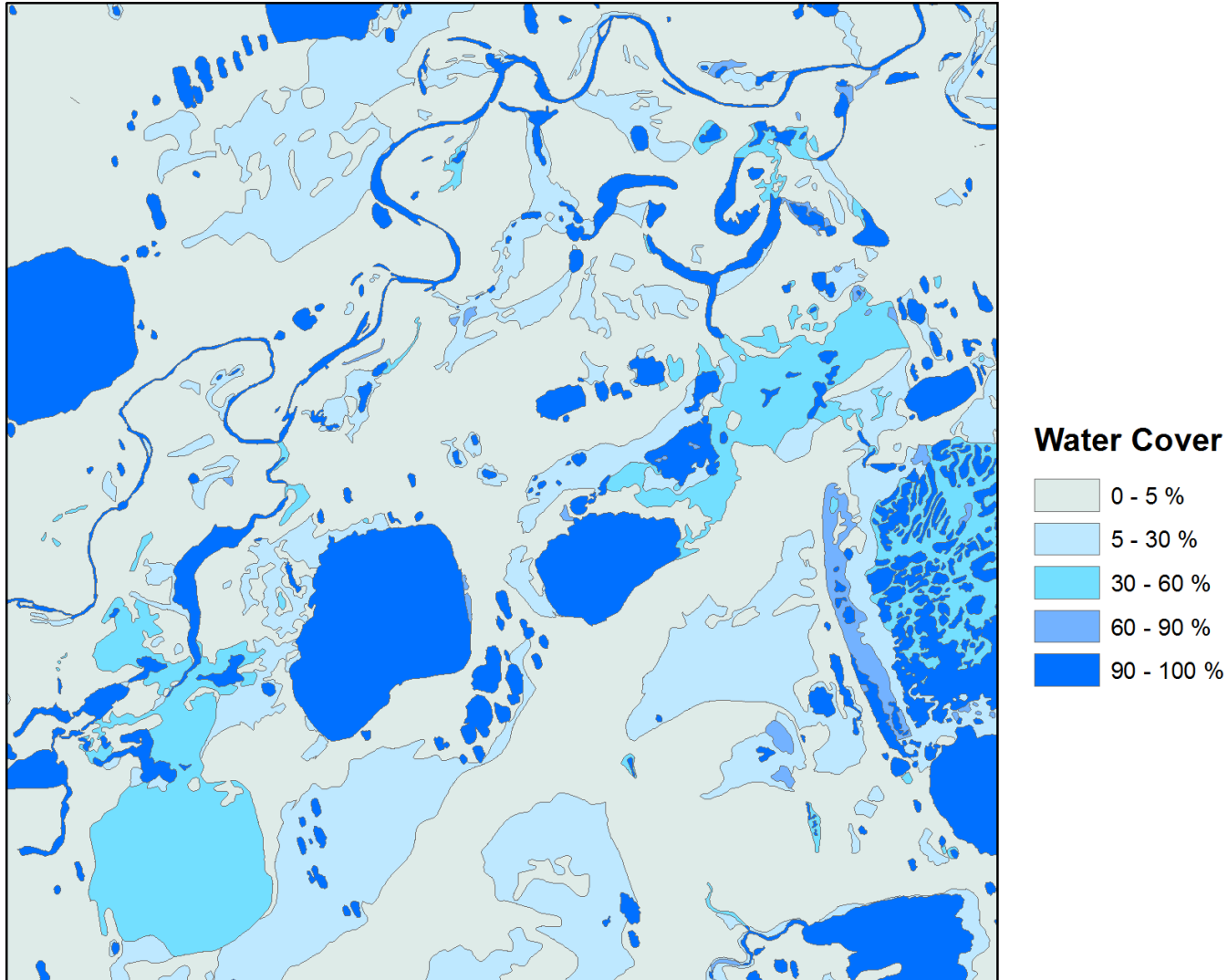
Surface Form

- Low-centered polygons relief > 0.5 m
- Low-centered polygons relief < 0.5 m
- Low-centered polygons with thermokarst pits
- Strangmoor
- Mixed high- and low-centered polygons
- High-centered polygons
- Pingo
- Non-patterned ground
- Reticulate patterned ground
- Frost scars
- Floodplain alluvium
- Water

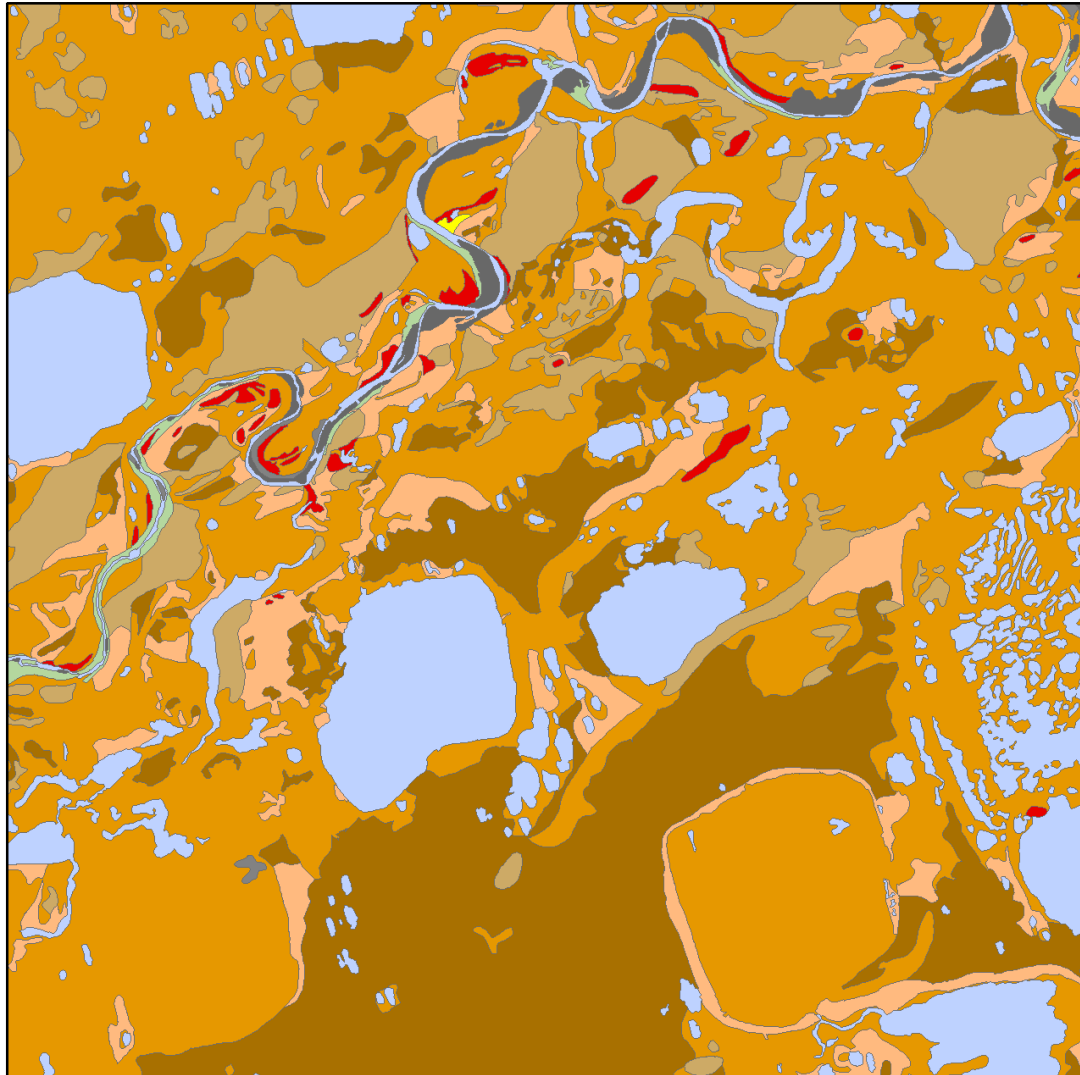
Mapping of geobotanical attributes before development



Mapping of geobotanical attributes before development



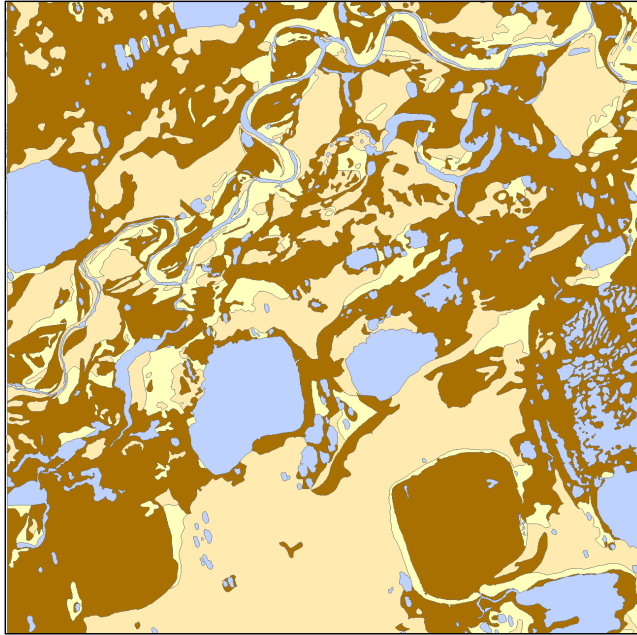
Mapping of geobotanical attributes before development



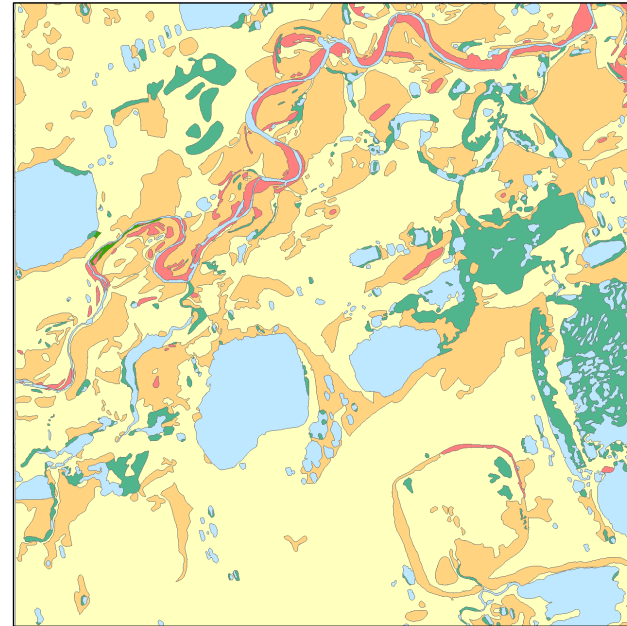
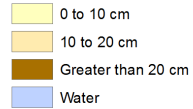
Soil

- Pergelic Cryoborolls
- Pergelic Cryaquolls or Cryosaprists
- Complex of a) Pergelic Cryohemists or Cryofibrists, b) Histic Pergelic Cryaquepts, c) Pergelic Cryaquepts
- Association of a) Pergelic Cryohemists or Cryofibrists or Histic Pergelic Cryaquepts, b) Pergelic Cryosaprists or Cryaquolls
- Association of a) Pergelic Cryaquolls or Cryosaprists, b) Pergelic Cryaquepts (frost boils)
- Pergelic Cryorthents
- Pergelic Cryopsammments
- Pergelic Cryaquepts
- Floodplain Alluvium
- Water

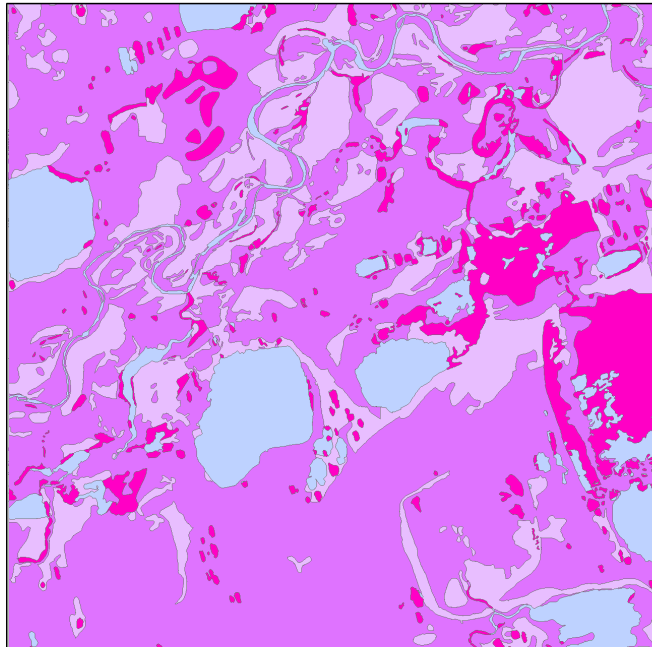
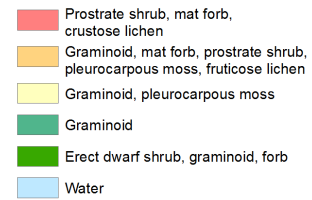
Maps derived from geobotanical maps



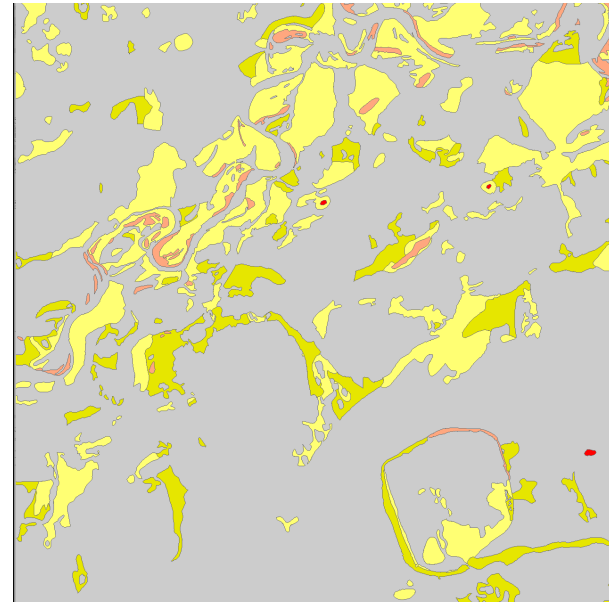
Peat
Thickness



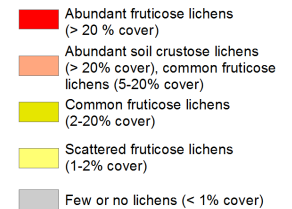
Plant
Growth
Form



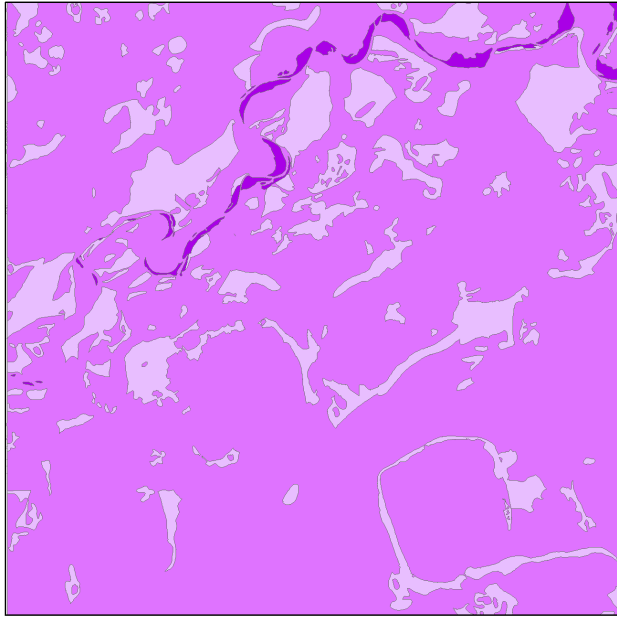
Breeding
Bird
Density



Lichen
Distribution

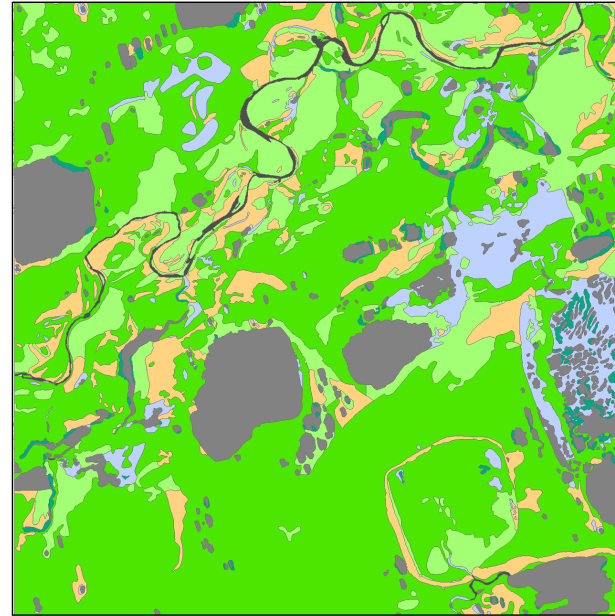


Maps derived from geobotanical maps



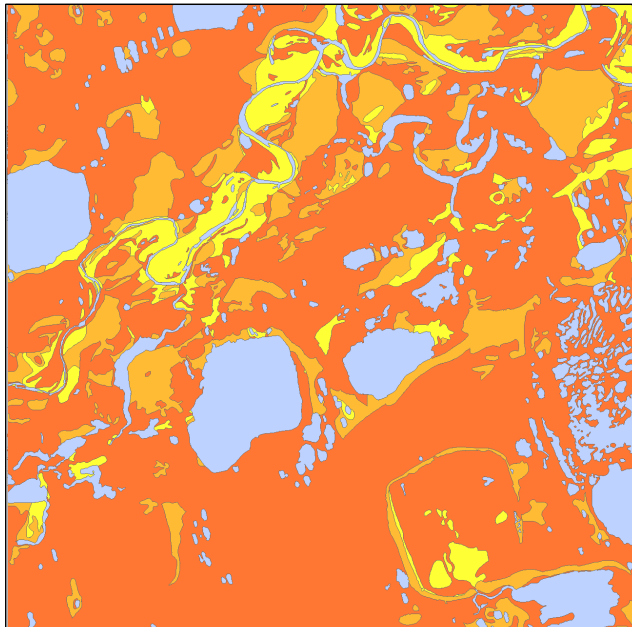
Snow Depth

- Less than 30 cm
- 30 to 60 cm
- Greater than 60 cm



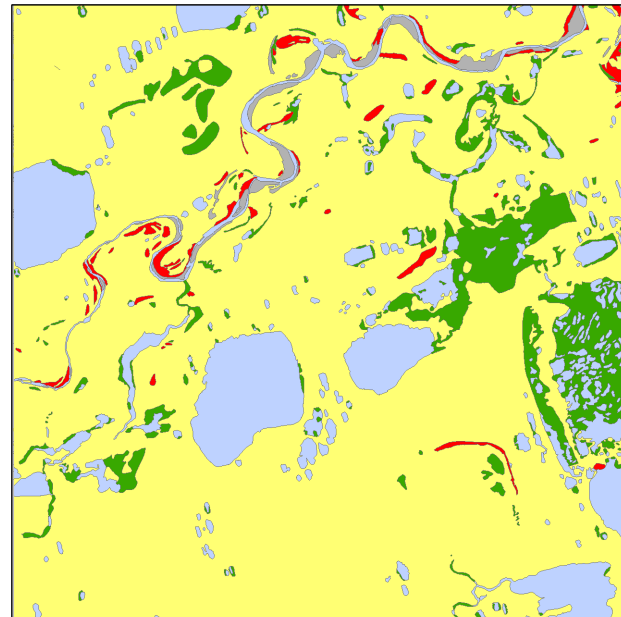
Water and Wet Terrain

- Flowing water (streams and rivers)
- Lakes and ponds with no vegetation; > 50 cm deep
- Lakes and ponds with aquatic grass; water 30 to 100 cm deep
- Lakes and ponds with sedges; water 15 to 30 cm deep
- Perennial standing water < 15 cm deep; often with polygonal or strangmoor landform features
- Transitional wet terrain; water table at or above surface early in summer, below surface by mid-summer
- Upland areas; water table absent or coincident with permafrost table all summer



Off-Road Vehicle Sensitivity

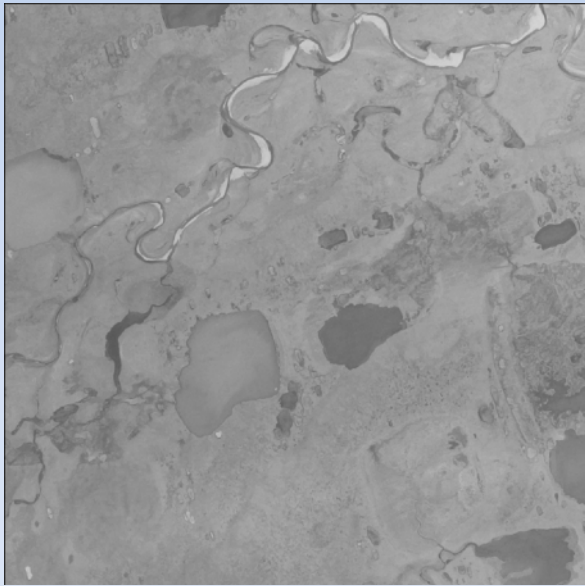
- High
- Moderate
- Low
- Water



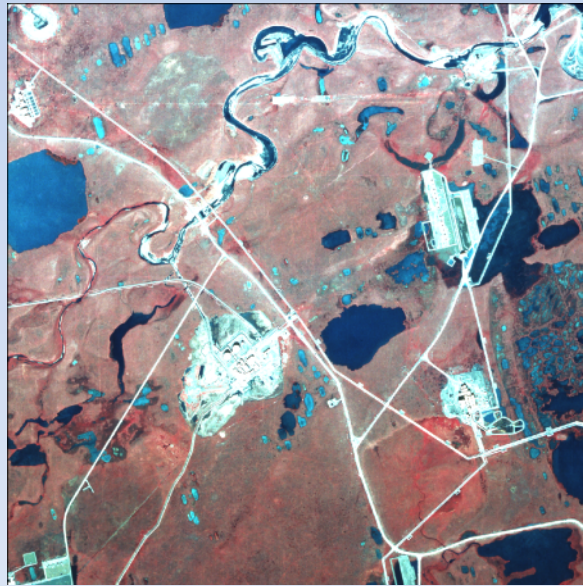
Oil Spill Recovery Potential

- Good to excellent
- Moderate
- Poor
- River gravel
- Water

Time series of aerial photography available from pre-development to present



1965 black & white



1982 color-infrared



2010 true color

Digitized polygons of pre-development geobotanical features and subsequent changes



GIS Attributes

- Vegetation
- Soils
- Landform
- Water
- Human disturbance
(for each year)
- Natural disturbance
(for each year)



Industrial Disturbance 1970

- Gravel road
- Peat road
- Gravel pad
- Continuous flooding
- Discontinuous flooding
- Deep tracks
- Shallow tracks
- >75% gravel debris
- < 75% gravel debris
- Excavation
- Barren tundra due to flooding



Industrial Disturbance 1972

- Gravel road
- Peat road
- Gravel pad
- Continuous flooding
- Discontinuous flooding
- Deep tracks
- Shallow tracks
- >75% gravel debris
- < 75% gravel debris
- Excavation
- Barren tundra due to flooding



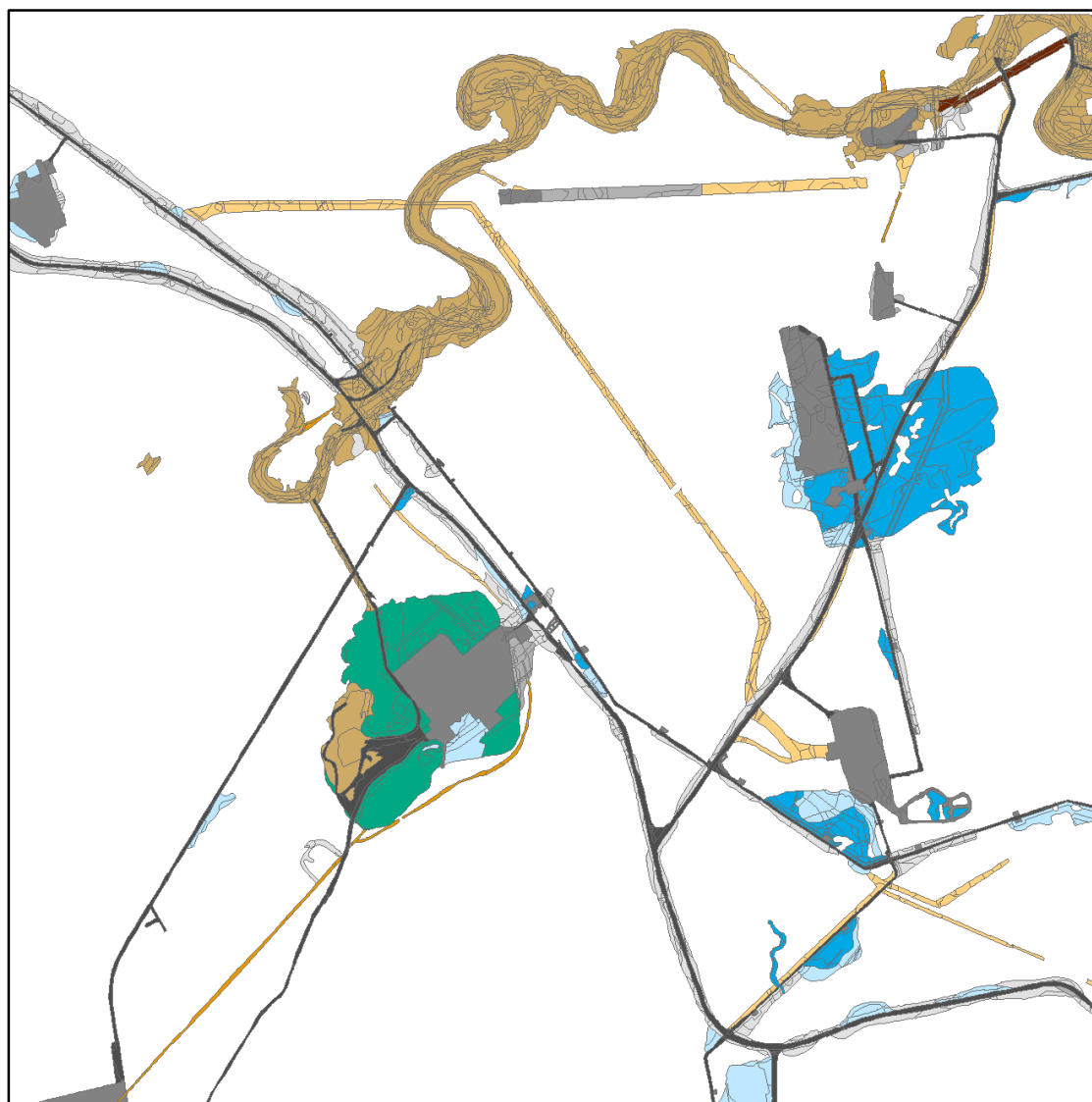
Industrial Disturbance 1973

- Gravel road
- Peat road
- Gravel pad
- Continuous flooding
- Discontinuous flooding
- Deep tracks
- Shallow tracks
- >75% gravel debris
- < 75% gravel debris
- Excavation
- Barren tundra due to flooding



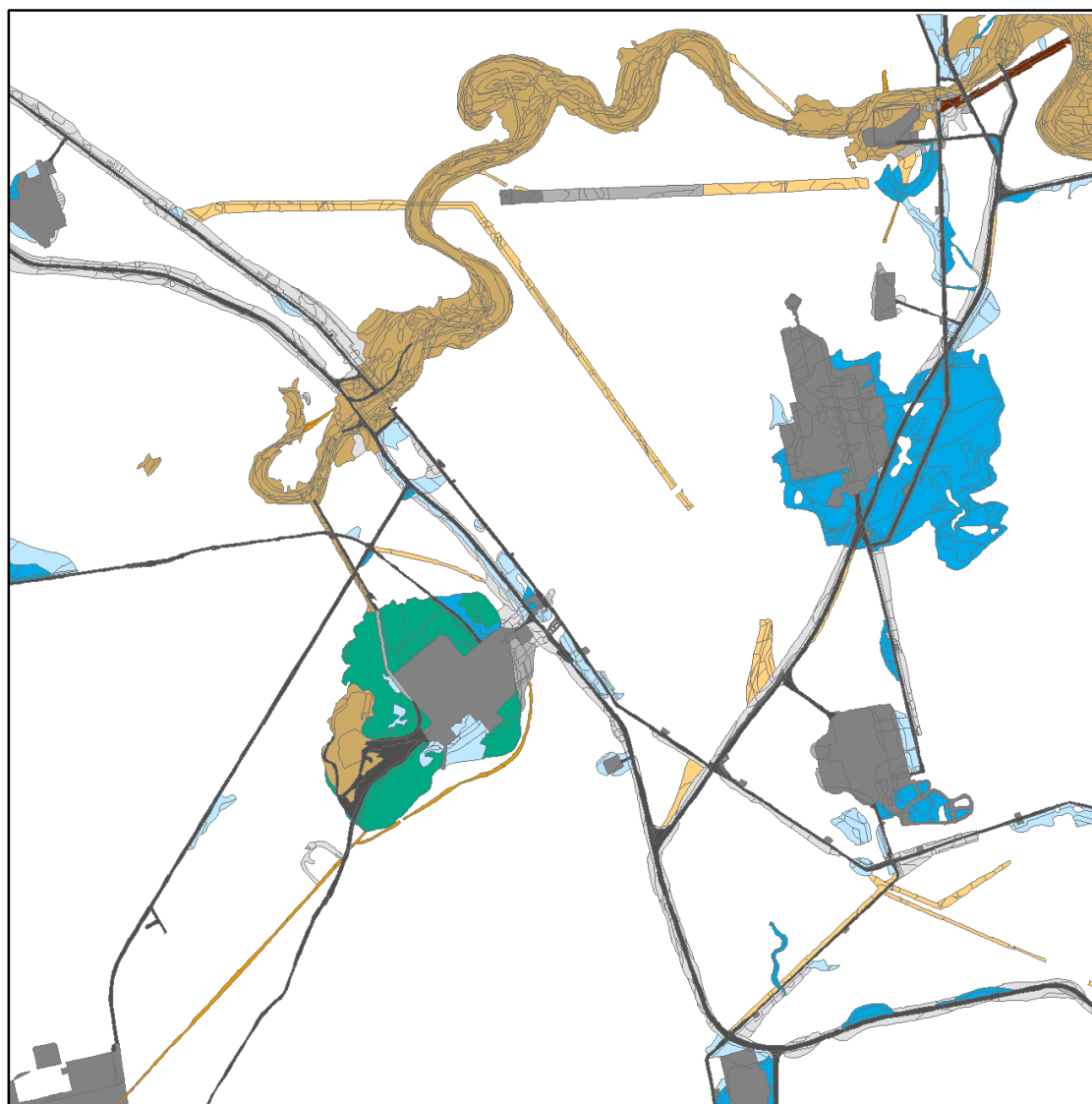
Industrial Disturbance 1977

- Gravel road
- Peat road
- Gravel pad
- Continuous flooding
- Discontinuous flooding
- Deep tracks
- Shallow tracks
- >75% gravel debris
- < 75% gravel debris
- Excavation
- Barren tundra due to flooding



Industrial Disturbance 1979

- Gravel road
- Peat road
- Gravel pad
- Continuous flooding
- Discontinuous flooding
- Deep tracks
- Shallow tracks
- >75% gravel debris
- < 75% gravel debris
- Excavation
- Barren tundra due to flooding



Industrial Disturbance 1983

- Gravel road
- Peat road
- Gravel pad
- Continuous flooding
- Discontinuous flooding
- Deep tracks
- Shallow tracks
- >75% gravel debris
- < 75% gravel debris
- Excavation
- Barren tundra due to flooding



Industrial Disturbance 1990

- Gravel road
- Peat road
- Gravel pad
- Continuous flooding
- Discontinuous flooding
- Increase thermokarst pits
- Deep tracks
- Shallow tracks
- >75% gravel debris
- < 75% gravel debris
- Excavation
- Barren tundra due to flooding
- Pipeline
- Powerline



Industrial Disturbance 2001

- Gravel road
- Peat road
- Gravel pad
- Continuous flooding
- Discontinuous flooding
- Increase thermokarst pits
- Deep tracks
- Shallow tracks
- >75% gravel debris
- < 75% gravel debris
- Excavation
- Barren tundra due to flooding
- Pipeline
- Powerline

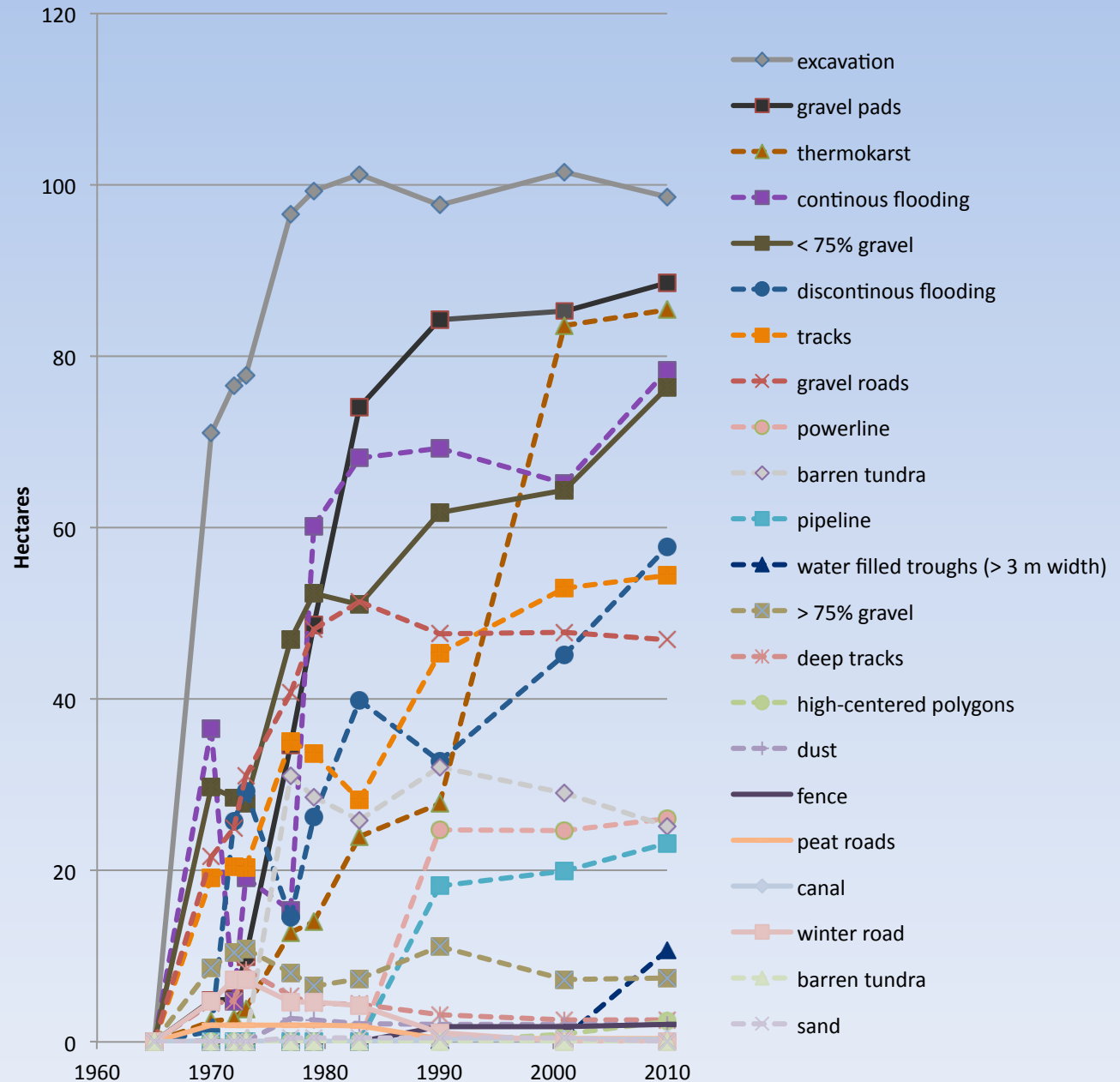


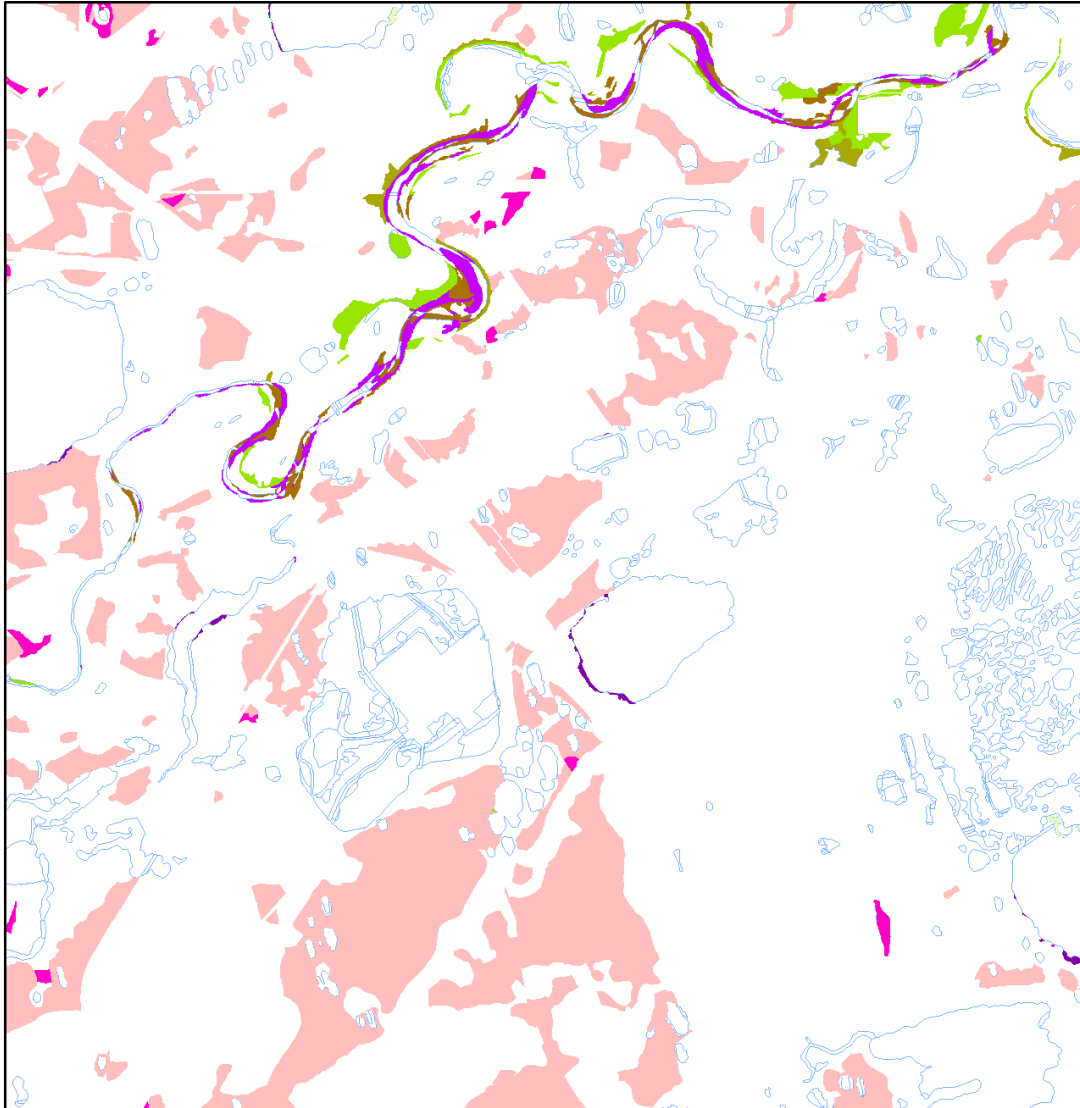
Industrial disturbance 2010

- Gravel road
- Peat road
- Gravel pad
- Continuous flooding
- Discontinuous flooding
- Increase thermokarst pits
- Deep tracks
- Shallow tracks
- >75% gravel debris
- < 75% gravel debris
- Excavation
- Drained lake bed
- Pipeline
- Powerline
- Fence
- Canal
- Ice-wedge degradation
- Ice-wedge loss









Disturbance due to industrial development

A total of 689 ha were affected by industrial development by 2010, 33% of the study area.



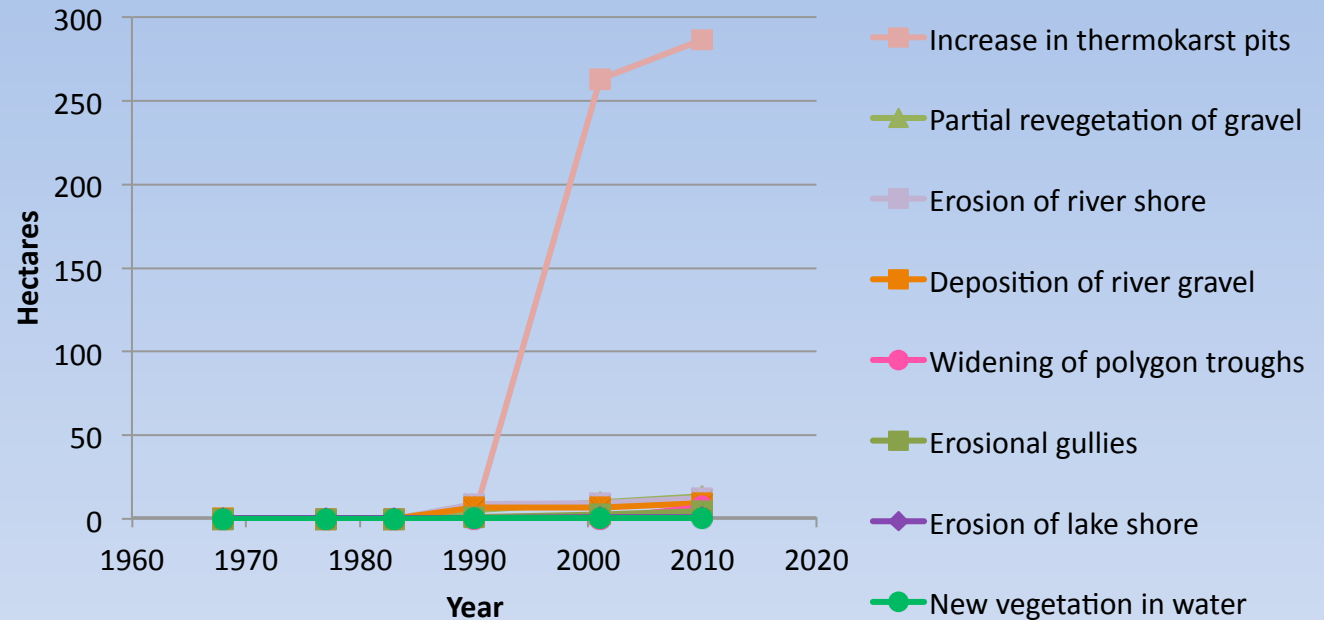


Other Historical Changes

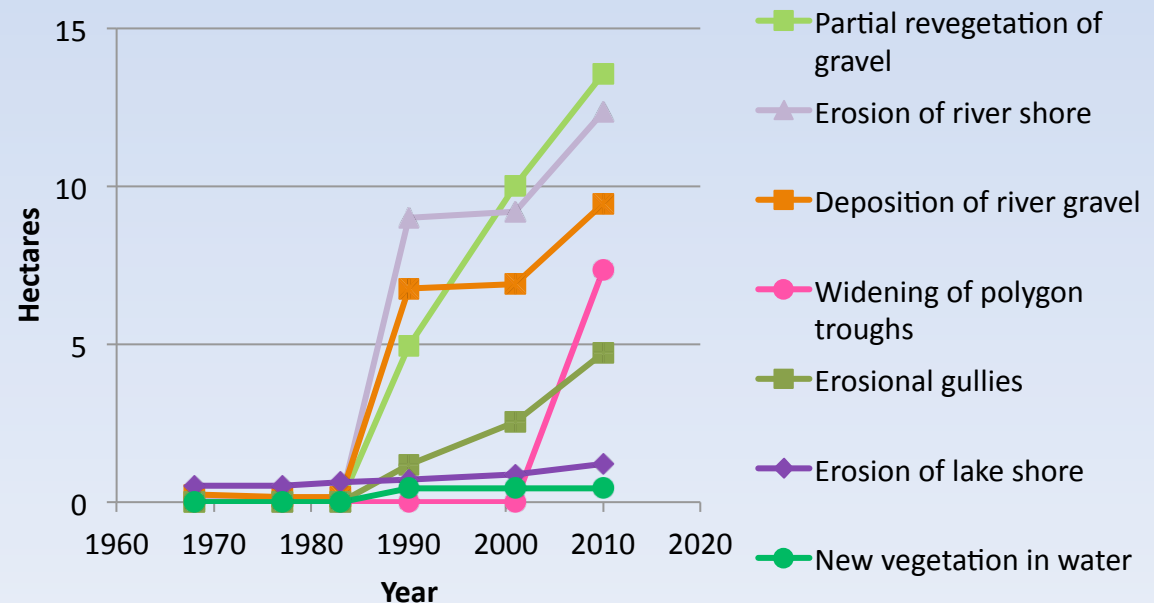
-  Increase in thermokarst pits
-  Partial revegetation of gravel
-  Erosion of river shore
-  Erosion of lake shore
-  Widening of polygon troughs
-  Deposition of river gravel
-  Erosional gullies
-  New vegetation in water

An increase in the standing water in the troughs between polygons due to permafrost degradation and melting of ice wedges and ice-rich frozen soils affected 287 ha in 2010, 14% of the study area.

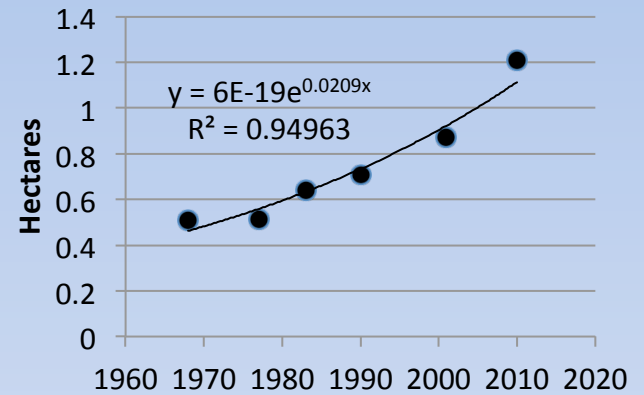
Area of change from causes other than oilfield development



Area of change, excluding thawing of ice-wedges



Total lake shore erosion for Map 32



Erosion of Lake Shore 1949-2010

1949

1968

1977

1990

2010

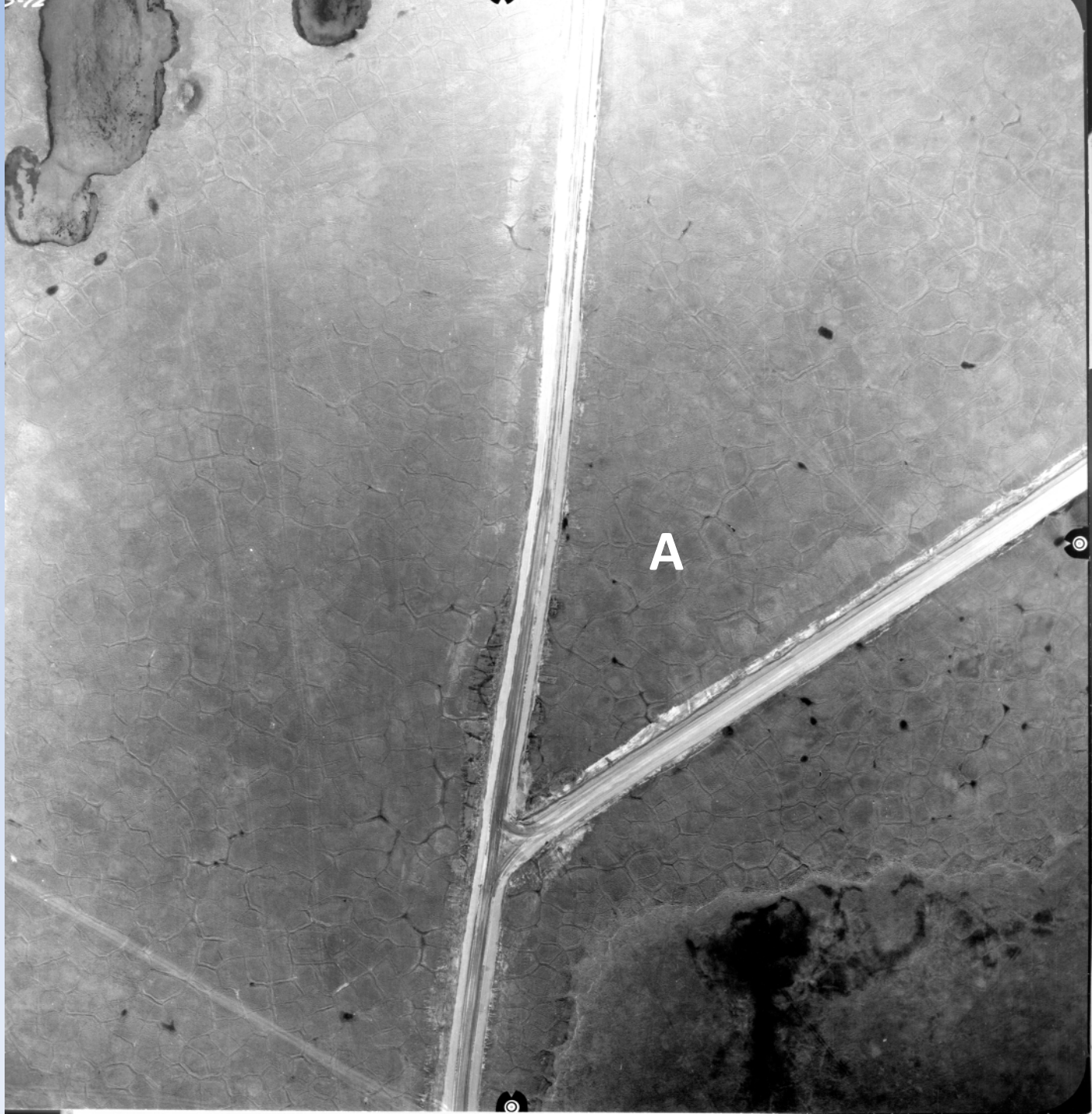
Permafrost degradation

1972 black & white 1:3,00



**2010 true color digital
(10 cm resolution)**

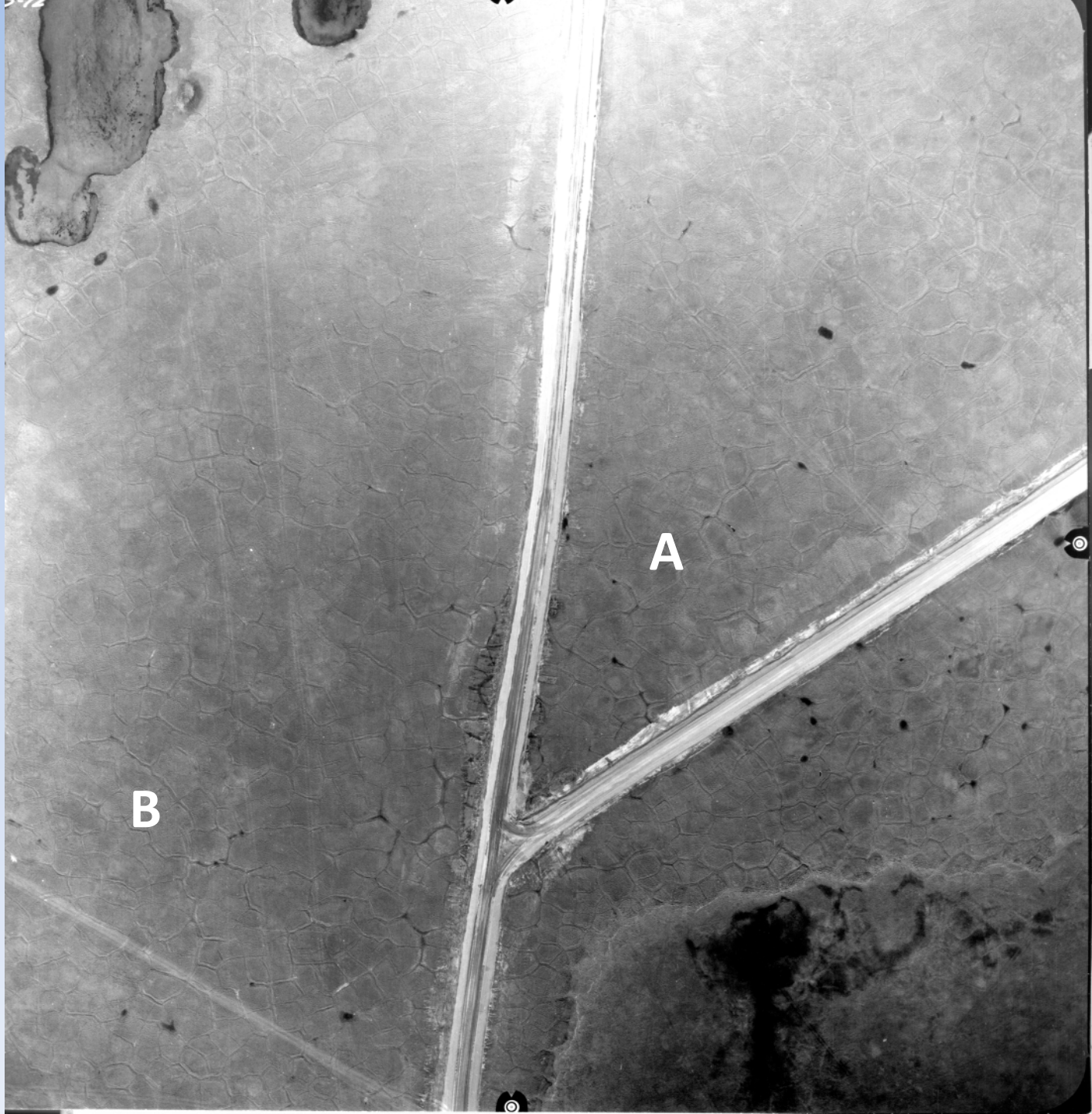




A



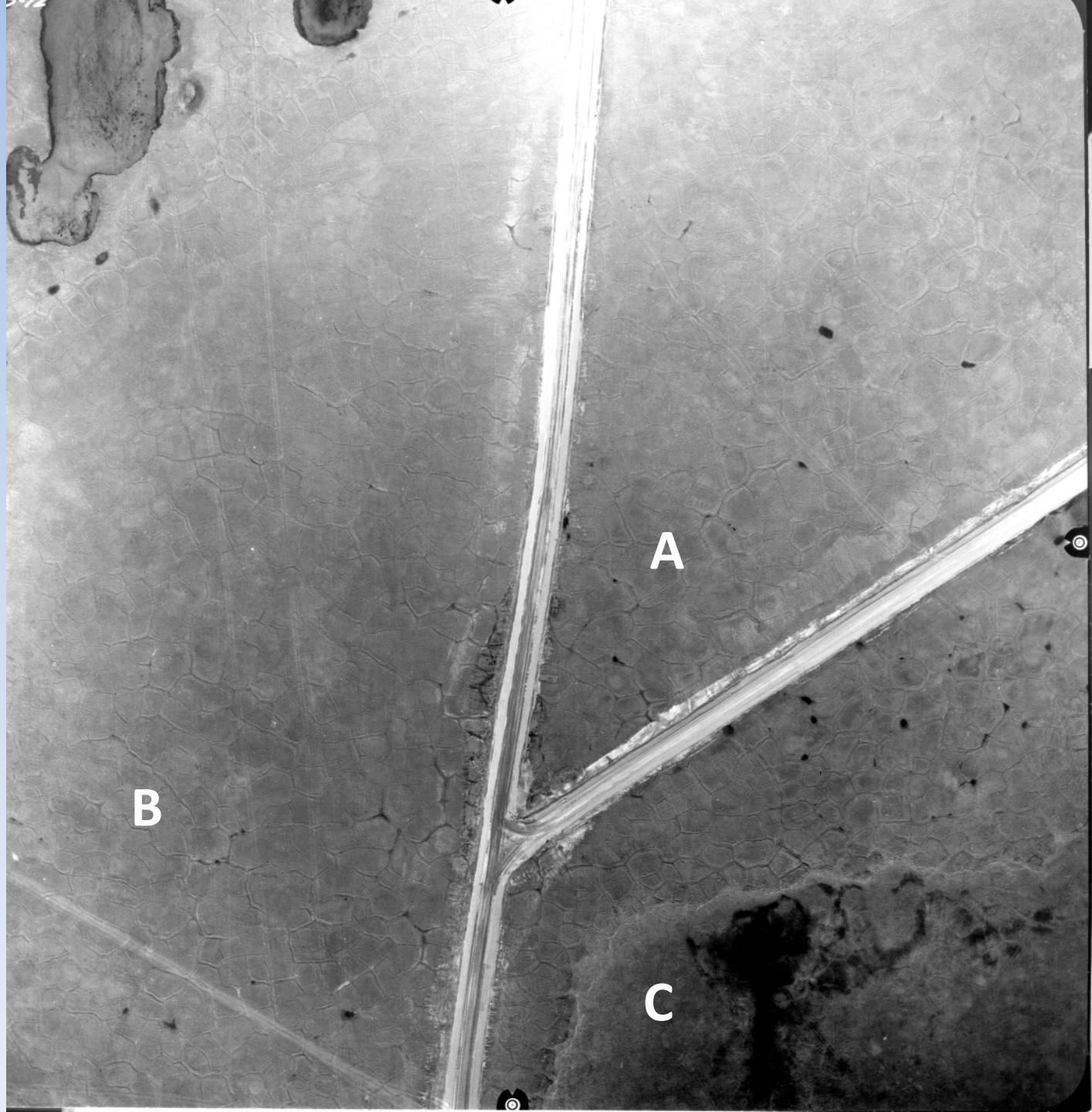
A





A

B





A

B

C

Plans for future analysis

- Develop more quantitative techniques to measure changes in thermokarst features
- Assess the relationship of thermokarst to infrastructure and various geobotanical features
- Apply similar methods to the other two map areas at Prudhoe Bay and several North Slope villages
- Partner with Indigenous Knowledge holders to document local-scale observations and implications of change
- Assess the utility of Landsat and Quickbird imagery to provide broad-area assessments of infrastructure and landscape changes that could be applied to the entire area of development on the North Slope

Major Findings

- The integrated geobotanical and historical disturbance mapping can be brought into geodatabase format and updated with recent imagery to extend the time-span of the change analysis.
- Most of the oilfield infrastructure was built between 1972 and 1983, but indirect impacts such as flooding and permafrost degradation continued to expand over the next 27 years.
- Lake shore erosion continues to increase, non-linearly.
- There was a large increase in the area showing surface effects of permafrost degradation between 1990 and 2001, possibly the result of reaching some “tipping point”.

Acknowledgements

Thanks to William Streever and BP Alaska Environmental Studies for providing recent imagery of the study area.

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Kiitos!

СПАСИБО!

Questions?