General Guidance for the Design of Tailings Dams in Northern Regions

S.A. Proskin and J.E.S. Boswell
Thurber Engineering Ltd., Calgary, AB, Canada
N. Sims
Northwest Hydraulics Consultants, Vancouver, BC, Canada
Preamble

1. Recent development in the field of tailings has generated both internal and external scrutiny of tailings dam safety and tailings management.

2. Northern regions have additional challenges tailings facilities.

3. Challenges include the several aspects of the geography:
   1. Permafrost foundation: quasi-stable frozen ground
   2. Permafrost landforms—often include ice features
   3. River and lake ice covers, ice jams and freshet
   4. Remote sites with limited transportation
   5. Limited supply of local resources: equipment, materials and workers
Outline

1. Preamble
2. Northern Mines
3. Geotechnical Aspects
4. Hydrotechnical Aspects
5. Environmental and Safety
6. Climate Change
Mines in NWT and NU
Permafrost Distribution in Canada
Mines in NW North America

Mines in Yukon and Alaska

- Red Dog Mine
- Fort Knox Mine
- Keno Hill
- Minto Mine
- Mount Nansen

Mineral
- Copper
- Diamonds
- Gold
- Gold, Silver
- Iron
- Lead, Zinc
- Silver

Status
- Abandoned
- Closed
- Operating
- Suspended
Permafrost in Alaska
Planning and site characterization

- Identifying permafrost and landforms
- Geotechnical logging of ice occurrences and measuring subsurface temperatures
- Gathering meteorological data
- Site logistics
Unfrozen Dams—Unfrozen Foundations

- Permafrost foundation is allowed to thaw
- Design needs to account for settlements associated with time dependent permafrost thaw
- Red Dog Mine tailings storage uses unfrozen rockfill dam with an HDPE liner on the upstream face to control seepage and filter zones
- Undergone four raises
- Installed a upstream blanket to reduce seepage through the thawed foundation

Source: Alaska Journal of Commerce

Source: Northern.org
Frozen Dams-frozen foundations

• Situated on continuous permafrost that is kept in a frozen state
• May include a frozen core or other frozen barrier to control seepage
• Granular fill with sufficient moisture to ensure saturation of pore space with ice upon freezing
• Construction methods include thin lifts of moisture conditioned granular fill that are allowed to freeze before placement of the next lift
• Examples: Ekati, Doris North-Hope Bay

Source: Nuna Logistics, Ekati
Other Geotechnical Considerations

• Thermal and Thaw Settlement Analysis
• Seepage Control and Water Management
  • Seepage is linked to the thermal regime
  • Warming due to water storage on upstream
• Special Construction
  • Frozen fill zones
  • Cooling ground to preserve permafrost
• Monitoring and Geotechnical Instrumentation
Hydrotechnical Aspects

Special attention on:
- Ice conditions on rivers, reservoirs
  - ice covers formation and break-up (ice jams)
  - de-icing
  - Frazil ice decreasing conveyance of pumps, valves,
- Inflow design flood should consider
  - Deglaciation due to climate change
  - Rain-on-snow events
- Hydrometric monitoring and ice
  - Inconsistent rating curves
  - Ice damaging gauges

Source: Natural Resources Canada
Source: Cape Bounty Arctic Watershed Observatory
Climate Change—Arctic

Arctic Climate Change Impacts

Shifting of permafrost regimes northward-warming permafrost.

- Thaw settlement of foundations
- Enhanced erosion
- Accelerated creep of warming ground ice

Shorted ice season and extending open water season for rivers and lakes.

- Shortens winter and ice road seasons.
Summary

1. Tailings facilities in northern Canada and Alaska have to manage additional risks associated with the geography: permafrost, river and lake ice, remote sites that stretch supply chains for equipment, supplies and workers.

2. Water retention structures built in the arctic in the 1960s demonstrated the feasibility of frozen dams with many lessons learned.

3. Tailings facilities built since the 1980s have taken those lessons to design, build and operate frozen and unfrozen tailings dams.

4. Climate change has been amplified in the arctic and has warmed permafrost, changed ice conditions with direct impacts on infrastructure.
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