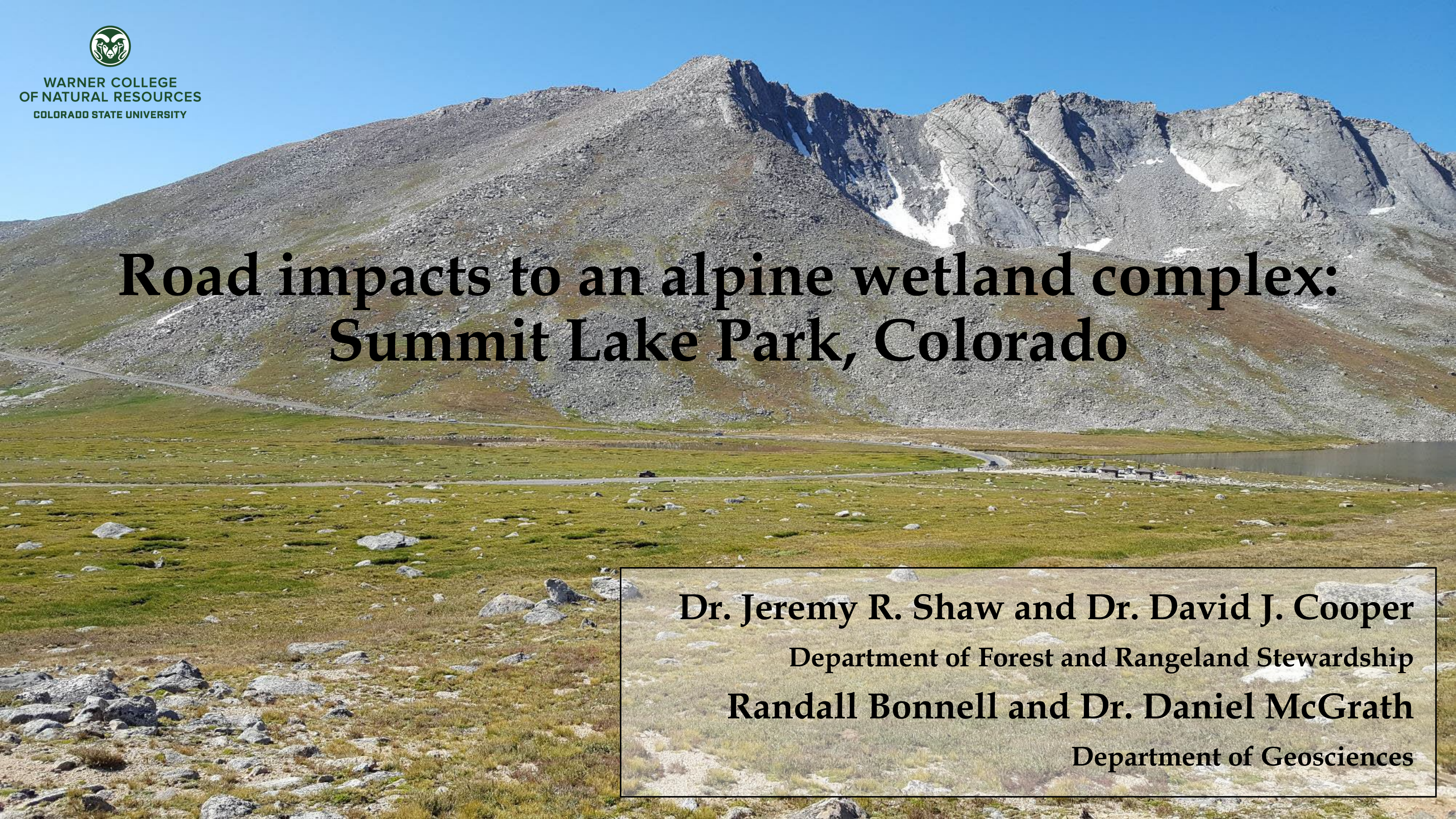

WARNER COLLEGE
OF NATURAL RESOURCES
COLORADO STATE UNIVERSITY

# Road impacts to an alpine wetland complex: Summit Lake Park, Colorado

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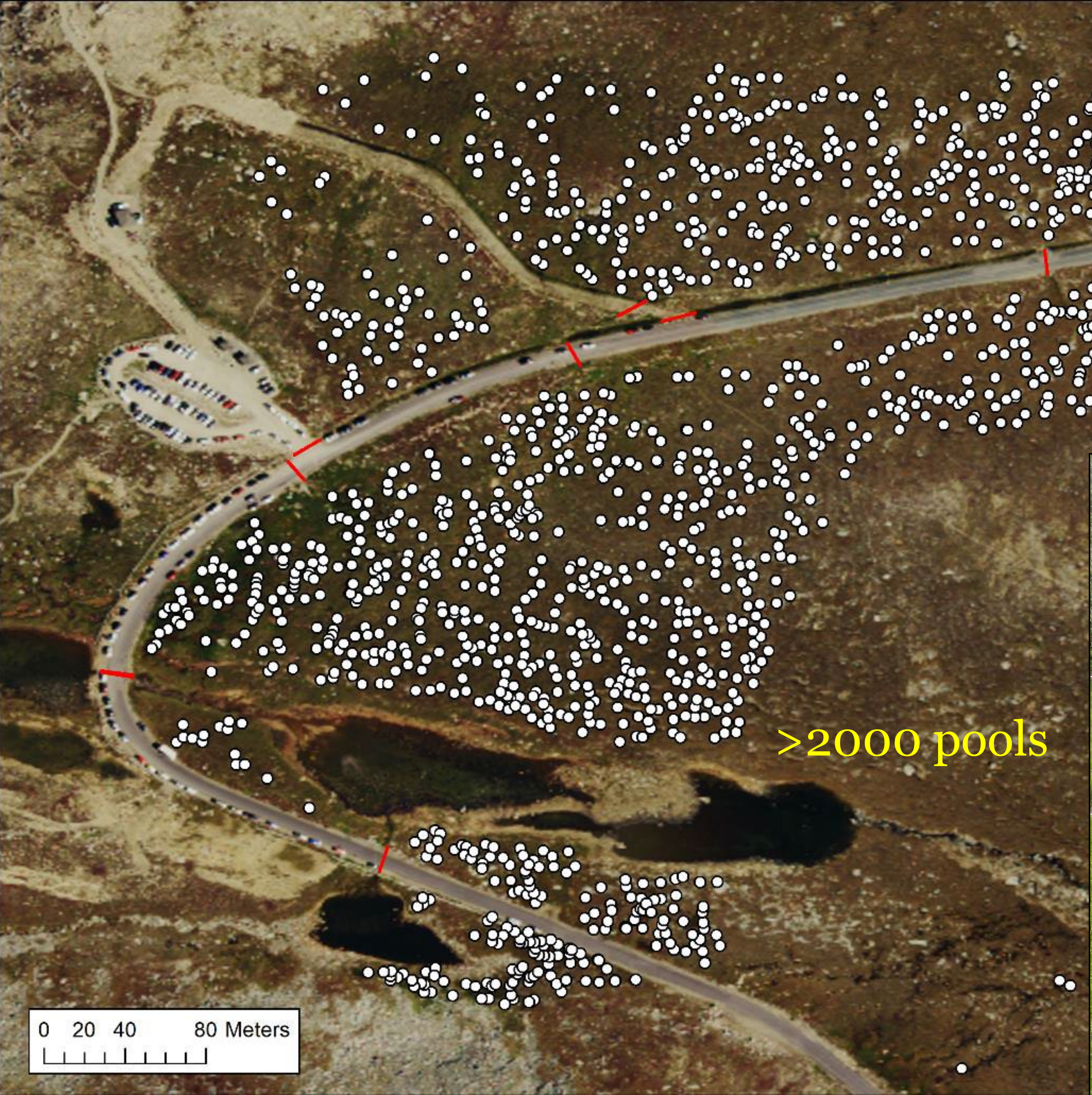
# Summit Lake Park Wetland Complex

- National Natural Landmark
- ~50 ac mosaic of wet & dry meadow, alpine tundra
- 12,800-13,100 ft elevation
- East-facing cirque shaded by summit, supports cool moist stable environment
- Supports rare & arctic disjunct plant species
- Silt-rich unsorted glacial sediment, full of large boulders
- Discontinuous permafrost perches water table in many areas
- Largest complex of **"alpine pools"** known in the Rocky Mountains


Windblown Fellfields
~Wetland & Upland Mosaic~

# **Microtopography** (20-40 cm) creates mosaic of wetland and upland communities


>2000 pools
0 20 40 80 Meters


Aapa mire – string fen,
Alberta


Sloping fen with pools - Alaska

# Mount Evans Highway (SH 5)

- Highest paved road in North America
- Construction began 1923, paved with asphalt in 1950s
- Permafrost melting beneath SH5
  - Ground subsidence (~1 m)
  - Buckling, warping
- Severe freeze/thaw damage
- Reconstruction required!
  - Stakeholders suspected ongoing impacts to wetland complex
  - Redesign to protect permafrost and wetland complex

- Pavement and water increase heat transfer into the ground
  = increased thaw depth
- Uninsulated roadways & ditches can create seasonal thaw ribbon
  = potential groundwater drain

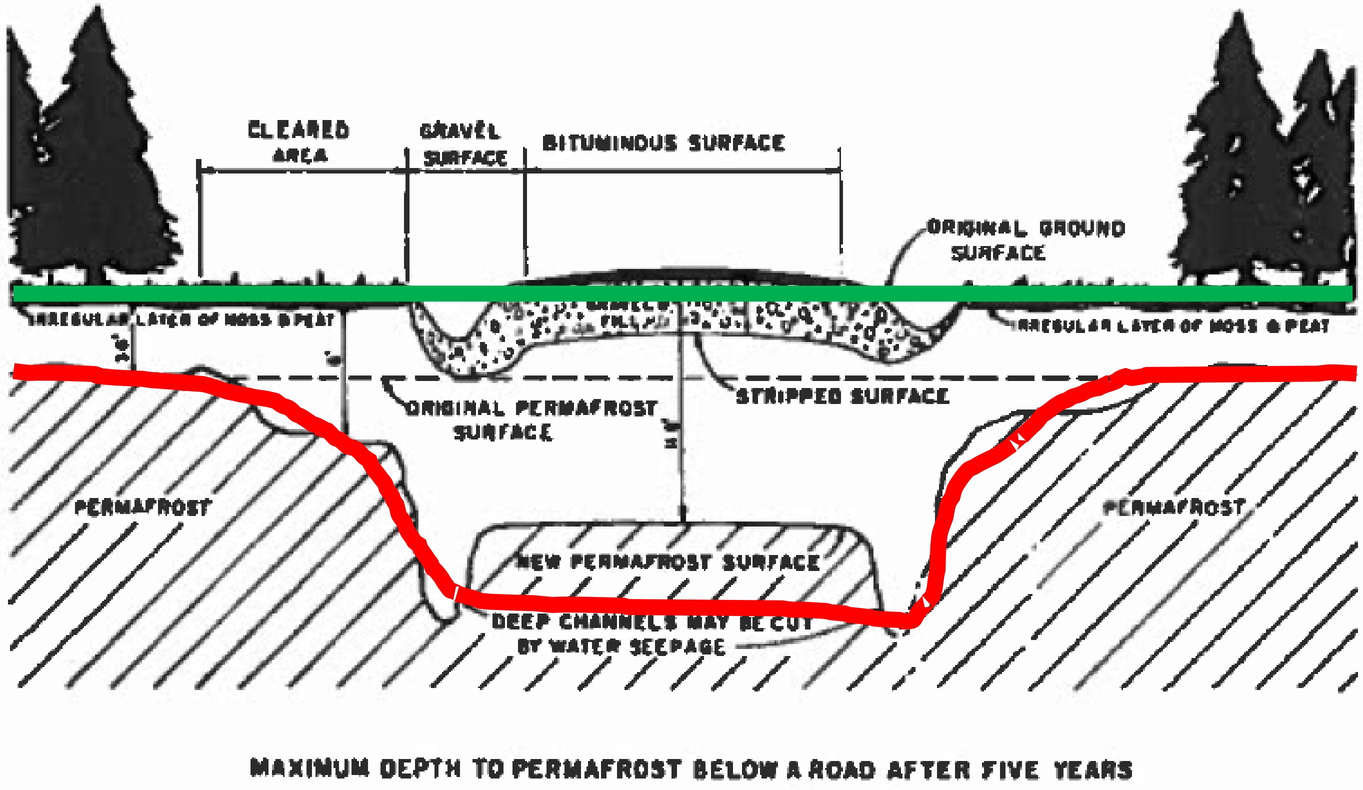



Figure 1 - Typical permafrost thaw zone under paved road (from TM 5-852-3)


DITCH

# Study Objectives

1. Assess potential effects of SH5 on:
    - Hydrologic patterns and processes
    - Permafrost thaw depth that could influence hydrologic processes
    - Vegetation composition and structure

2. Identify options to minimize hydrologic, thermal, and ecological impacts caused by roadway

# Approach to Assessing Potential Impacts

**Hydrology**

- Surface flow paths from 1 m LiDAR
- Shallow groundwater flow paths with tracer study
- Compared water levels along transects above & below road

**Permafrost**

- Thaw depth from ground penetrating radar transects

**Vegetation**

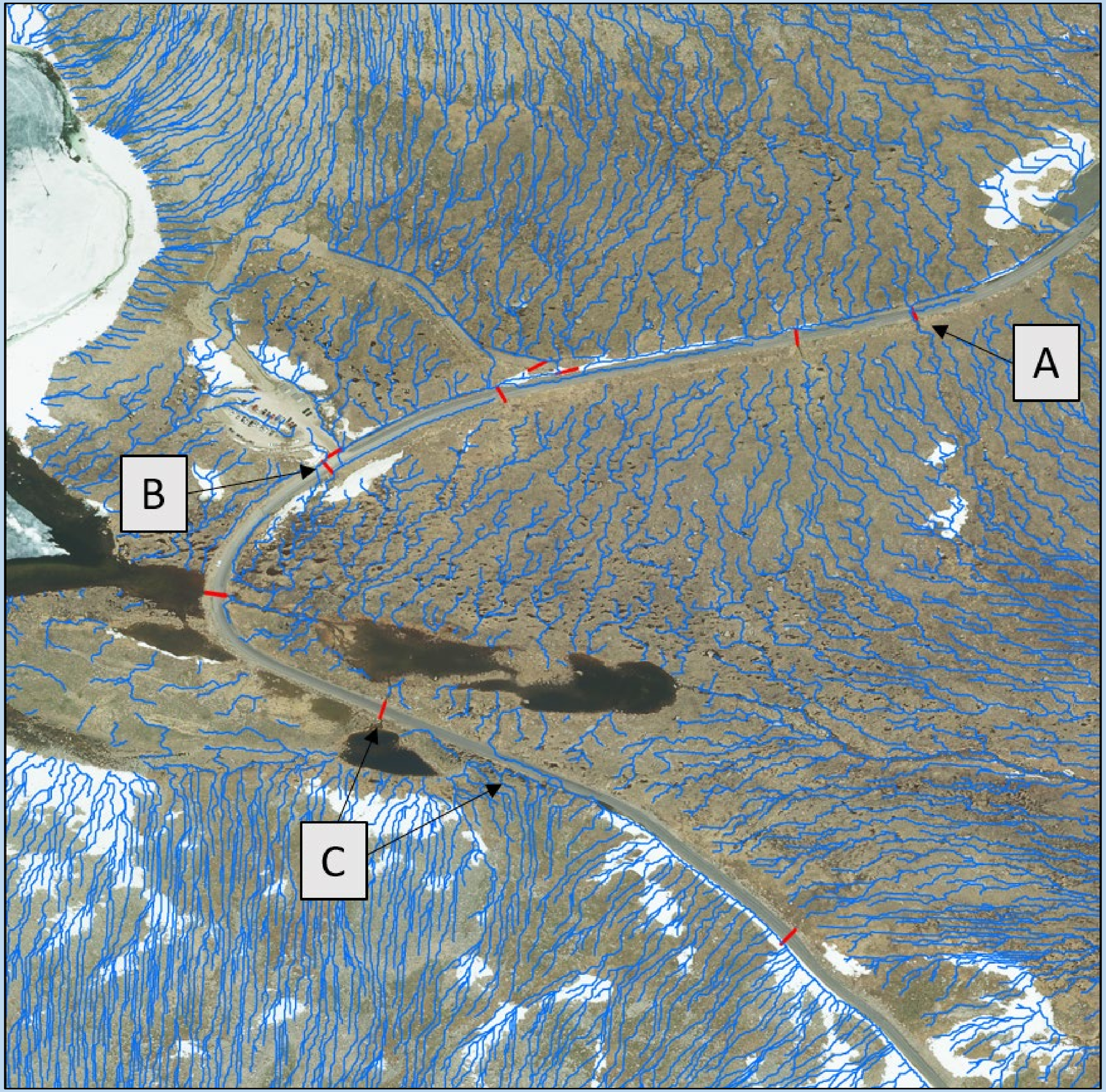
- Community composition in alpine pools

# Altered Surface Flow Paths

Roads and ditches divert nearly all surface flow paths

Widespread loss of sheetflow below roads

Runoff concentrated into 3 crossings

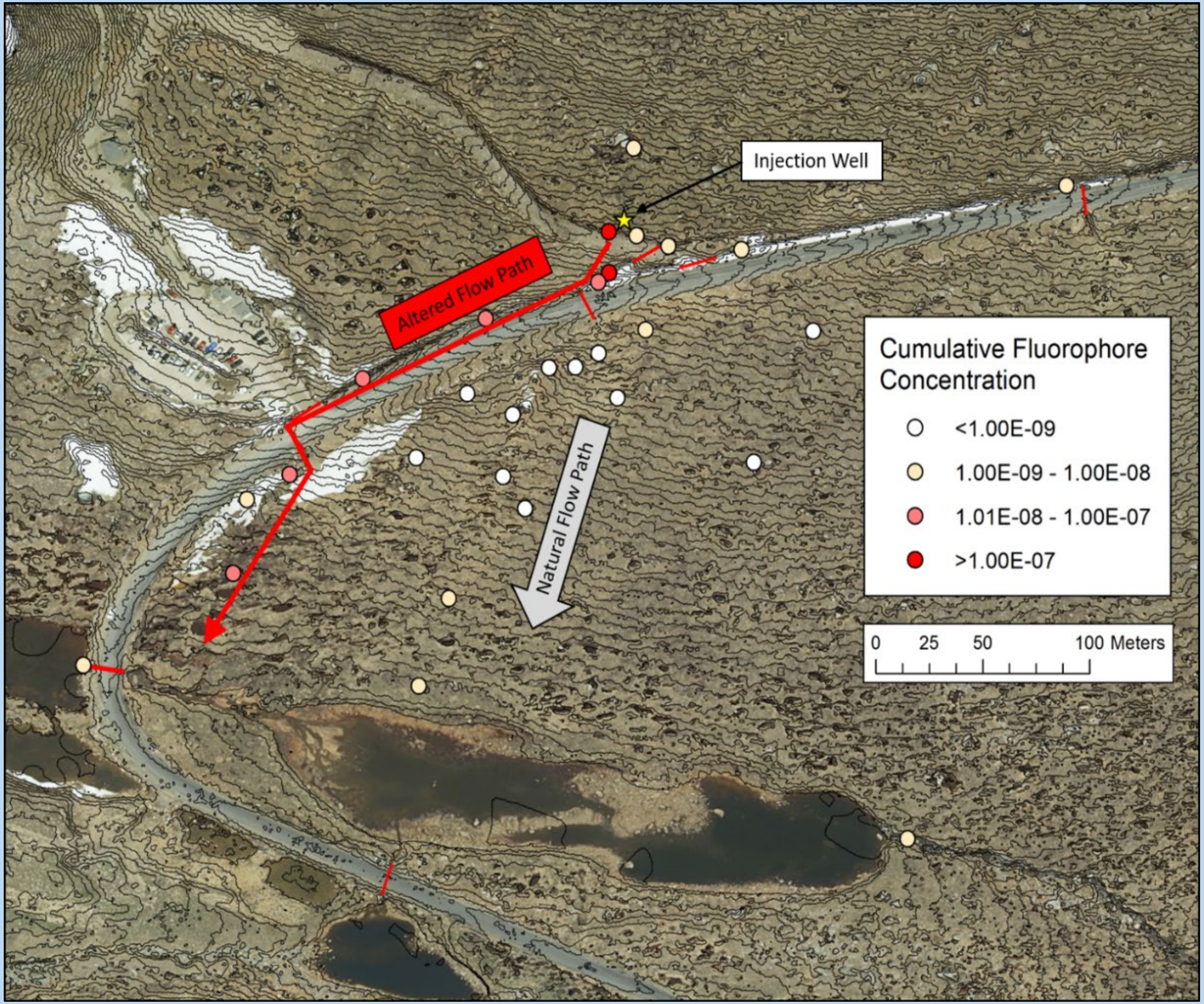


# Altered Subsurface Flow Paths

Shallow groundwater intercepted by ditch and thaw ribbon beneath road

Roadway diverts shallow groundwater

Discharged near culvert outlet to form the “fen” (flooded turf)



# Fluorescein tracer study

# 6 TRANSECTS

1: culvert ~functional

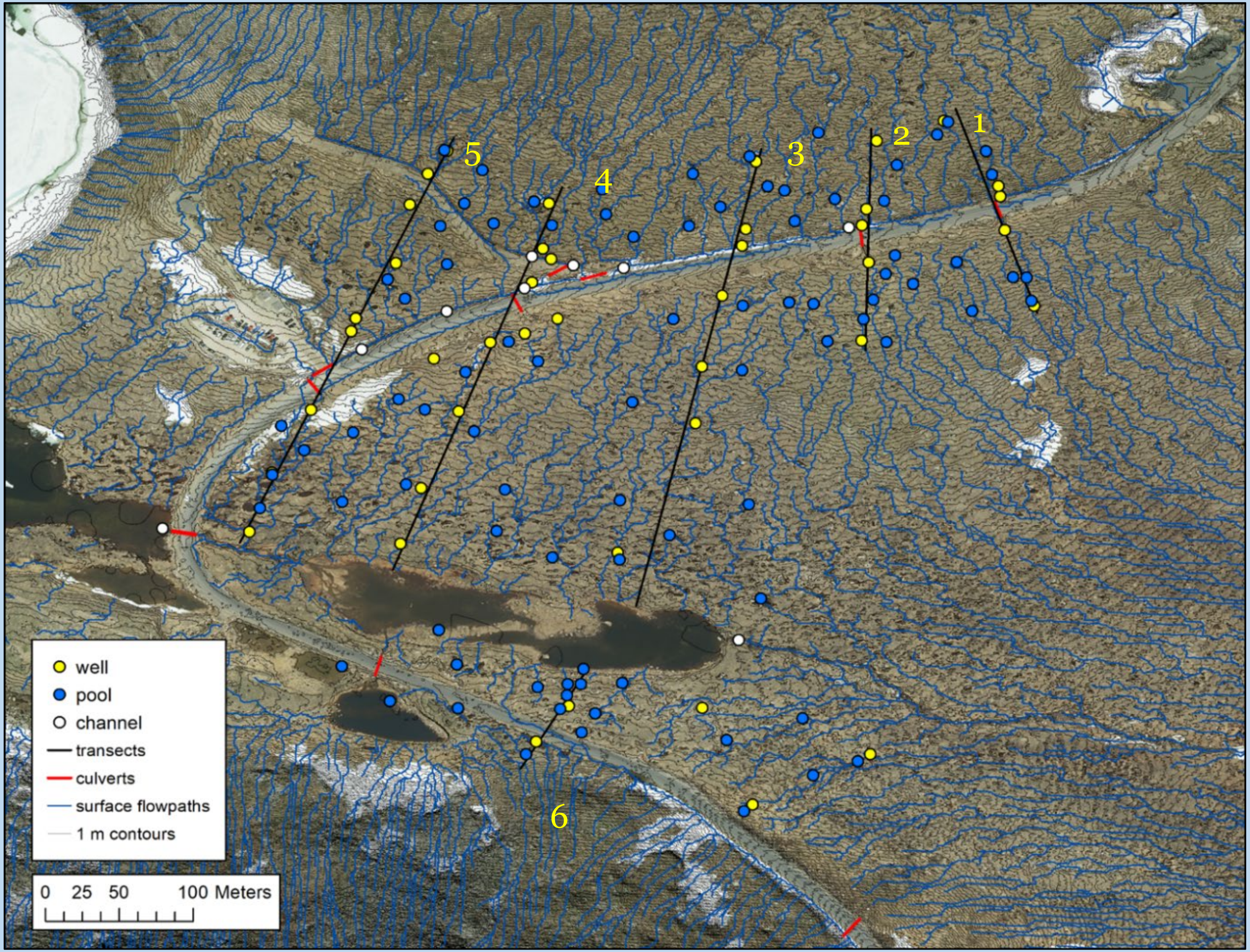
2: culvert nonfunctional

3: no culvert

4: buried culvert, nonfunctional

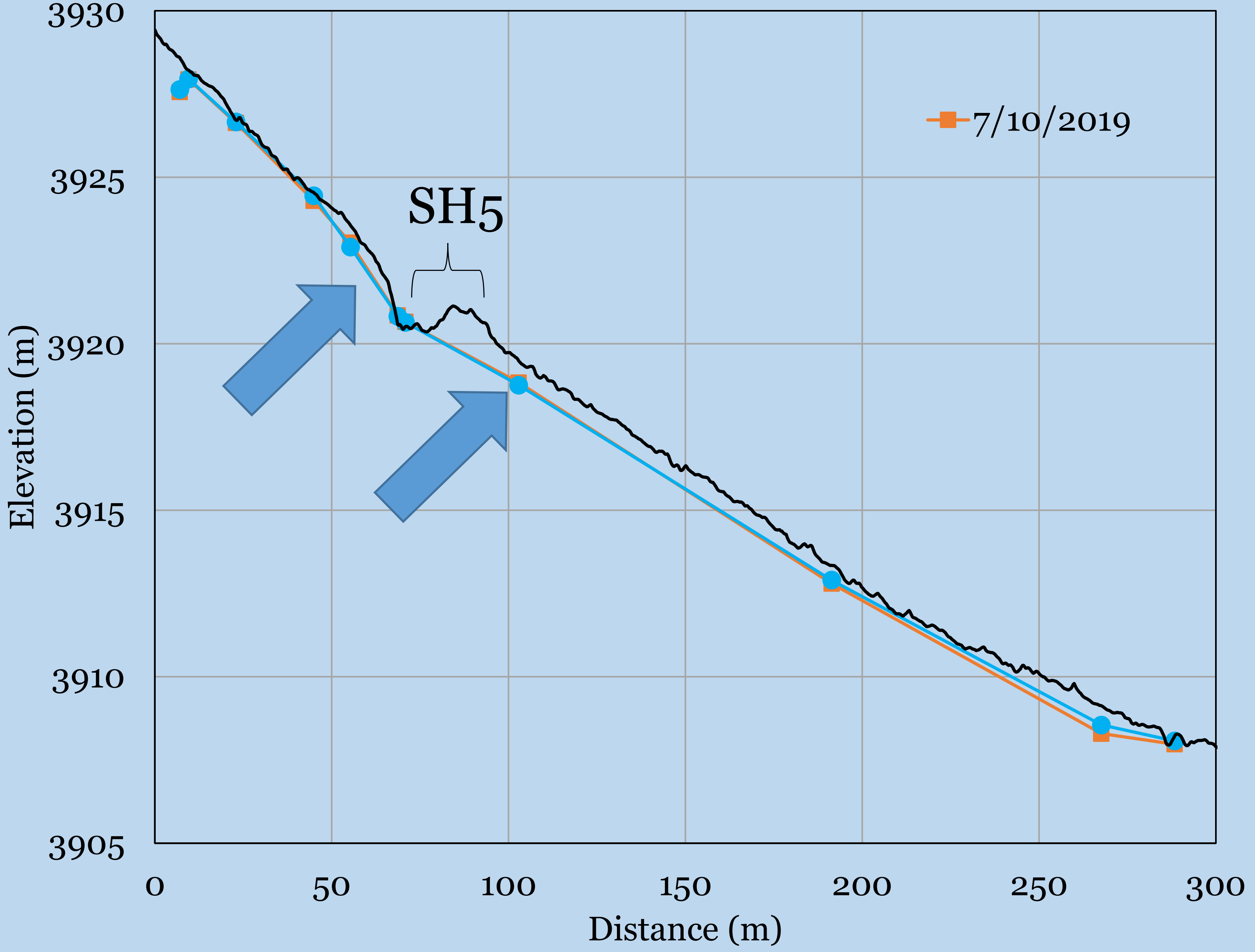
5: culvert, significant flow additions

6: no culvert, some ditch spillover



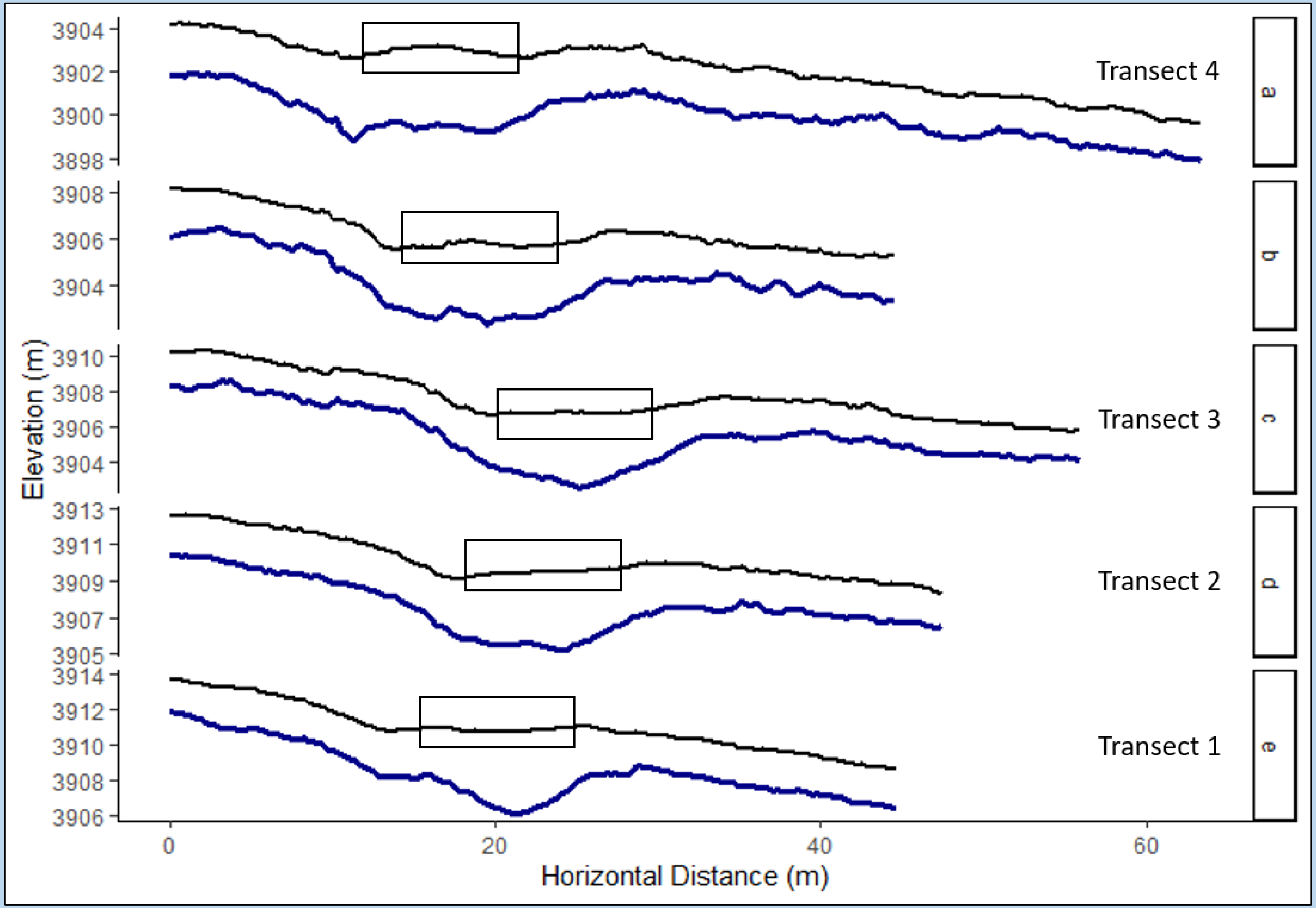
# Altered Water Table Depth (Transect 3)

- Minor groundwater drainage upslope of ditch
- Lowered water table downslope of road
- Ditches and thaw ribbon drain groundwater



# Altered Thaw Depth

- ~2 m deep outside of road corridor
- Thaw ribbon 3-6 m deep below road & ditch
- Groundwater diversion

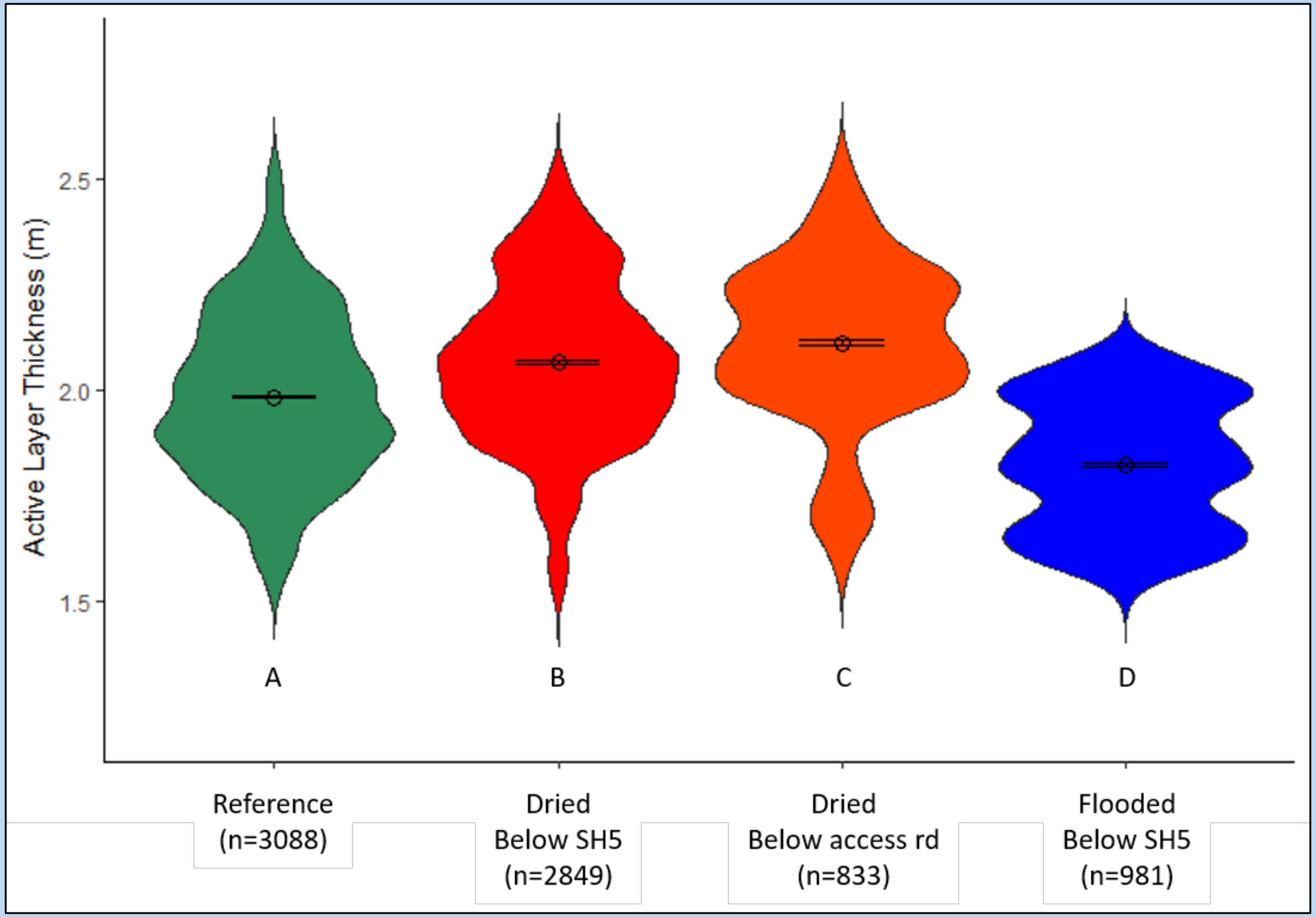


# Roads & ditches affect permafrost depth *outside of the road corridor*

Permafrost table deepest in dewatered areas below SH5 and access road

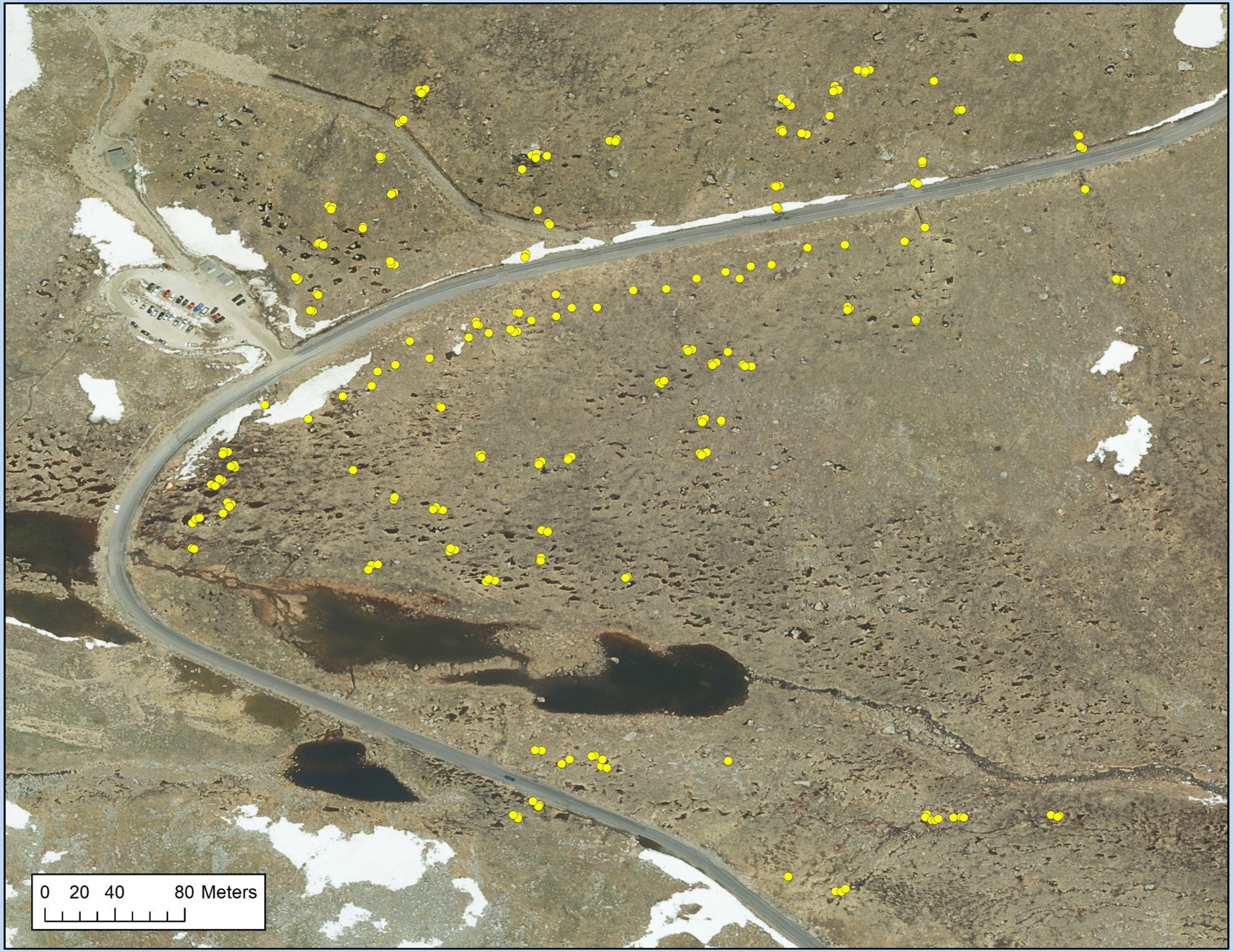
Permafrost table shallowest in flooded areas below culvert outfalls

Ice rich permafrost slower to melt than drier soil (↑ thermal mass)



# Vegetation Analysis

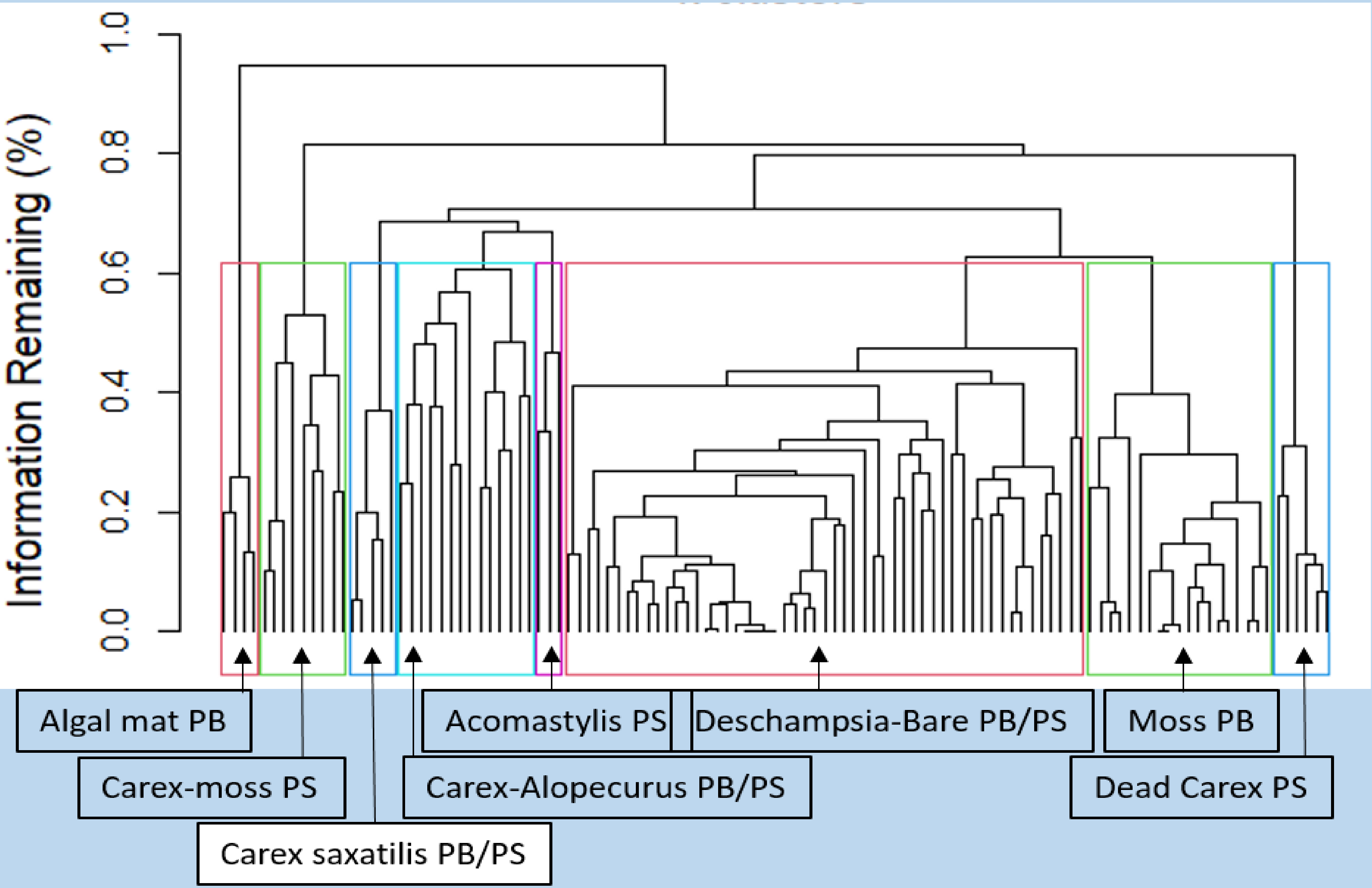
- 238 plots (1 m²)
- Turf = 112
- Pool bottoms = 63
- Pool sides = 50
- Ditch bottom = 6
- Ditch sides = 6



# Alpine pool vegetation – 8 community types

**Pool Bottoms:**

- Algal mat (perennial water)
- Sarmentypnum sarmentosum (reference)
- Vascular plants (dry)
- Bare, eroding (dry)
- Bare, dead Carex (flooded)



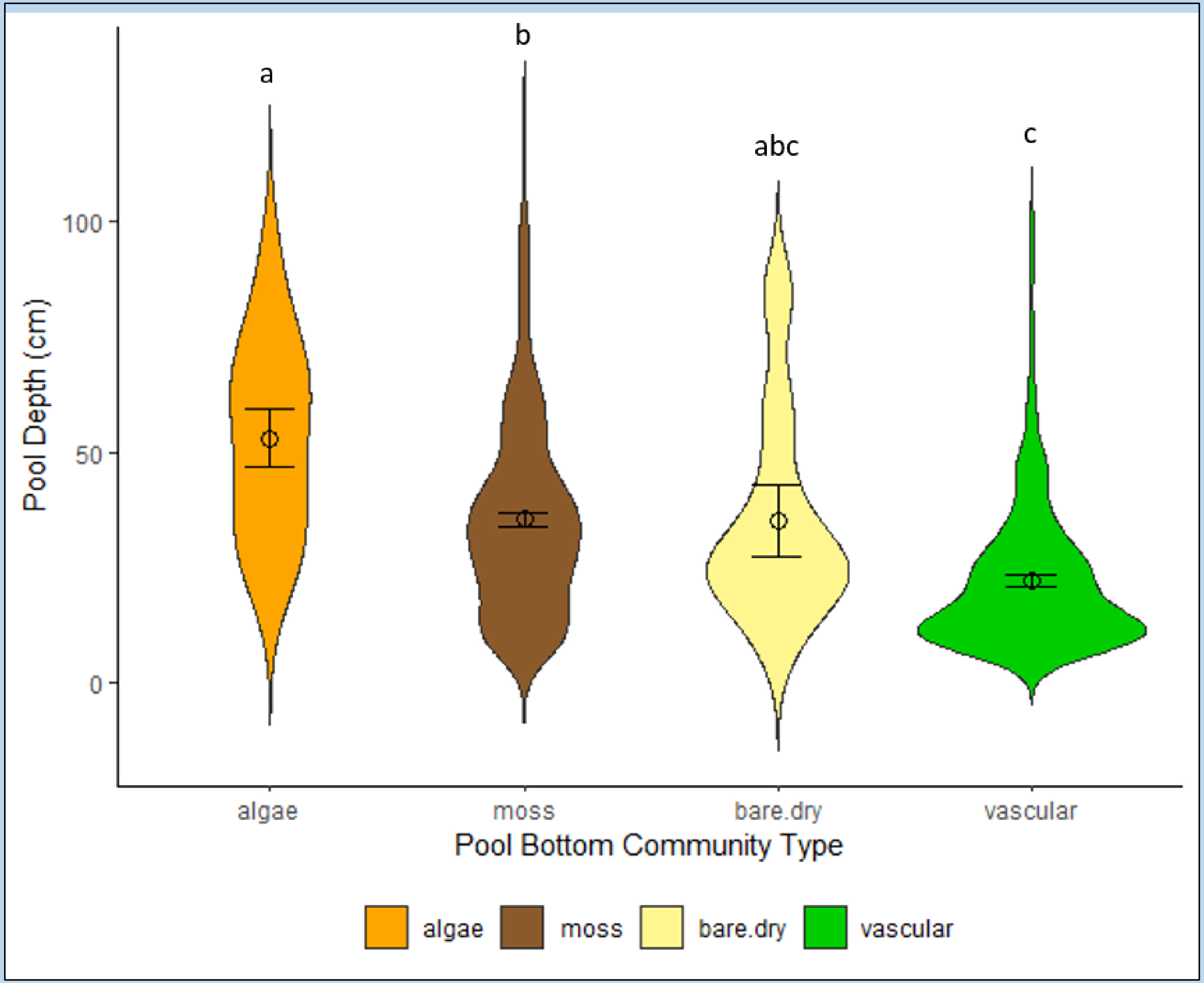
# Pool bottom vegetation varies by pool depth in reference areas

Algae = deepest (perennial)

Moss = deep (wet)

Bare = variable

Vascular = shallow (dry)

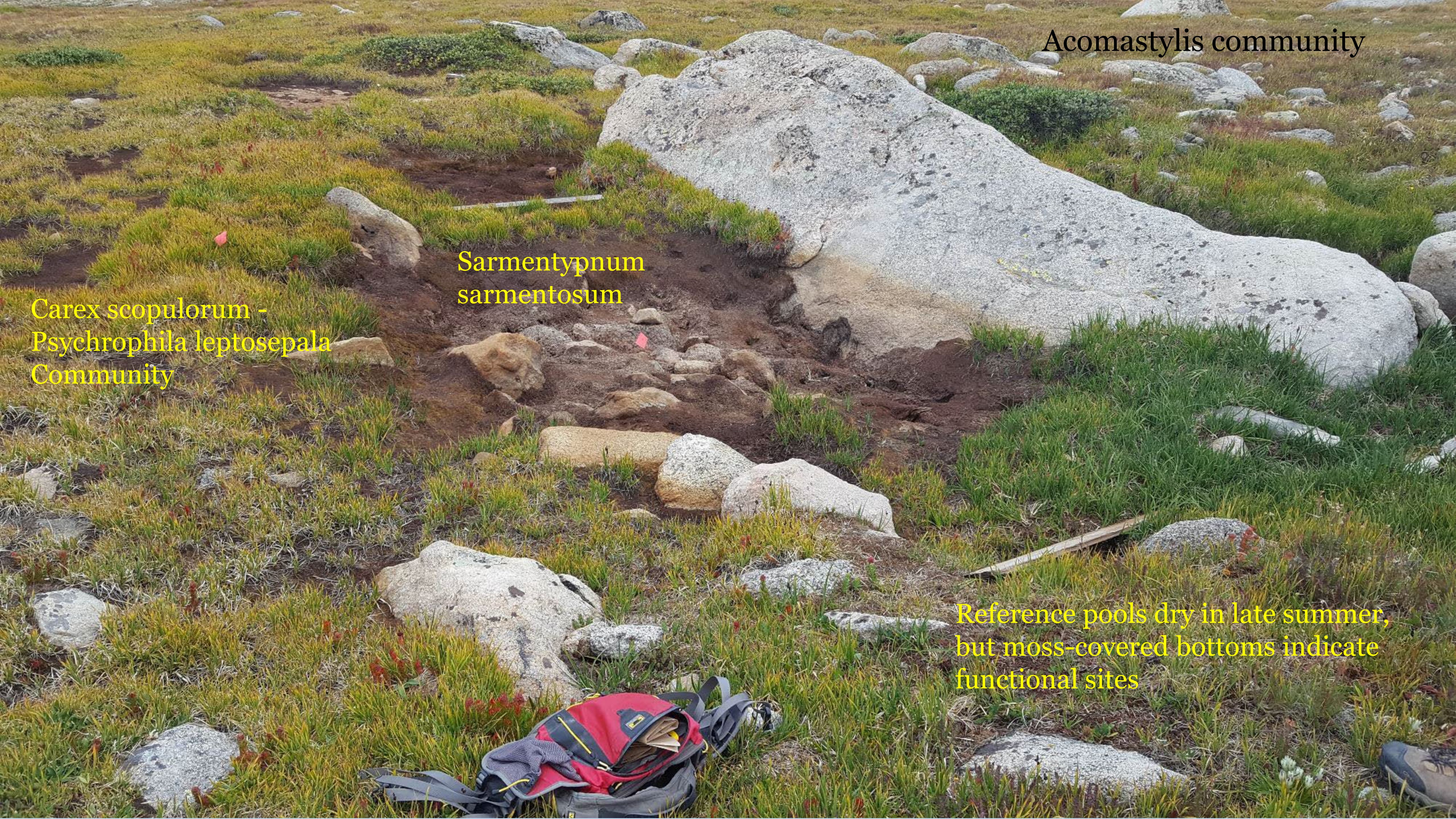


# Reference pools with organic soil

Pool bottoms = algal mat or *Sarmentypnum sarmentosum* (moss)

Pool sides & turf = *Carex-Psychrophila*, many others

# Reference pools with *Sarmentypnum*


Acomastylis community
Sarmentypnum sarmentosum
Carex scopulorum - Psychrophila leptosepala Community
Reference pools dry in late summer, but moss-covered bottoms indicate functional sites

# Flooded pools at culvert outfalls

Pool bottoms = bare soil and litter
Pool sides = dead *Carex scopulorum*
Turf = *Carex scopulorum* monoculture

*May be the most disturbed part of the study area

# Dried Pools: Vegetated

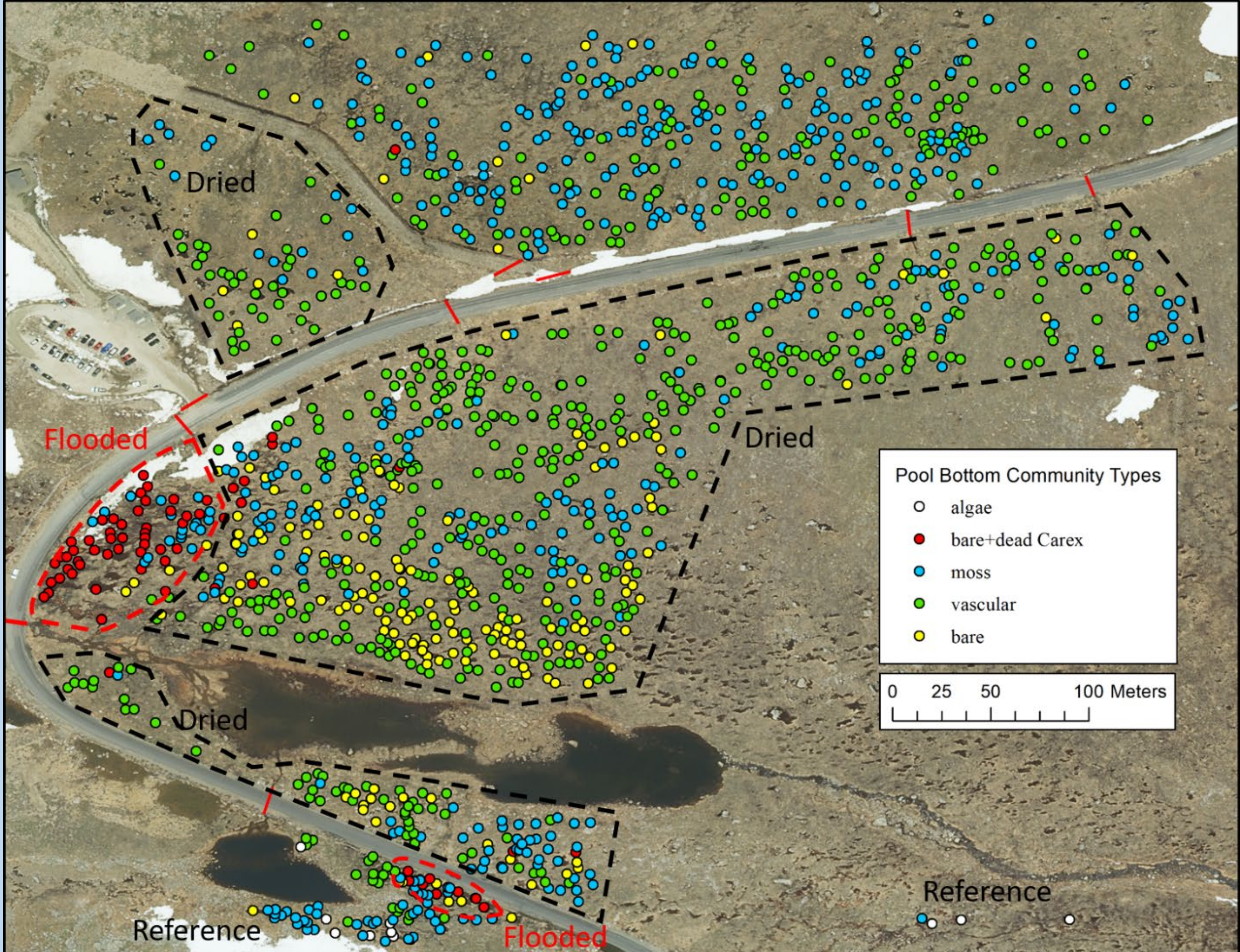
*Carex ebenea*
*Carex saxatilis*
*Deschampsia brevifolia*
*Alopecurus magellanicus*
Other turf spp
--------------------------------
*Anthropogenic drying*

# Dried Pools: Unvegetated

Pool bottoms = bare sediment
Pool sides = bare sediment, eroding

Distribution of Pool Types (n = 1,429)

Clear zonation of flooded and dried pool bottom community types

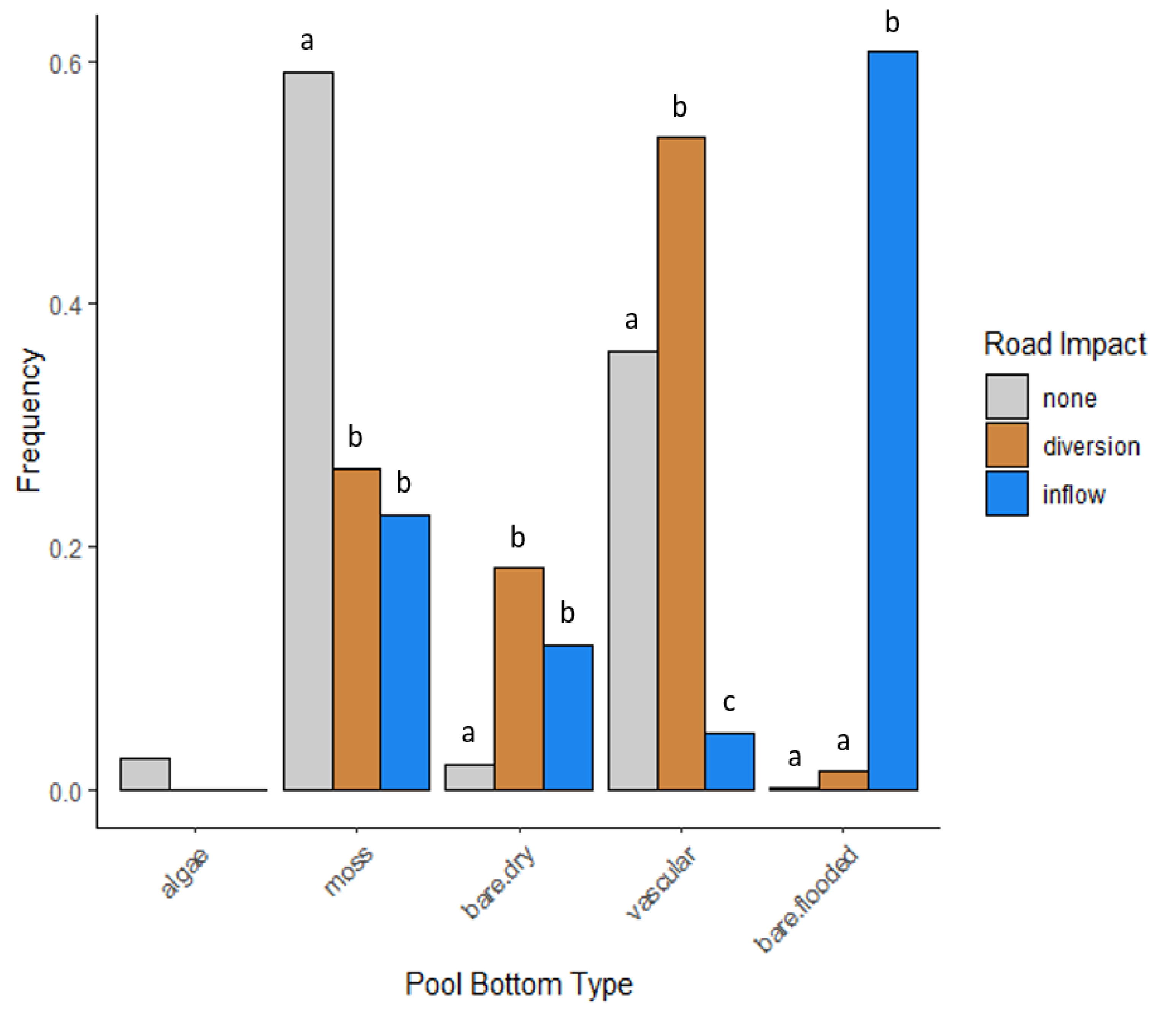


# Frequency of Pool Bottom Communities affected by roads

Moss communities significantly reduced where dried or flooded

Dried = moss replaced by vascular plants or bare

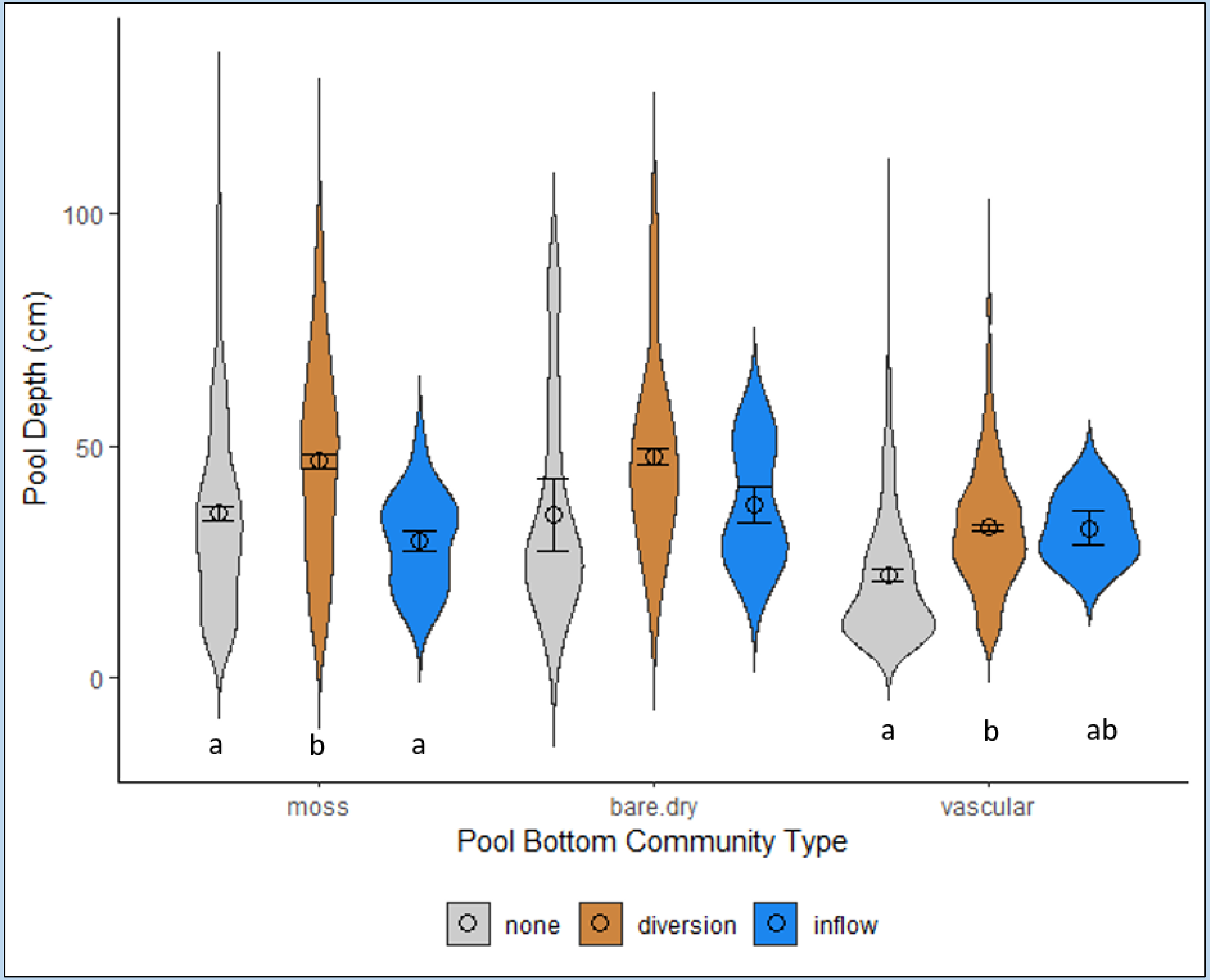
Flooded = moss and vascular plants replaced by bare soil with dead Carex margins



# Pool bottom vegetation contracted to deeper pools in dried areas

Loss of sheet-flow and shallow groundwater = can only survive in deepest pools closer to water table

Signal less clear in flooded pools, maybe sampling artefact



# Conclusions

- Ditches, subsided road, and thaw ribbon beneath road divert surface runoff and shallow groundwater
  - Large areas downslope of road have been dewatered
  - Flooded below culvert outfall, impacts may be most severe
- Alpine turf communities are somewhat resilient to hydrologic alterations
  - ~Unaffected by dewatering
  - Converted to *Carex scopulorum* monocultures **when flooded**
- Alpine pool communities very sensitive to hydrologic alterations
  - Useful for mapping road impacts
  - Likely useful as indicators of climate change

# Conclusions: Alpine Pools

- Reference
  - Pool Bottoms: aquatic moss or algal mat (perennial)
  - Pool Sides: *Carex scopulorum*
  - = Restoration targets, depending on pool depth
- Flooded
  - Pool Bottoms: bare
  - Pool Sides: dead *Carex scopulorum*
  - Adjacent Turf: *Carex scopulorum* monoculture
- Dried
  - Pool Bottoms & Sides: colonized by species that are most common in the subalpine and rocky and snowbed areas of alpine = *Carex ebenea, Carex saxatilis, Deschampsia brevifolia, Alopecurus magellanicus*
  - Or bare, eroding sediment

# Road Design Elements to Protect Permafrost

**Sustainable road = keep the ground cold and keep the roadbed dry**

- Elevated permeable embankment with ventilation tubes
  - Convective ground cooling during winter through pores and tubes
  - Helps to insulate ground during summer
  - Allows surface water movement to remain diffuse
- Rigid foam insulation under asphalt
  - Additional ground insulation
- Eliminate ditches
  - Remove heat input to ground
  - Remove groundwater drains

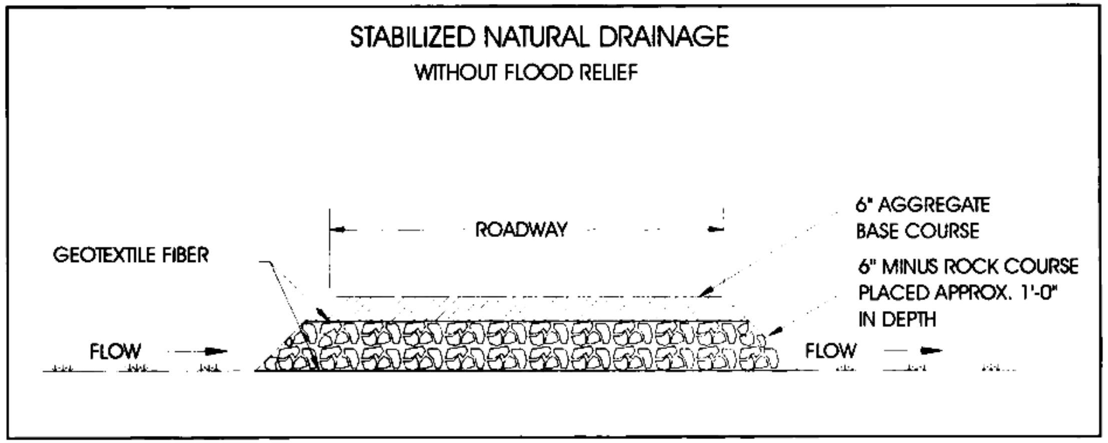



Figure 45. Typical Drawing: Stabilized natural drainage without flood relief.

# Next Steps…

- Road redesign ongoing
  - Incorporating permafrost protection techniques
- Construction in 2024(?)
- Continued monitoring through post-construction to quantify changes due to road rebuilding
  - Focus on alpine pools
- Develop vegetation restoration plan and design using post-construction hydrologic data

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