Investigating for Dry Stack Tailings Facility Closure: Multidisciplinary Evaluation at the Pogo Mine, Alaska

Dan Neuffer* and Christopher Stevens, SRK Consulting (U.S.) Inc., USA
Russell Staines, SRK Consulting (Australasia) Pty Ltd., Australia
Makoto Umedera and Sally McLeod, Sumitomo Metal Mining Pogo LLC, USA
* dneuffer@srk.com, Ph. +1-907-273-3604

Summary

Sumitomo Metal Mining Pogo LLC (Pogo) is the operator of the Pogo underground gold mine, located near Delta Junction, Alaska. The mine has been in operation since 2006 and produces between 380,000 and 400,000 ounces of gold annually. Filtered tailings from the flotation circuit and waste rock from the mine are placed in the dry stack tailings facility (DSTF). Expansion of the DSTF from 7 M tonnes to 18 M metric tonnes has prompted further evaluation of the facility for closure planning. This paper presents data from several components of a multidisciplinary DSTF closure study, including geotechnical and geochemical test results, in situ temperature and pore pressure measurements, and estimated freezing characteristics of tailings samples.

Results of this study indicate the DSTF is physically stable and is comprised of materials that are non-potentially acid-generating; these findings support operational material placement practices and elements of the DSTF closure plan. Geotechnical field and laboratory testing indicate that effective friction angles and dry densities of in situ DSTF materials are consistent with previous slope stability analyses. Geotechnical borehole drilling, thermal monitoring, and analysis indicate the presence of permafrost within the DSTF. Pore pressure measurements and drilling observations indicate a phreatic surface near the base of the DSTF. This study narrows the focus of data collection for future closure planning and provides an example of physical and chemical conditions within a dry stack tailings facility in a continental, subarctic climate. These findings are pertinent for planning, design, permitting, operation, and closure of dry stacks in similar climates.

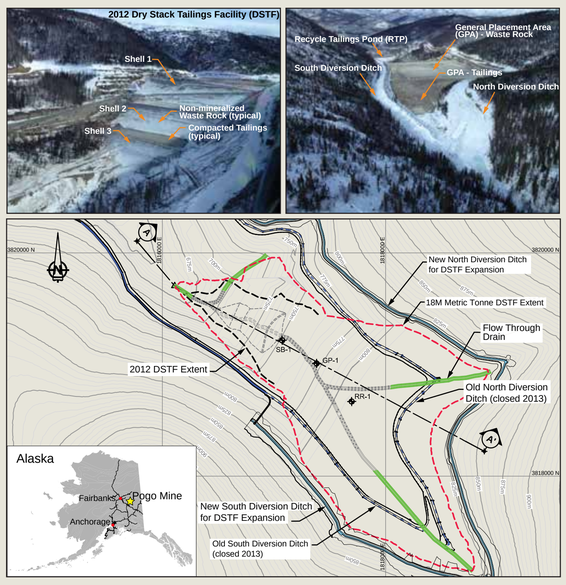
Pogo Dry Stack Tailings Facility (DSTF)

Pogo Mine is an underground gold mine operated by Sumitomo Metal Mining Pogo LLC (Pogo), located approximately 60 km northeast of Delta Junction, Alaska.

The site is characterised by a continental climate with relatively low annual precipitation (~356 mm), relatively cool summers (mean of 10°C), and cold winters (mean of −13°C). Warm (>-2 °C) discontinuous permafrost is present beneath naturally vegetated terrain.

DSTF History

- DSTF has been in operation since February 2006. Placement of approximately 5.3 M metric tonnes of tailings and waste rock through 2011
- Original design capacity of approximately 6.8 M metric tonnes
- 2011 - DSTF material balance confirmed the need for expansion of the facility by 2013
- 2012 - Increase of the permitted DSTF storage capacity from 6.8 M tonnes to 18 M metric tonnes was approved
- 2012 - Update of DSTF closure study was initiated
- 2013 - Pogo completed expansion of the surface water diversion ditches and haul road



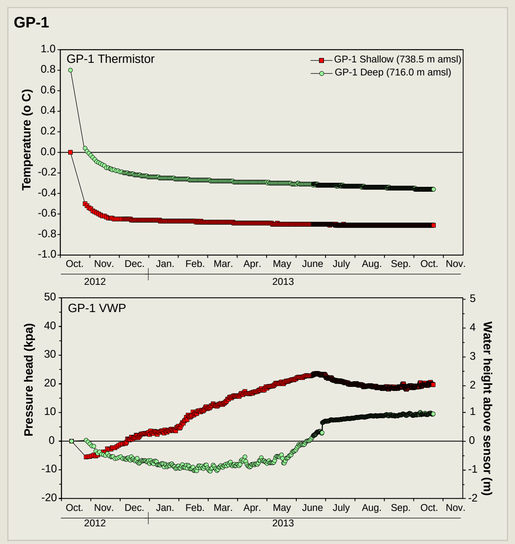
Ground Temperature and Pore Pressure

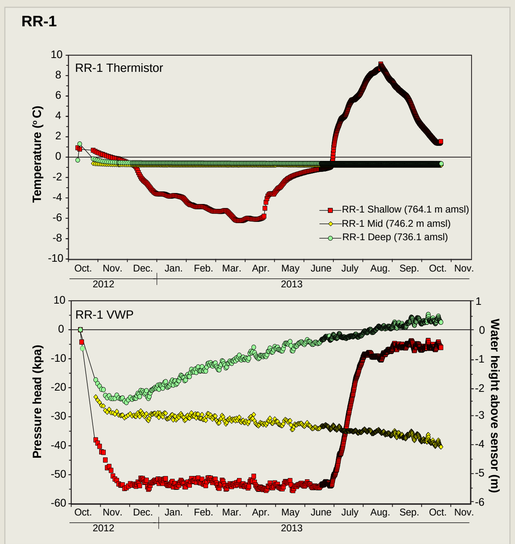
Temperature

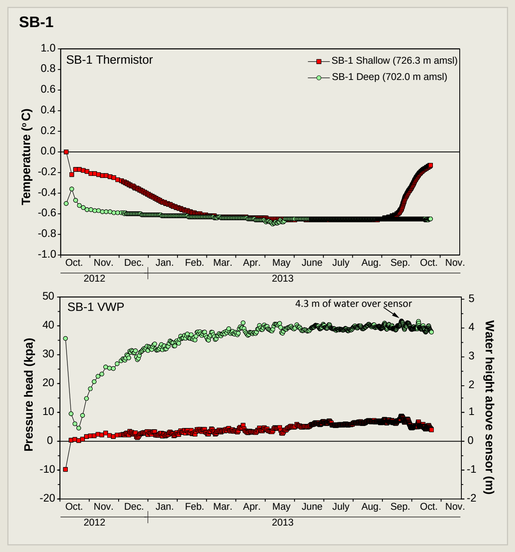
- Ground temperatures thermally equilibrated over a two- to three-month period following installation
- Shallow ground temperatures ranged from 9.1°C to −6.2°C in response to surface heating and cooling (VWP Sensor RR-1 Shallow)
- Deep ground temperatures below the depth of seasonal variation ranged from −0.4°C to −0.8°C
- Permafrost, as thermally defined, is present within the DSTF

Pressure

- VWP recorded both positive and negative pore pressures
- Positive pore pressures recorded at the site may be caused by a phreatic water surface above the sensor
- Negative pressures may be caused by either soil matrix suction in unsaturated materials or cryosuction under freezing conditions
- SB-1 Deep sensor - maximum pressure of 41.7 kPa, equivalent to a water height of 4.3 m above the sensor

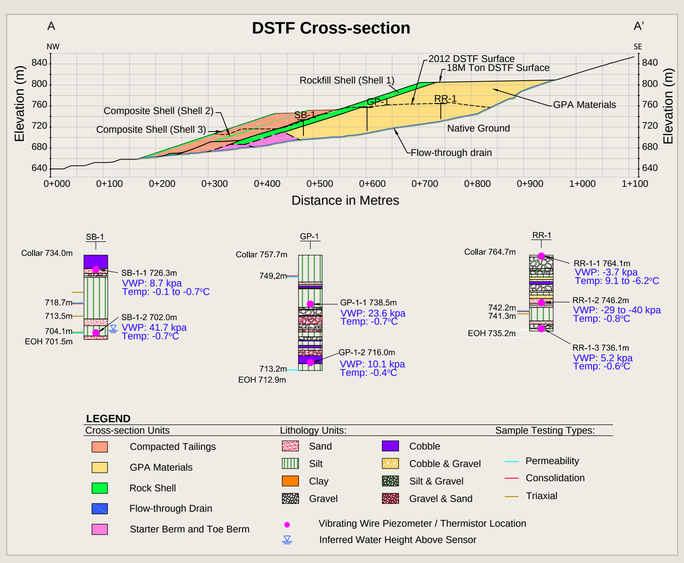






Subsurface Investigation

- Subsurface investigation to evaluate DSTF geotechnical, thermal, hydrogeological, and geochemical characteristics
- Major components of the facility include the starter and toe berms, shells, general placement area (GPA), and flow-through drain
- Three sonic boreholes were vertically drilled at SB-1, GP-1, and RR-1 (total depth of 107 m)
- Sonic core, standard penetration testing (SPT), and Shelby tube samples were collected
- Four Shelby tube, 38 modified California and 49 geotechnical grab samples
- Laboratory testing included grain size, Atterberg limits, natural moisture and density, consolidated-undrained triaxial shear, flexible wall permeability, and consolidation
- Vibrating wire piezometers (VWP) were installed at SB-1, GP-1, and RR-1 to measure ground temperature and pore pressure



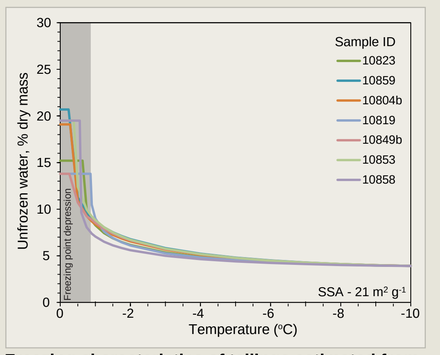
Tailings Freezing Characteristics

- Phase state of water in the DSTF affects physical stability, surface water runoff characteristics, permeability, and geochemical reactivity of materials in the stack
- Estimated unfrozen water content curves for DSTF tailings indicate liquid pore water is present at subfreezing temperatures
- The unfrozen water content at −1°C is estimated to range between 7 and 11% of the dry mass
- Presence of unfrozen tailings can be inferred from the relatively warm ground temperatures, the fine-grained nature of the tailings, observational evidence from the drill core, and the estimated freezing characteristics

Summary of Measured DSTF Ground Temperature

Site	Sensor description	Sensor depth[1] (m b.g.s.)	Elevation[2] (m a.m.s.l.)	Temperature (°C)	Measurement date/period
SB-1	Shallow	7.6	726.3	−0.1 to −0.7	10/3/2012 to 10/22/2013
SB-1	Deep	31.9	702.0	−0.7	10/22/2013
GP-1	Shallow	19.2	738.5	−0.7	10/22/2013
GP-1	Deep	41.8	716.0	−0.4	10/22/2013
RR-1	Shallow	0.6	764.1	9.1 to −6.2	10/1/2012 to 10/22/2013
RR-1	Mid	18.6	746.2	−0.8	10/22/2013
RR-1	Deep	28.7	736.1	−0.6	10/22/2013

1. Sensor depth is based on the depth below ground surface (b.g.s.) at the time of sensor installation (October 2012).
2. Elevations are presented as metres above mean sea level (m a.m.s.l.).

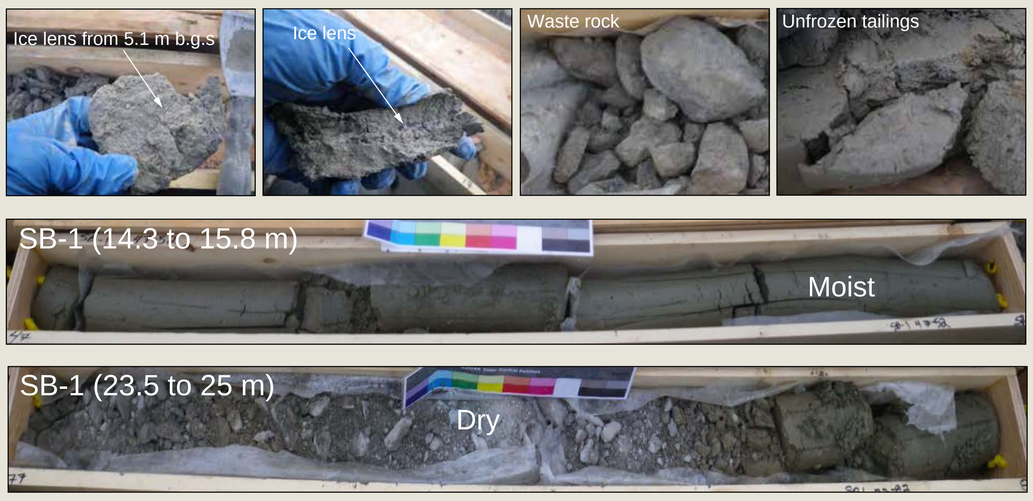


Freezing characteristics of tailings estimated from grain size distribution Atterberg limits, estimated specific surface area

Dry Stack Tailings and Waste Rock

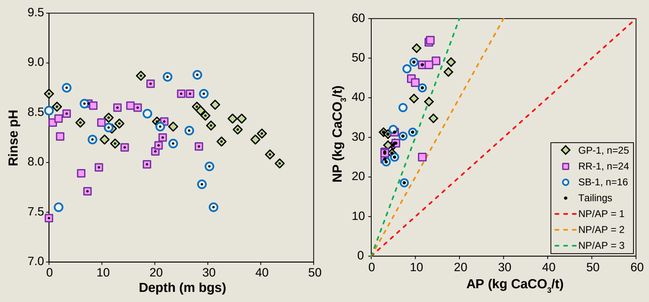
- Silt-size tailings were described in the field to be moist, with most intervals unfrozen (gravimetric moisture content from 13 to 22%)
- Sand and gravel waste rock were described in the field to be dry (gravimetric moisture content from 2 to 10%)
- Dry densities of tailings ranged from 1.68 to 1.97 g/cm^3
- SPT blow counts corrected to $(N_1)_{60}$ in tailings averaged 13 for 10 samples (range from 2 to 21)
- Effective friction angles of tailings ranged from 34−35°

Sonic drill rig used for recovery of core and installation of VWP at boreholes SB-1, GP-1, and RR-1

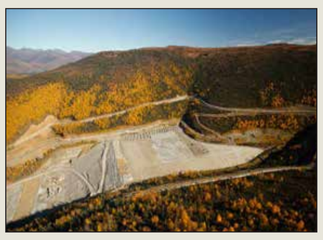


Acid-generating Potential

- Geochemical characteristics of DSTF materials affect water quality associated with the facility
- Rinse pH values were in the range of pH 7 – 9
- Nearly all samples were classified as non-potentially acid-generating (non-PAG) based on neutralization potential (NP) to acidification potential (AP) ratios greater than three (NP/AP > 3)



Key Findings and Implications for DSTF Closure



This study contributes to further understanding of the geotechnical, thermal, hydrologic, and geochemical conditions of the Pogo Mine DSTF to support closure planning. Specifically, this study confirms specific aspects of the DSTF operational construction and closure plans while narrowing the focus of data collection for future closure planning.

- Geotechnical investigation, thermal monitoring, and analyses indicate the presence of both frozen and liquid water within the DSTF
- Pore pressure measurements and drilling observations indicate a phreatic surface near the base of the DSTF and isolated, perched saturated zones within the dry stack
- Density and shear strength of DSTF materials indicate static and pseudostatic slope stability of the stack and stability against liquefaction
- Geochemical analyses of DSTF materials show that acidic drainage from the stack is unlikely
- DSTF ground temperatures confirm the presence of permafrost, as thermally defined by temperatures at or below 0°C
- DSTF can be expected to thermally evolve as additional material is added and in relation to changes in local climate and microclimatic effects
- Monitoring of VWP and evaluation of surface water and groundwater from and adjacent to the DSTF may further constrain components of the DSTF water balance, including runoff, seepage, and flow-through drain flux.
- Evaluation of the long-term metals-leaching potential of DSTF materials through laboratory testing, comparison to operational monitoring data, and water quality modelling may inform selection and design of a closure cover system

Acknowledgements

The authors thank the following: Megan Miller, for geotechnical logging of drill core and installation of VWP sensors; Ben Green, for supporting design of the VWP program; and Ivan Clark and Dan Mackie for their discussion of hydrologic processes. Alaska Department of Natural Resources and Alaska Department of Environmental Conservation have provided and continue to provide valuable feedback for the DSTF closure study. The authors also thank Sumitomo Metal Mining Pogo LLC for supporting this study.