Patterns of snow accumulation and soil temperatures at vegetated and unvegetated drilling mud sumps, Mackenzie Delta, Northwest Territories, Canada

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Abstract

The influence of snow accumulation on ground-temperatures of two abandoned drilling-mud sumps in the outer Mackenzie Delta was investigated in winter 2003/2004. The sumps were abandoned in the 1970s. The cap of one sump is bare (Sump 1) and the other is vegetated with alder and willows up to 3 m height (Sump 2). In winter 2003/2004, snow drifts 1 to 2 m thick accumulated around the perimeter of both sump caps. Drifts approximately 1.5 m thickness accumulated on the top of the vegetated cap at Sump 2, but less than 50 cm snow was present on the top of the bare cap of Sump 1. Snow depth in natural areas adjacent to the sumps was 40 to 60 cm. In late winter 2004, subnivean temperatures on the vegetated sump were between -3.5 and -4.5 °C, in contrast with -15 to -20°C beneath the thin snow pack on the bare sump cap. Shallow ground temperature measurements indicated that following active-layer freeze-back on the bare sump cap (Sump 1), temperature at the top of permafrost dropped to -14°C by March. Thick snow accumulation on the top of the vegetated sump (Sump 2) inhibited freeze-back of the active layer. Latent heat supplied by cooling of warm permafrost and presence of insulative snow cover inhibited near-surface cooling later in winter. Minimum permafrost temperatures on the vegetated cap were only -1°C. Gradual freeze-back of the active layer and warm permafrost temperatures (> -1.0°C) were observed around the perimeter of both sumps where the snow drifts greater than 1 m thickness had accumulated. An increase in permafrost temperatures can lead to the thawing of saline drilling fluids and may promote lateral migration of contaminants. If ice-rich permafrost is degraded, thaw settlement can lead to collapse of the sump cap. The field data demonstrate that in permafrost terrain, sump abandonment practices should consider contouring and reclamation plans that inhibit snow accumulation.

Introduction

In permafrost areas, drilling wastes produced by the oil and gas industry during exploration are disposed of in sumps (*Figure 1*). Sumps consist of large pits excavated in permafrost. When drilling is complete, sumps are backfilled with the intent that the permafrost will aggrade into the waste and the active layer and will be maintained in the cap materials therefore preventing interaction between surface water and underlying wastes (Kokelj, 2002)

The Water Resources Division is interested in the long-term stability of drilling-mud sumps and the containment of drilling waste within these sumps.

Abandonment practices and local environmental conditions influence the long-term integrity of sumps. The oil and gas industry has improved abandonment practises and current guidelines are intended to improve site selection.

Snow accumulation and revegetation may affect the long-term integrity of drilling-mud sumps in permafrost terrain. Snow drifts accumulate on the lee of slopes. Willows and alder may also cause drifts to accumulate. Thick snow cover is associated with warm permafrost temperatures as snow retards heat loss from the ground in winter.

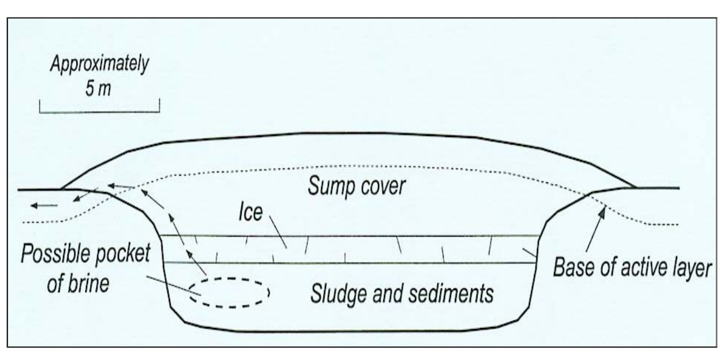

Figure 1. Schematic cross-section of a drilling mud sump (Dyke 2001, Figure 1)

Objectives

To determine the influence of topography and vegetation on snow accumulation and ground-thermal conditions at abandoned sumps

Methods

Two sumps abandoned in the 1970s in the outer Mackenzie Delta were investigated. These sites are located in similar terrain approximately 5 km apart:

A) The cap of Sump 1 was vegetated only with grasses (*Figure 2*);

B) The cap of Sump 2 was vegetated with alder and willow up to 3 m height (*Figure 3*)

Transects were established across the two sump caps

•Active-layer depths were determined along the transects

•Snow depths at the end of winter were determined along the transects

•Shallow ground-temperatures (5, 50 and 150 cm depths) were monitored on the tops and perimeters of the sumps and in adjacent undisturbed terrain

Figure 2: Sump 1 (Unvegetated)

Figure 3: Sump 2 (Vegetated)

Results

The following information was collected from Sump 1 (*Figure 4)* and Sump 2 (*Figure 5)* during the summer 2003 and winter 2004.

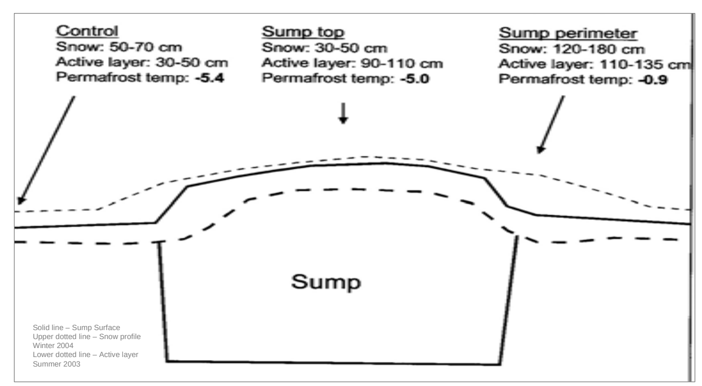

Figure 4. Active layer, snow depth and mean annual temperature at the top of permafrost measured at Sump 1 (unvegetated) and at an adjacent control site, summer 2003 and winter 2004.

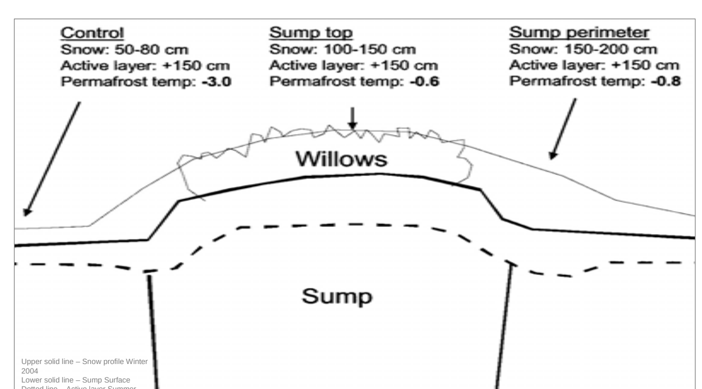

Figure 5. Active layer, snow depth and mean annual temperature at the top of permafrost measured at Sump 2 (vegetated) and at an adjacent control site, summer 2003 and winter 2004

Recommendations

1. Sumps constructed in permafrost terrain should be abandoned with proper contouring to inhibit snow accumulation around the perimeters.
2. Shrub growth should be controlled on sump tops.

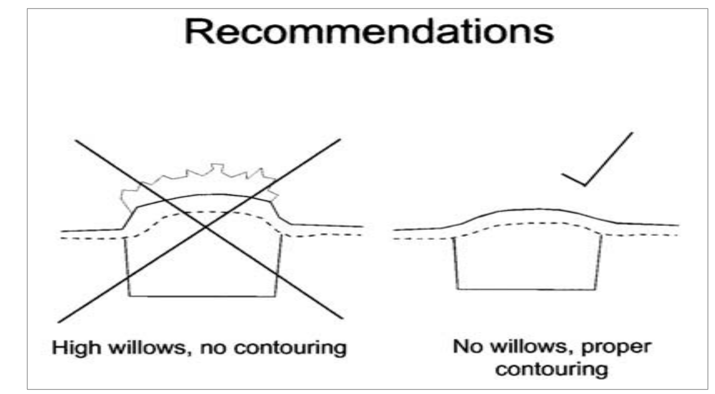

Figure 6: Recommendations for sump construction and maintenance

Conclusions

1. Snow accumulates around the perimeter of sump caps.
2. Snow can accumulate on the tops of sumps with high willows.
3. Thick snow accumulation can retard ground-heat loss in winter. Perennial snow accumulation can result in warming of the permafrost.
4. Warming of permafrost associated with snow accumulation may cause long-term degradation of permafrost in sumps.

References

1. Dyke, L.D. (2001) Contaminant migration through the permafrost active layer, Mackenzie Delta Area, Northwest Territories, Canada. *Polar Record,* **37** (202) pp. 215-228

2. Kokelj, S.V. and GeoNorth Ltd. (2002) Drilling mud sumps in the Mackenzie Delta Region: construction, abandonment and past performance. *Department of Indian Affairs and Northern Development*.

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