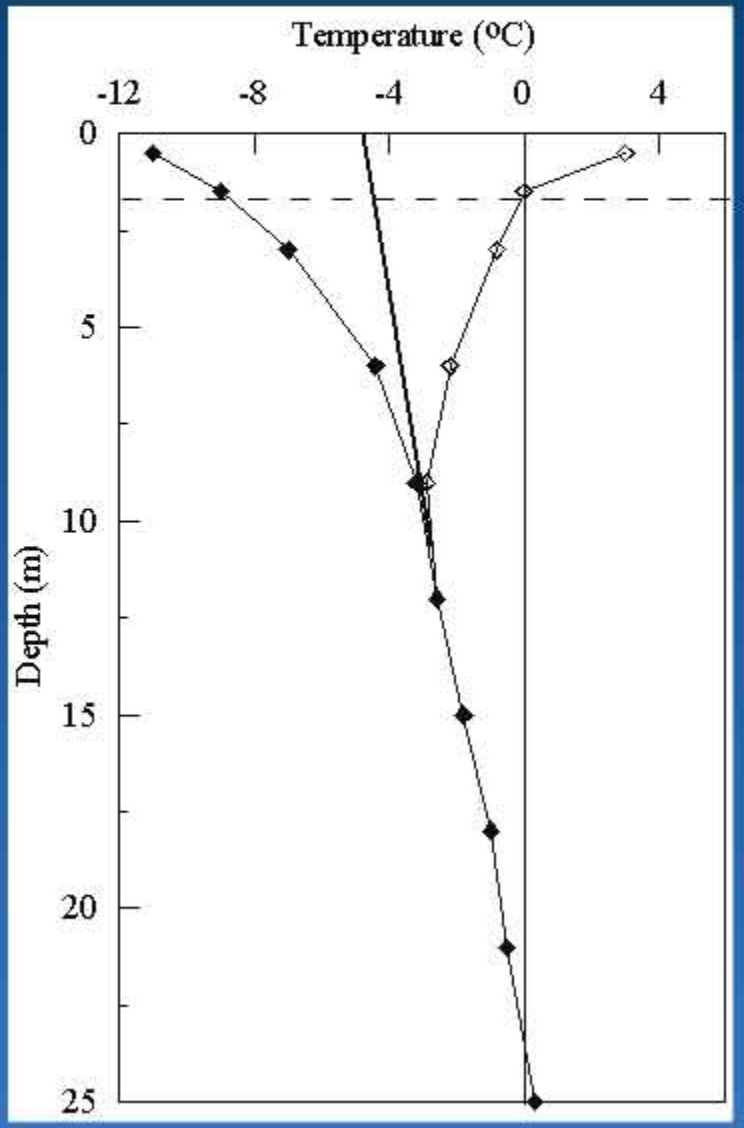
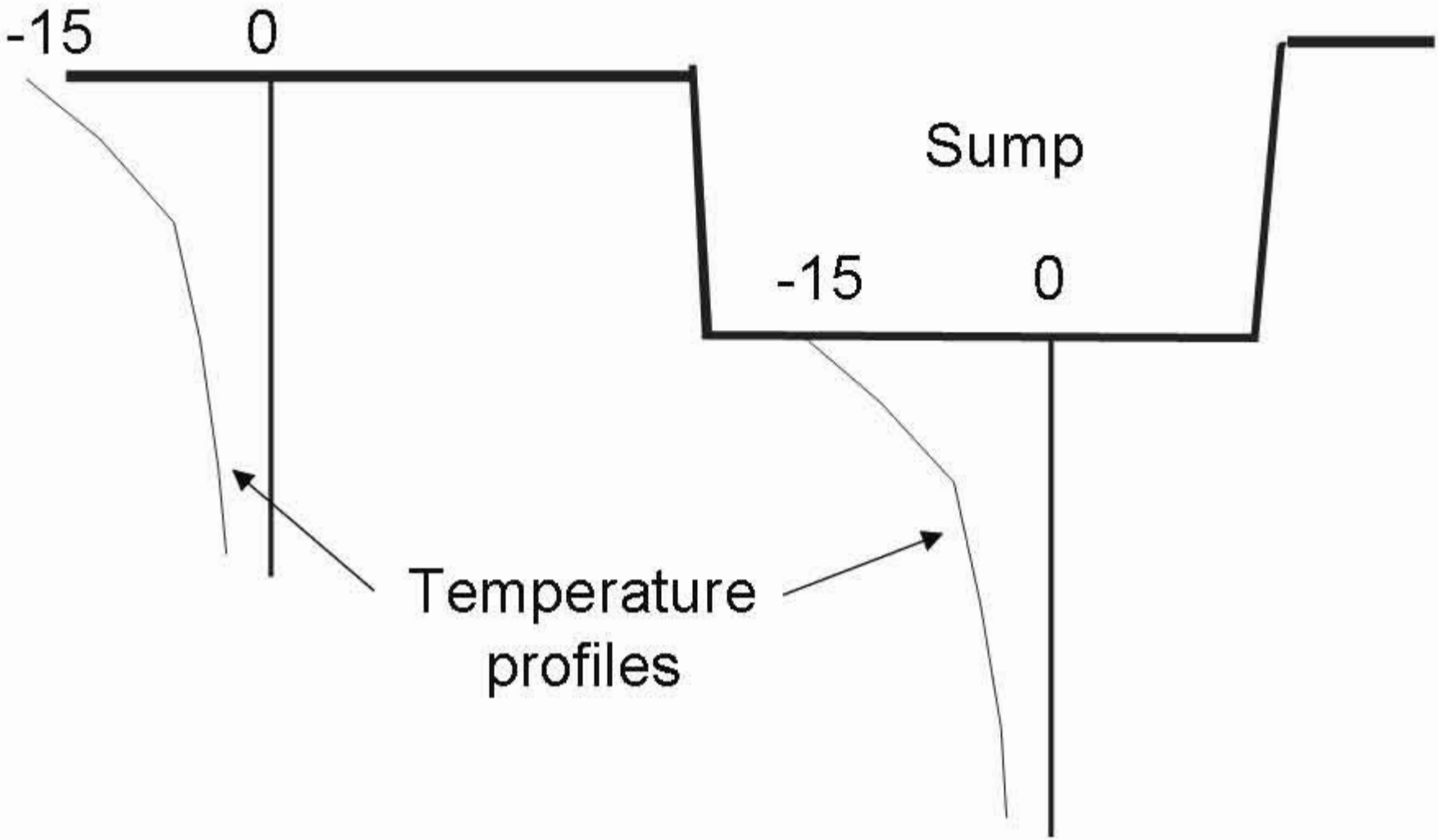

PETRO
CAN
DEVON
NUNA I-38
69°09'34.5"N
133°20'09"W

Ground-temperatures

- Establish temperature envelope for sump top and perimeter
- Reevaluate ground-thermal conditions in the future



Winter temperature profiles in an open sump and adjacent terrain



Acknowledgements

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- Carleton University, Department of Geography and the NSERC Northern Chair
- Inuvialuit Joint Secretariat
- Natural Sciences and Engineering Research Council of Canada
- Water Resources Division, Department of Indian Affairs and Northern Development

Final Considerations

- A capacity for basic science in the North will greatly improve our ability to manage the development of oil and gas resources

Conclusions

- The Mackenzie Delta region is a complex and dynamic environment
- The design of infrastructure should consider both spatial and temporal variation in permafrost conditions
- Improved management of drilling waste disposal in permafrost requires the collection of data that can indicate:
  - Effective containment
  - Causes of success or failure
- This may be facilitated by the development of sump monitoring guidelines

Sump monitoring

- An effective monitoring program will:
  - Determine the integrity of sumps
  - Indicate if remediation is necessary
  - Provide data to guide future management of drilling wastes
  - Address community concerns
- Design and implementation requires input from regulators, locals, scientists and industry

Sump monitoring

1. Key monitoring/research questions must be identified to investigate:
   - sump integrity
   - if remediation is necessary
   - guide future design and abandonment practices

2. Design of appropriate methodology will:
   - guide data collection
   - ensure consistency of data collection and comparability of data

3. Data must be compiled and archived by the regulators

4. Data require timely analysis

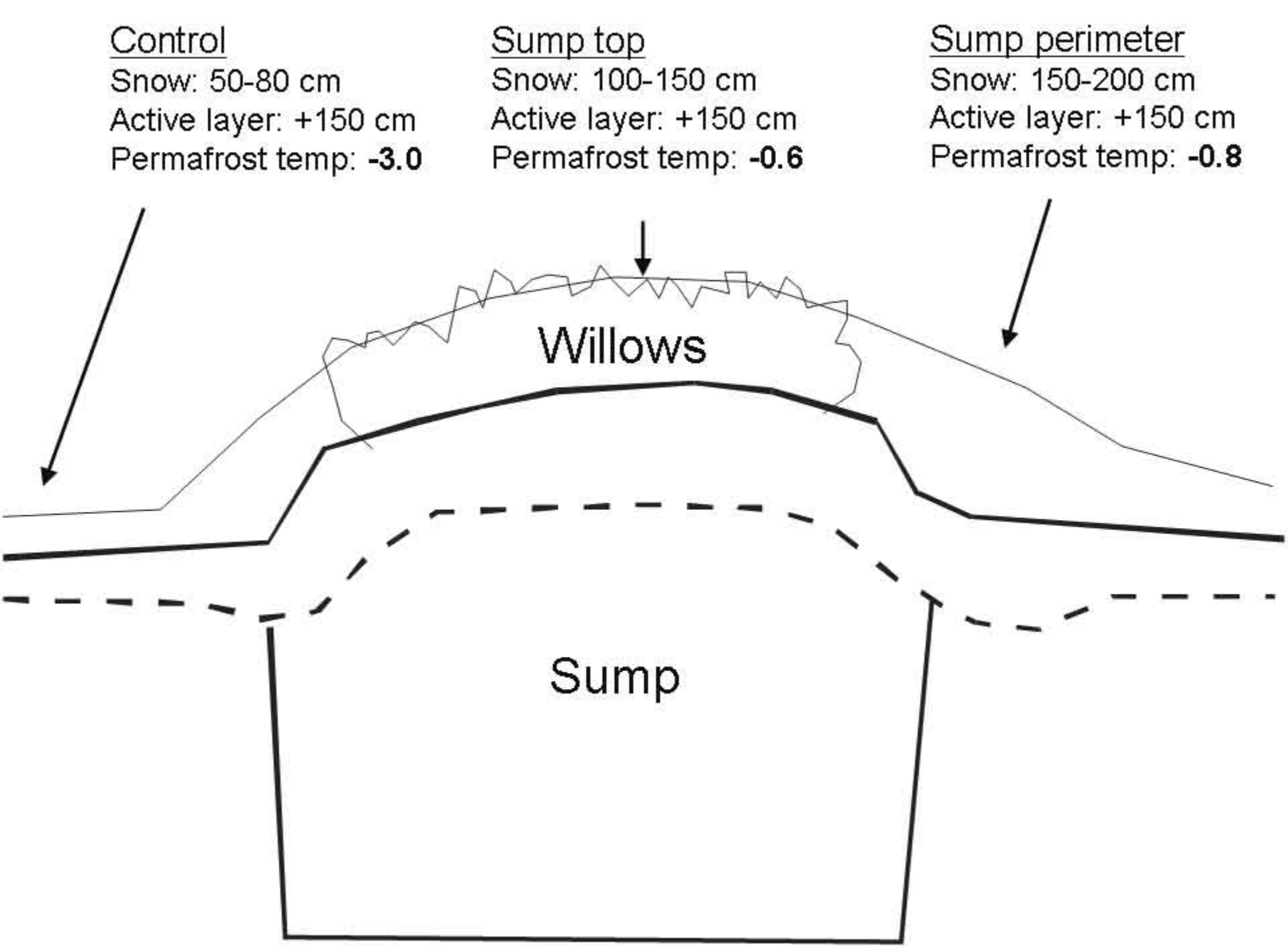
5. Feedback mechanism should be formalized

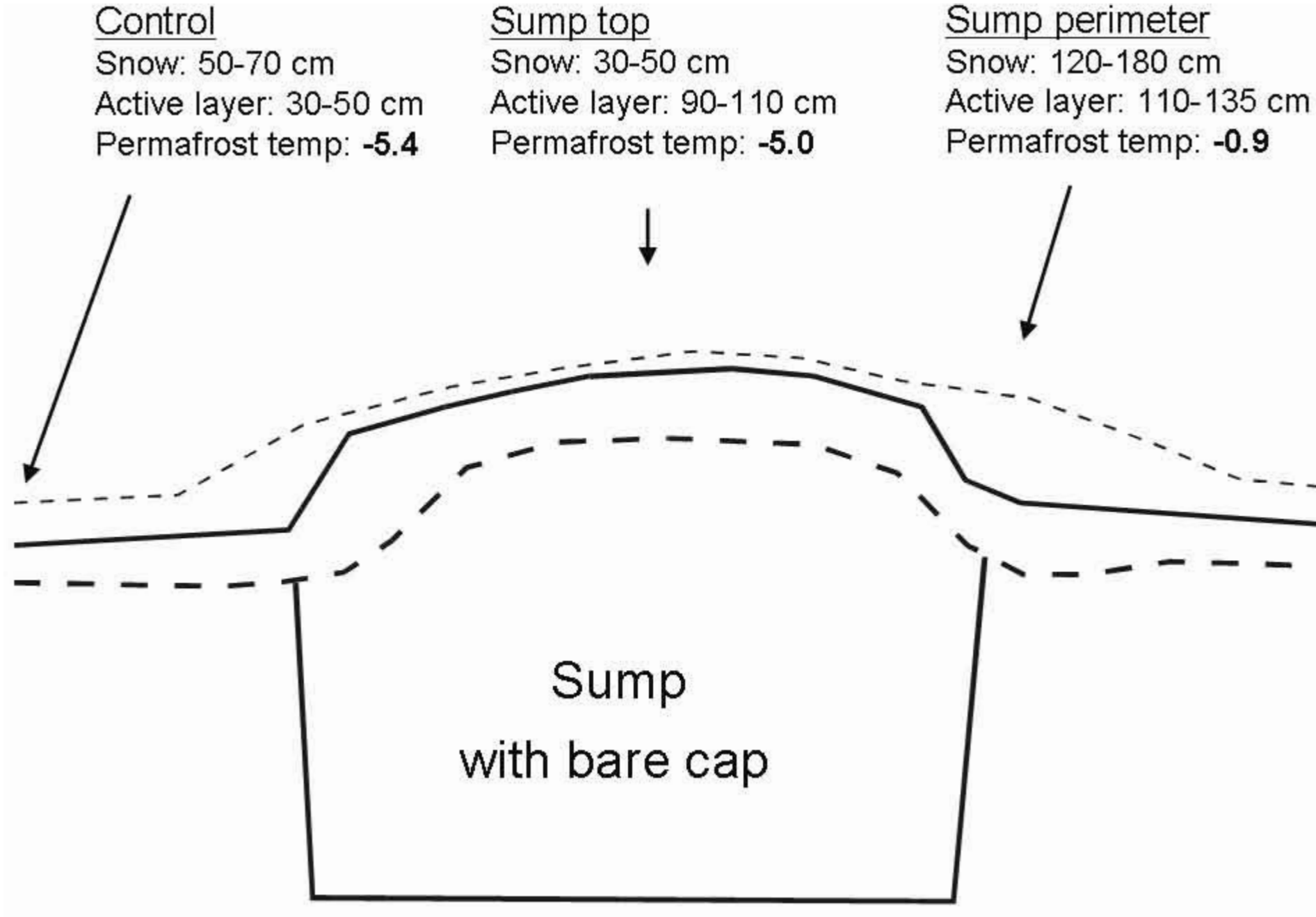
Monitoring of contemporary sites

- Considerable monitoring efforts have been initiated to determine the performance of drilling-mud sumps
- To maximize the potential of resources directed towards sump monitoring, several items require attention

Management implications:

- These investigations can indicate the potential causes of long-term degradation of sumps
- The investigations may direct practices to maximize the performance of sumps in permafrost terrain


Control
Snow: 50-80 cm
Active layer: +150 cm
Permafrost temp: -3.0
Sump top
Snow: 100-150 cm
Active layer: +150 cm
Permafrost temp: -0.6
Sump perimeter
Snow: 150-200 cm
Active layer: +150 cm
Permafrost temp: -0.8
Willows
Sump


Control
Snow: 50-70 cm
Active layer: 30-50 cm
Permafrost temp: -5.4
Sump top
Snow: 30-50 cm
Active layer: 90-110 cm
Permafrost temp: -5.0
Sump perimeter
Snow: 120-180 cm
Active layer: 110-135 cm
Permafrost temp: -0.9
Sump
with bare cap

Field activities

- Shallow thermistors installed on sump top, perimeter and in adjacent undisturbed terrain
- Active-layer and snow transects were established across the top and adjacent to abandoned sumps

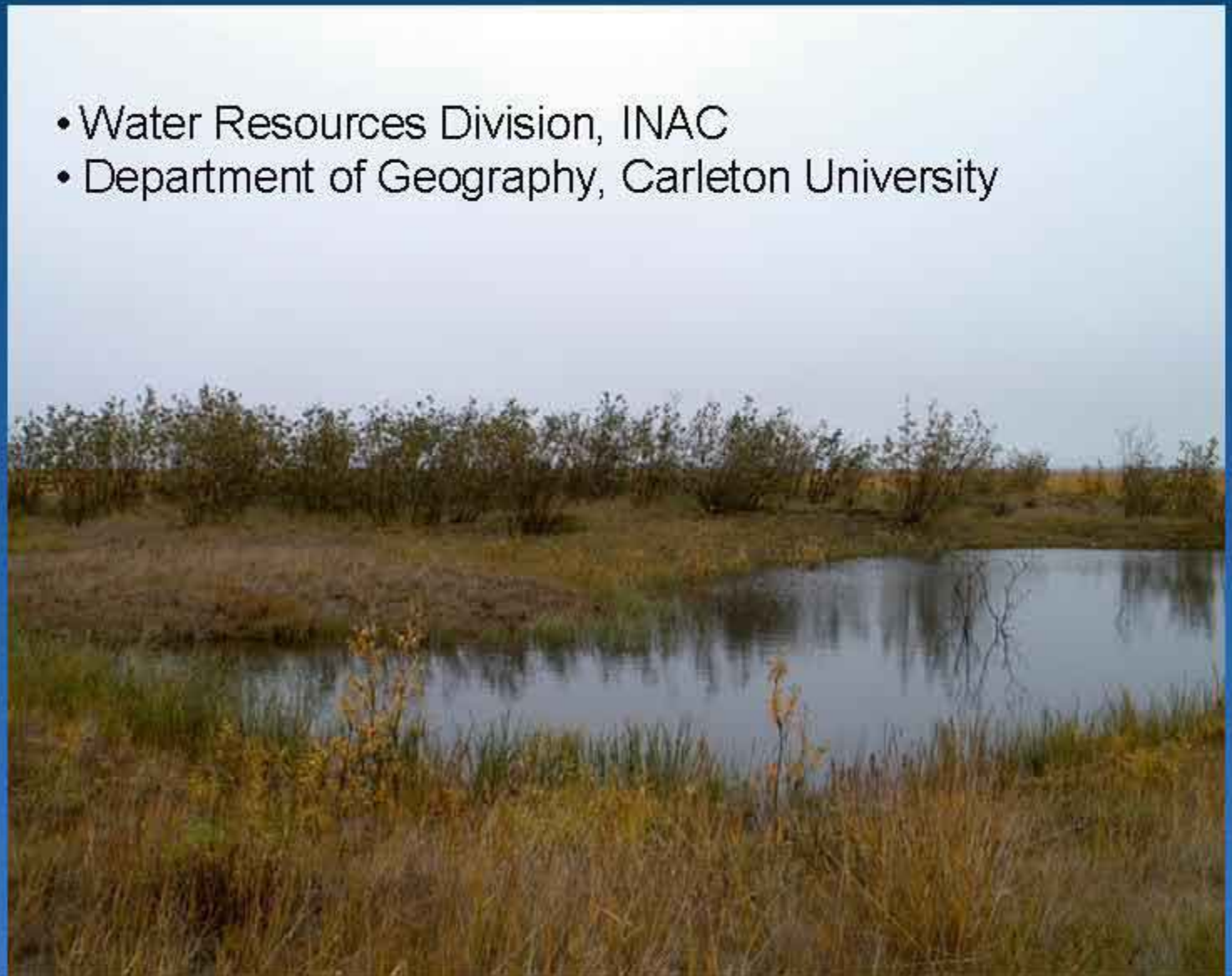
Ground-temperatures were determined at and around two sumps in the outer Delta

High willows

No willows

The effect of revegetation on ground-thermal conditions at abandoned sumps

- Water Resources Division, INAC
- Department of Geography, Carleton University



Project objectives:

- To determine soil chemical conditions around abandoned sumps
- To determine the long-term influence of disturbance on habitat conditions
- To determine the influence of ecological change on ground-thermal conditions

Environmental conditions at abandoned sumps in the Kendall Island Bird Sanctuary

- Canadian Wildlife Service
- Department of Indian and Northern Affairs
- Carleton University
- University of Alberta

ESRF objectives:

- Develop a protocol to guide the collection of information on the environmental conditions at abandoned sump sites
  - Sump inventory
  - Phase 1 site assessments (ESRF, Industry)
- Establish a public database to store information collected in assessment
- Assess the environmental risk associated with each site
- Provide information to determine factors that influence sump behaviour

1. 2004 Drilling-mud sump inventory study, Inuvialuit Settlement Region (ESRF/Industry)

ESRF Technical Advisory Group, ChevronTexaco, ConocoPhillips, Imperial Oil, and Shell

Previous work on sumps includes:

- Reports based on observations
  - Methods vary
  - Lack of field data to support observations
- Field investigations (EM surveys, soil sampling etc.)
  - Not many field data exist
  - Data vary for different sites
  - Not all data are accessible
- Workshop
  - Concerns of the Inuvialuit have been expressed
  - Requirement to monitor new sites
  - Need information on old sites

Observations suggest:

- The integrity of the sump cap is associated with:

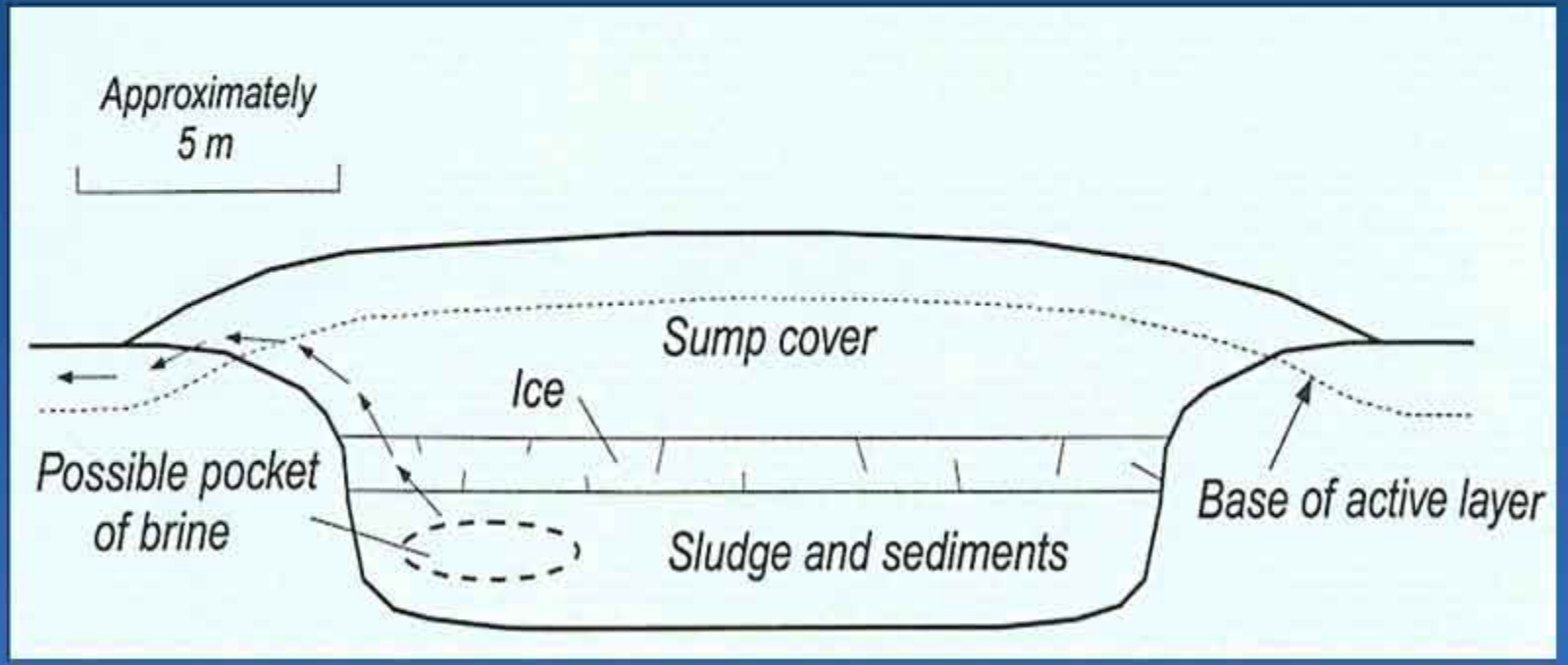
  a) abandonment practices

  b) site conditions

  c) patterns of snow accumulation and possibly revegetation

Sump studies

In permafrost terrain, sumps are constructed to encapsulate drilling muds in frozen ground

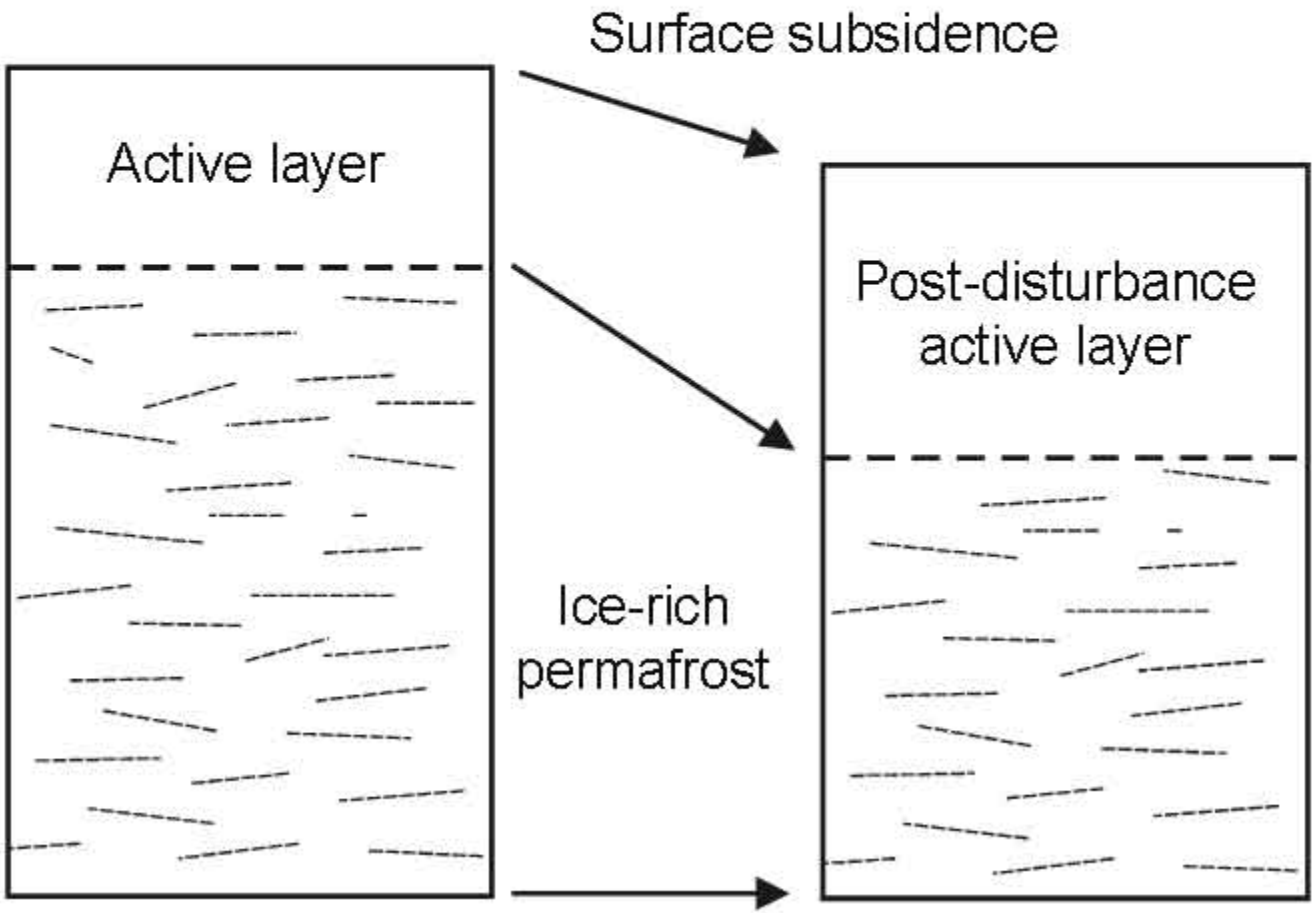


Dyke, 2001, Fig. 1

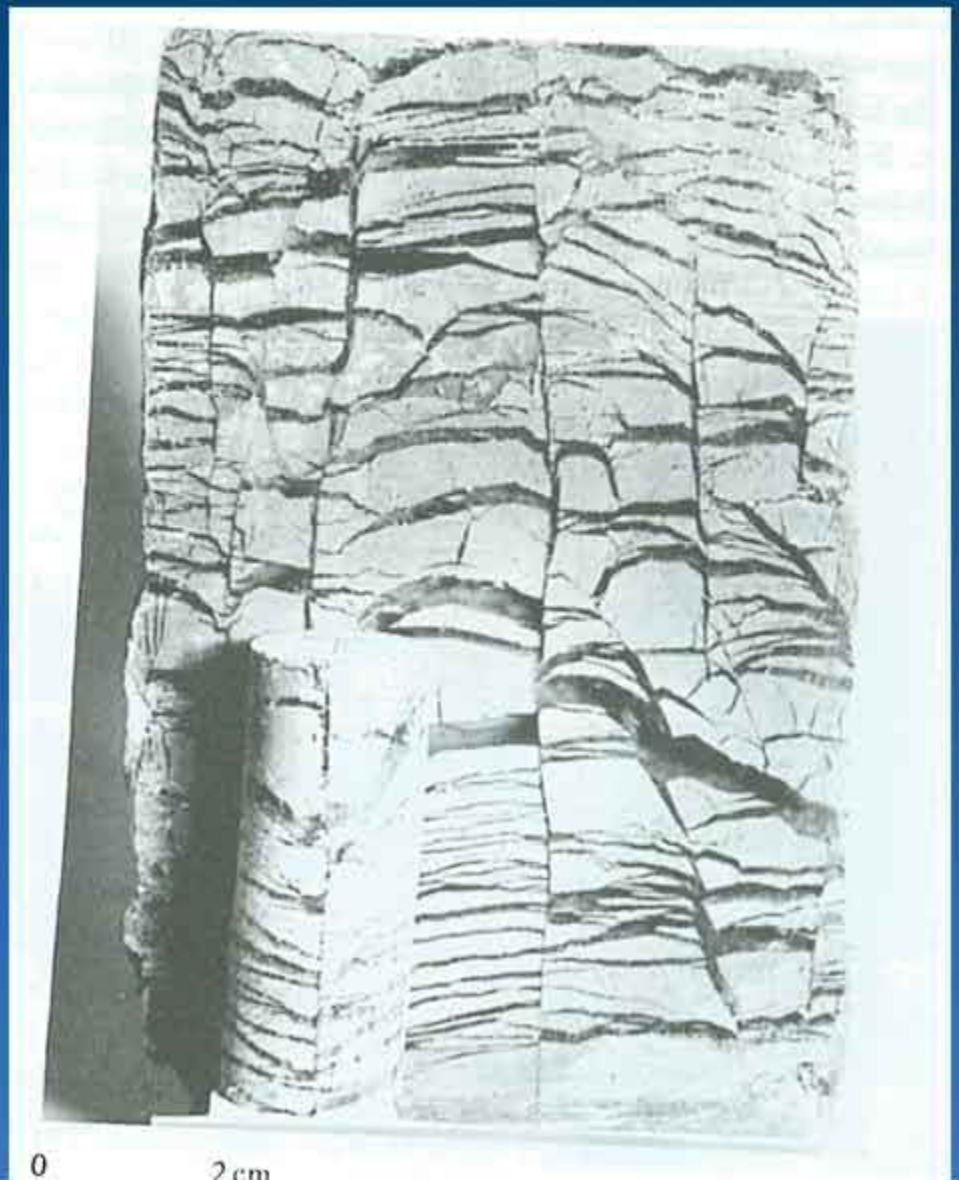
Management implications:

Understanding the distribution of ground ice is required to plan and design of infrastructure

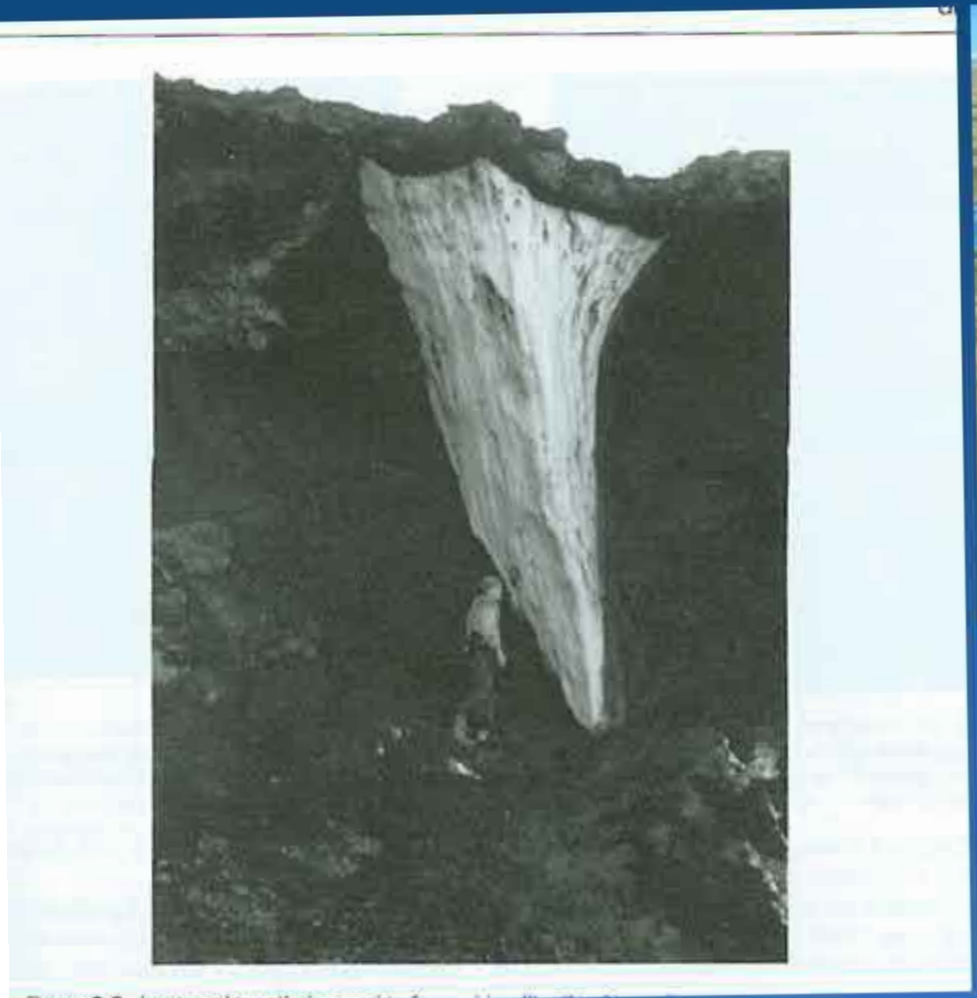
Surface subsidence associated with active-layer deepening and thawing of ice-rich permafrost



Segregated ice lenses (Williams and Smith, 1989)



Ice-wedge in cross-section, western Arctic coast (French 1996)



Ice-wedge polygons, Yukon Coastal Plain

Thermal-contraction crack, drained lake bottom, Illisarvik, western Arctic Coast (Mackay, 1980).

Ground ice

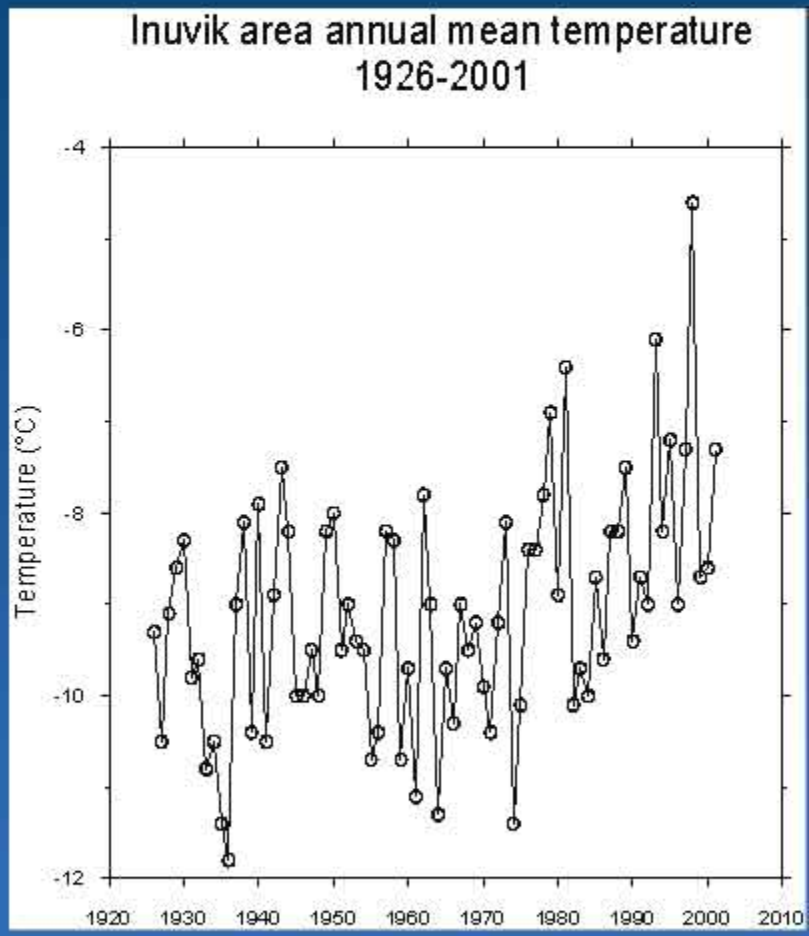
Management implications

- This data may indicate change in permafrost temperatures over the last 30 years
- Establishing the relation between climate conditions and permafrost temperature is critical to planning the design and managing the long-term integrity of infrastructure in permafrost terrain

Climate change and permafrost

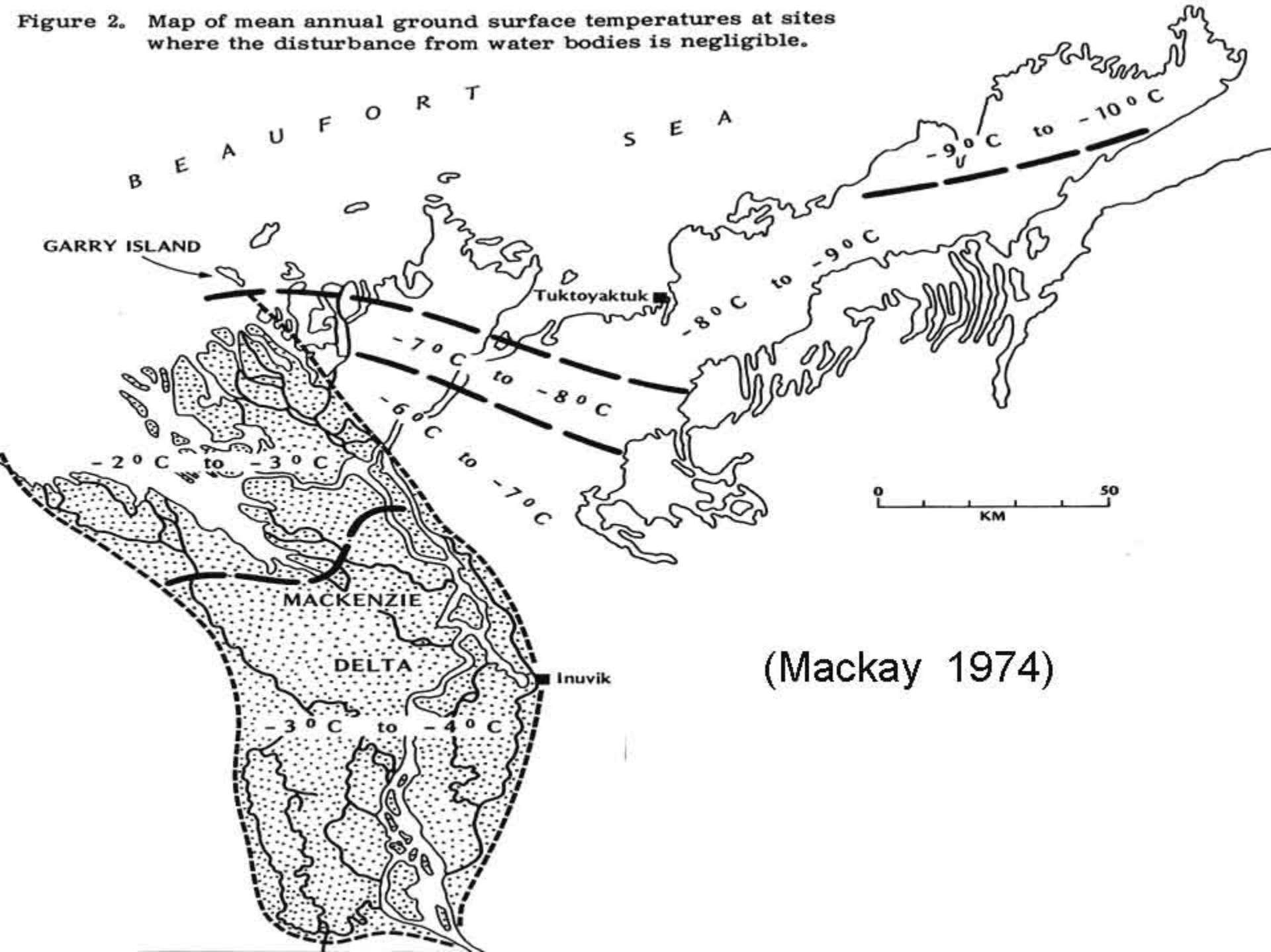
- Mean annual air temperatures in the western Arctic have increased 0.5 to 1 degree Celsius per decade since the 1970's

- Permafrost temperatures on Richards Island have increased about 1.5 deg C since the 1970's (Burn pers. comm.)

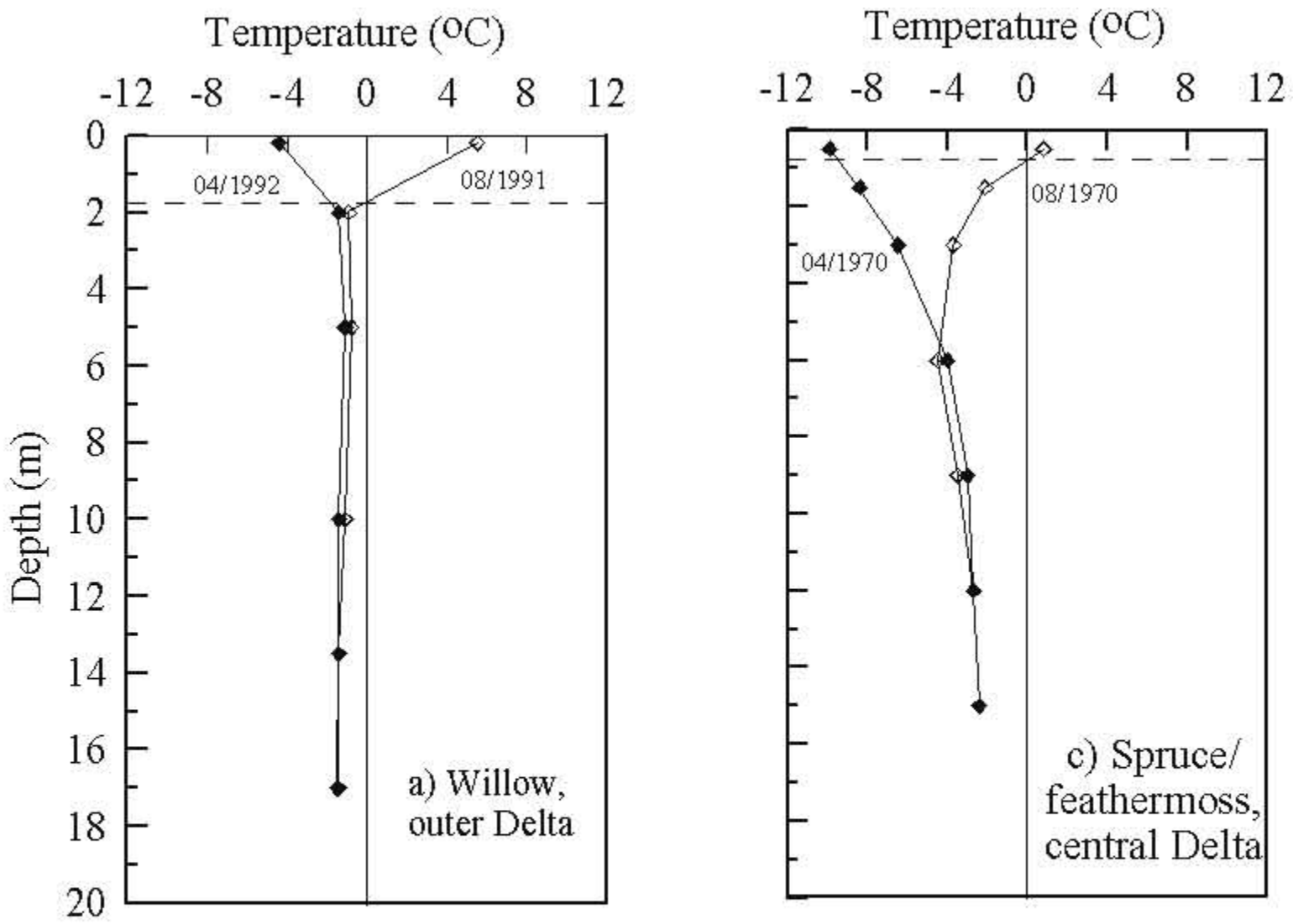


C.R. Burn

Figure 2. Map of mean annual ground surface temperatures at sites where the disturbance from water bodies is negligible.



(Mackay 1974)



Permafrost-temperature profiles for two sites in the Mackenzie Delta (from Dyke; Smith, 1975).

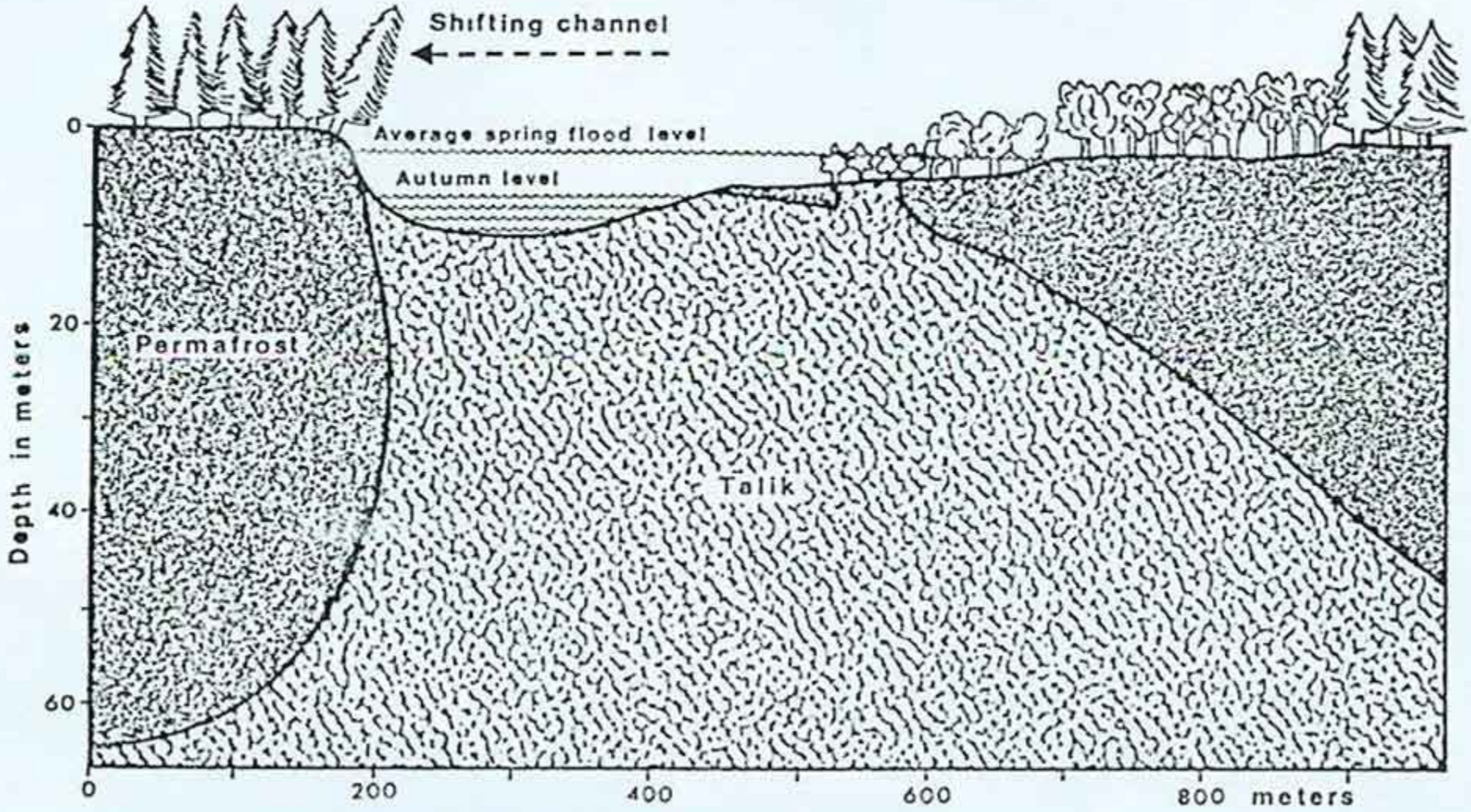
Spruce community

- Infrequent flooding
- Development of surface organic horizon
- Interception of snow by canopy

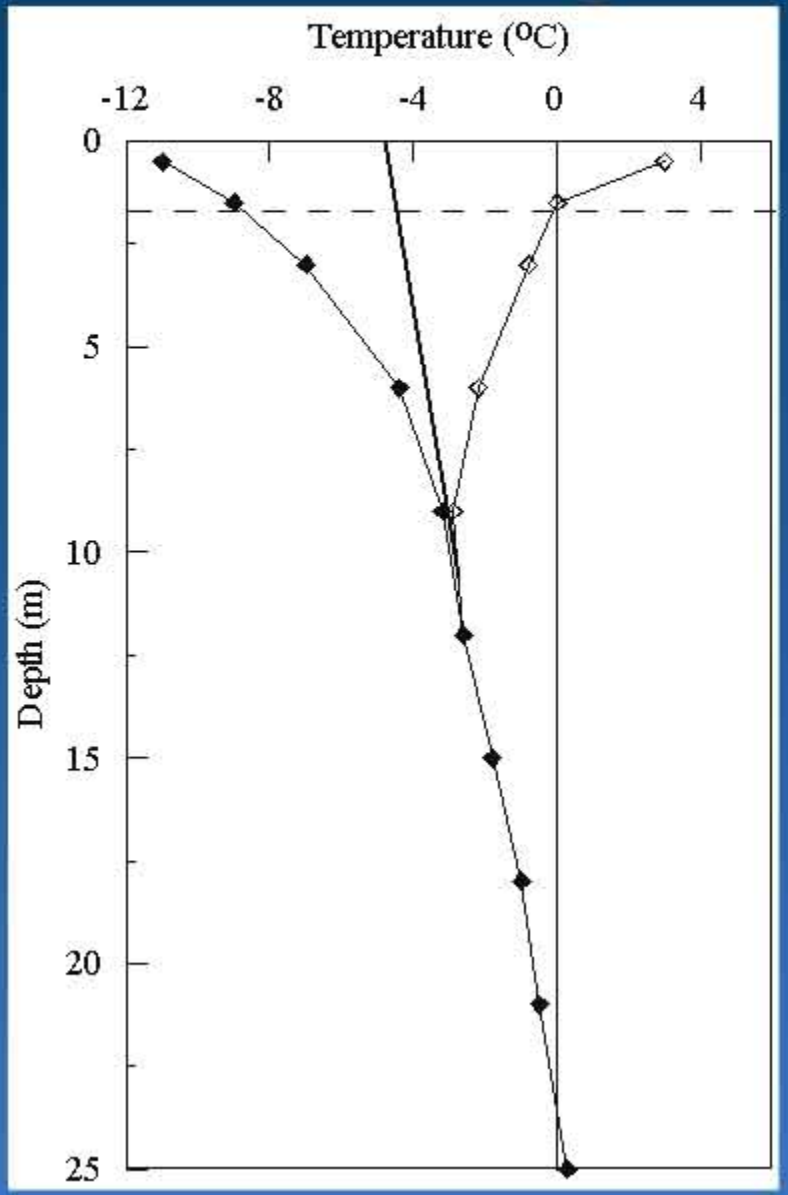
Willow community

- Frequent flooding
- Thick snow accumulation

Schematic of permafrost configuration beneath a shifting point bar (Smith 1975)



Permafrost ground temperatures are a function of the surface energy balance and the geothermal gradient



Definitions:

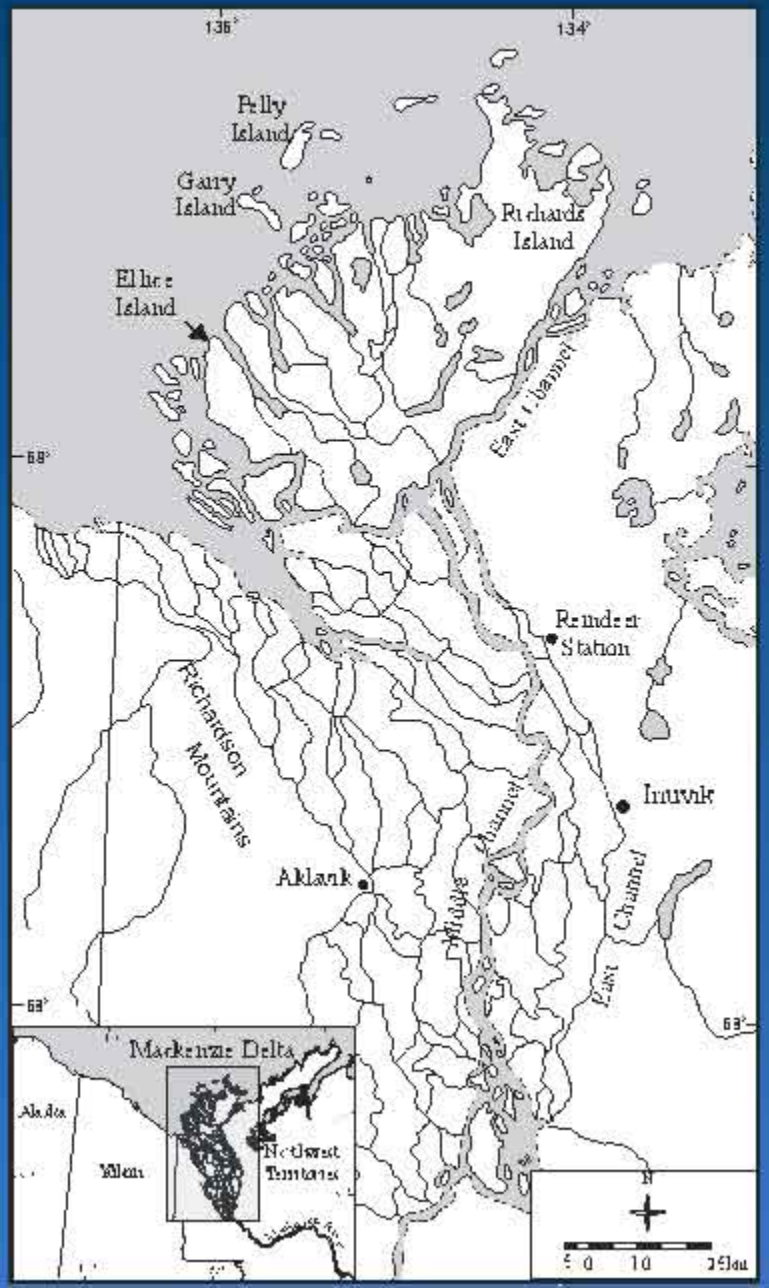
- **Permafrost**
  - Earth materials which remain below 0 degrees C for at least 2 consecutive years

- **Active layer**
  - Near-surface soils or rock that thaws and refreezes on an annual basis

Tundra uplands

Rising river levels and lake flooding

Mackenzie Delta region



Objectives

- To describe the Mackenzie Delta environment
- To provide an overview of the design and past performance of drilling-mud sumps in permafrost environments
- Summarize current sump research
  - Sump inventory and assessment (ESRF)
  - Environmental conditions at abandoned drilling sumps (CWS)
  - Ground-thermal evolution of abandoned drilling sumps (WRD)
  - D-20 reclamation (ConocoPhillips)
- Overview sump monitoring
- To emphasize the importance of integrating science and resource management in the NWT

Drilling-mud sumps in the Mackenzie Delta region

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In partnership with the Inuvialuit Joint Secretari
and the Aurora Research Institute