Pit Lake Quantity and Quality Study Entirely by Remote Operated Vehicles

Mine Design, Operation and Closure Conference

May 5th through 9th, 2019

Thompson Creek Mine: Location

Thompson Creek Mine: Setting

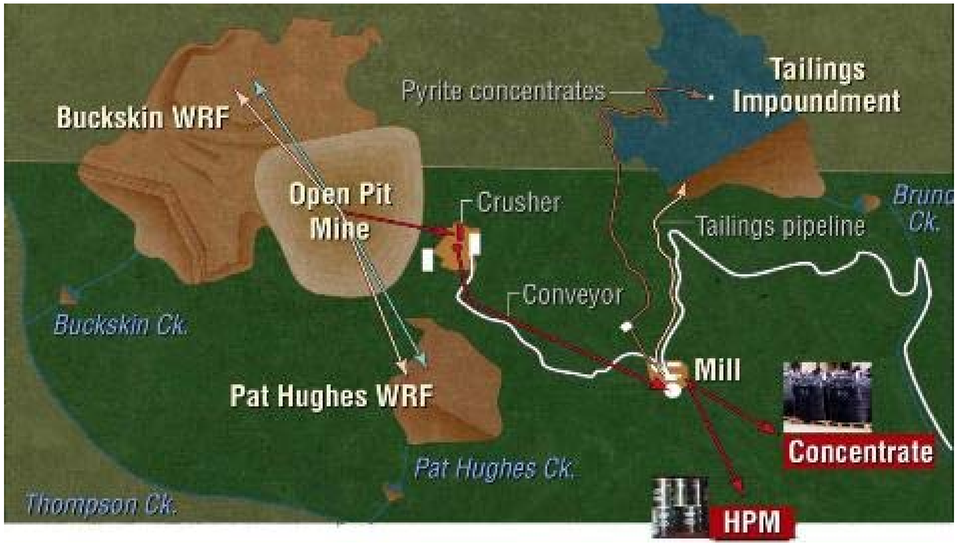
centerra GOLD

Our site is sandwiched between the Sawtooth National Recreation Area, Frank Church River of No Return Wilderness, and the White Clouds Recreational Area. We are located on the banks of the Salmon River which is a designated Outstanding Resource Waterbody

As you can imagine in an area like this careful planning is critical. – Design, Operations and Closure.

Our Sites – Thompson Creek Mine

- Thompson Creek Mine is the world's fourth largest open-pit primary molybdenum mine
- Operations began in 1983, using conventional open-pit mining and an on-site 25,500 tpd mill
- In December 2014 placed on care and maintenance



Thompson Creek Mine History

- **1967** First Claims are Staked
- **1974** Environmental Impact Assessment
- **1979** Development Decision
- **1981** USFS approved Environmental Impact Statement
- **1981** Begin Construction
- **1983** First Molybdenum Ore is Milled
- **1993** Operations Suspended
- **1994** Thompson Creek Mining Company (TCMC) Resumes Mining
- **2006** Merged with a Publically Traded Company
- **2012** Discontinued Phase 8 stripping for Company financial purposes (RIF)
- **2014** Depleted Phase 7 ore and began Care & Maintenance (RIF)
- **2015** Began Beneficiation – Slow strip Phase 8 until August
- **2016** Operating budget for beneficiation
  - October 20th – acquired by Centerra Gold

MINING OPERATIONS

- Typical truck and shovel operation
- 17 – 190 ton haul trucks
- 3 - Large front shovels with 993 loader backup
- 7200’ overland conveyor from crusher to mill
- 135,000 tons per day capability – double shift, 365 days/year

MILLING ACTIVITIES

Molybdenite

- Concentrate
  - Sent to Langeloth smelter, ~56 % Mo, roasted to MoO_3
- HPM
  - >98% MoS_2
  - Solid lubricant
  - Size graded
  - Shipped directly to the customer

Project Description – Pit Lake Study

- In the early days of the mining project several assumptions were made regarding WQ at closure. By approx. 2000 the company realized active water treatment would be necessary following closure. This was the driver to developing an understanding of water quality and the filling rate of the pit as active dewatering ceased. These concepts were incorporated into the Plan of Operations for mining Phase 8 at site.

- Models were developed from 2006 through 2010. These were used in the EIS process to evaluate the updated impacts of closure as well as throughout the mine's life cycle to update bonding levels and make management decisions regarding restart plans following periodic shutdowns.

Utility & Need for Update of Models

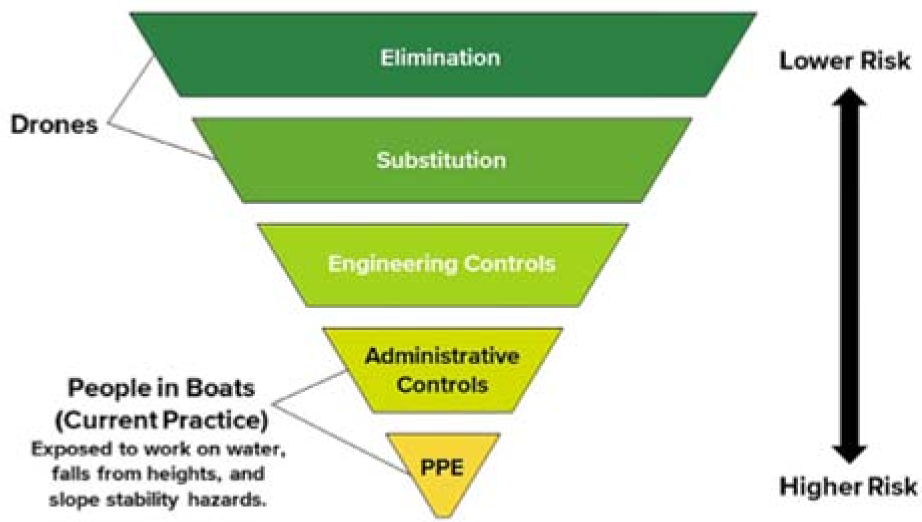
UTILITY

- Accurately account for incremental volume increases from month to month and year to year.
- Gauge the cumulative volume in terms of duration for dewatering to facilitate a restart of mining activities.
- Forecast the duration until pit has filled to control elevation.
- Measure/characterize quality and inflow patterns (month to month) to be used in design of Long Term Water Management Strategy following closure.
- Periodically update bonding levels.

NEED FOR CHANGE???

- The existing Stage-Storage Curve was based on As-Built topography of the Phase 7 mine pit. → December 2014
- The estimated inflow rates were based heavily on empirically derived estimates. → Very little data was available for climatic conditions at site, runoff rates, what sources would require capture/treatment, ….
- Predicted long term water quality was based entirely on empirically calibrated models. → No segregated source water quality data was available at the time.
- Bonding approaches taken to date have been coarse. → Admittedly less than adequate to fund recognized responsibilities to satisfy the Company’s commitments to environmental stewardship (Social License).

Considerations for Field Activities



Stage-Storage Model

- As-Built Mining as bench is advanced downward. – Note the geometry, predictable regular intervals, etc.

Stage-Storage Model

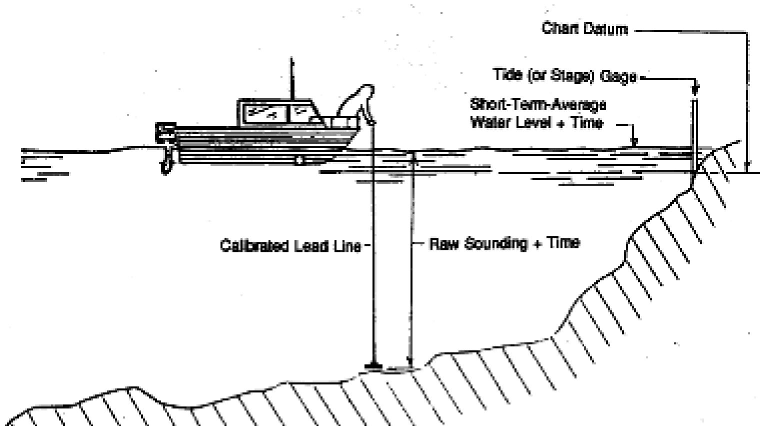
- Topographic fatigue. – Contrast to shape regular bench cuts.

Stage-Storage Model

- Significant Additional Displacement – December 2016 failure of highwall.

Stage-Storage Model – Recalibration Needs

- Bathymetry Study (Topography below the waterline).

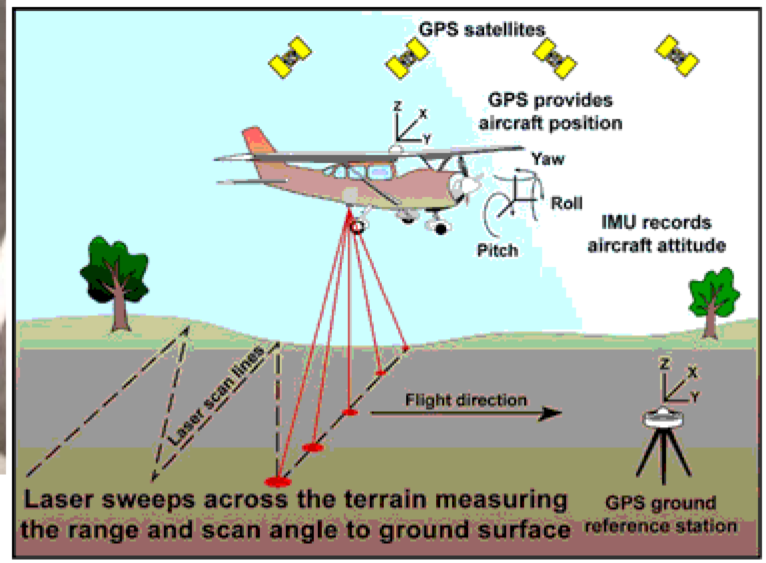


- Traditional Approach – Manual Weighted Tapes, Acoustics, etc.

Stage-Storage Model – Recalibration Needs

- Topographic survey (Topography above the waterline).

- Traditional Approach – Transom and rod (manual or automated Total station), GPS, Orthographic photo, etc.



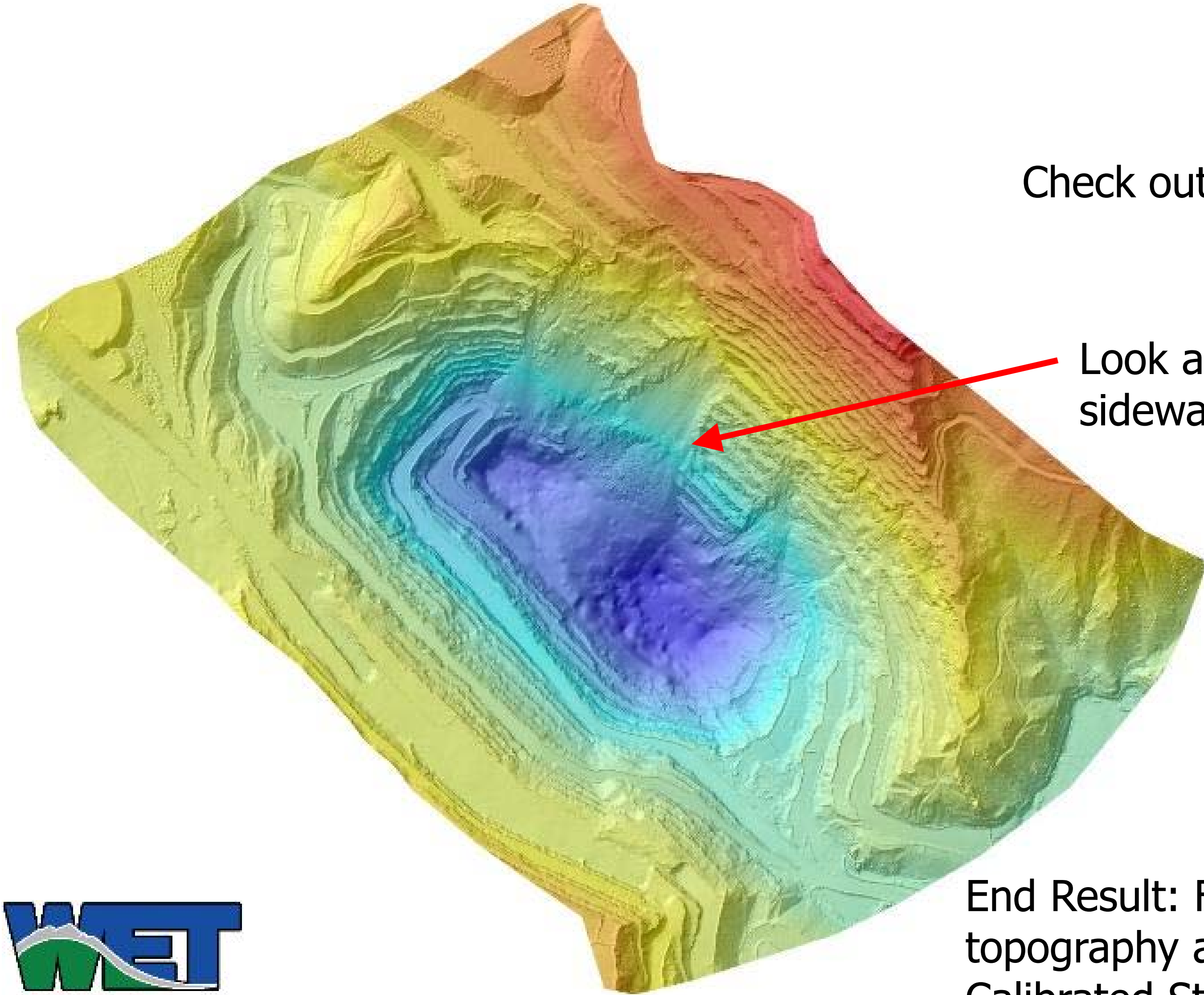
Stage-Storage Model – Recalibration

Selected Methods

Bathymetry

Topography

Stage-Storage Model – Recalibration Result



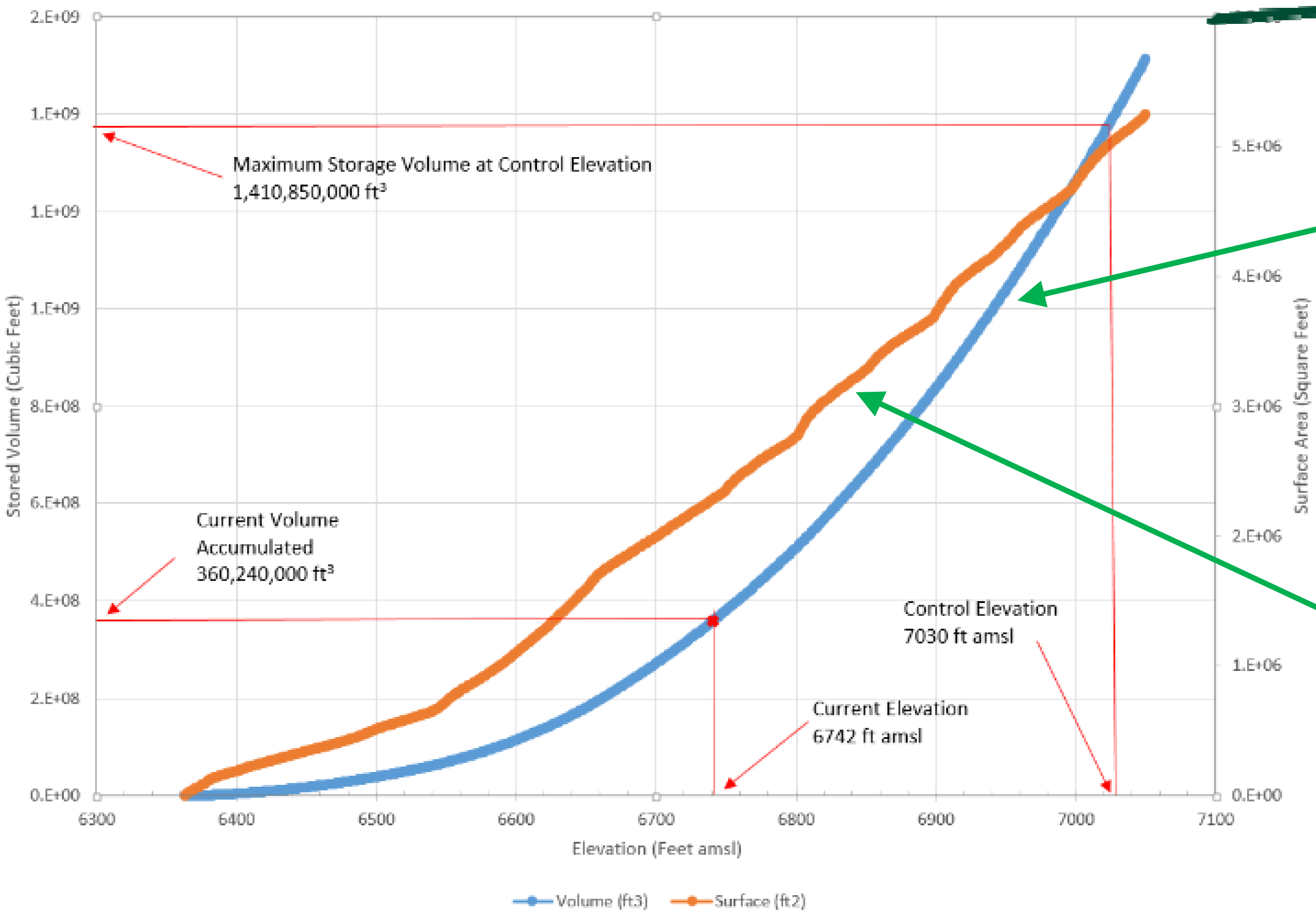
Check out those graphics.

Look at the shape of the sidewall failure underwater.

End Result: Fully integrated topography above and below water. Calibrated Stage Storage Model.

Stage-Storage Model – Recalibration Result

Pit Lake Stage Storage Curve



Volume valued for Dewatering Duration, buffering affects, etc.

Surface Area valued for estimating Evaporative losses, Thermal absorption, etc.

Pit Water Quality

- Matrice 600: 6 rotor or Hexa-copter
  - 6kg (Approx. 13lbs) lift capacity
  - Max. Fly time of 16 min @ max payload.
  - Avg. time to sample point + Avg. time at sample point (sample or measurement collection time)= Total Time for Roundtrip Travel = 12 min.

- YSI CastAway: A Conductivity-Temperature-Depth (CTD) probe
  - Weighs 0.45kg (Approx. 1.0lbs)
  - Capable of measuring parameters at a rate of 5 times per second (decent/ascent).
  - Bluetooth connection and companion software.

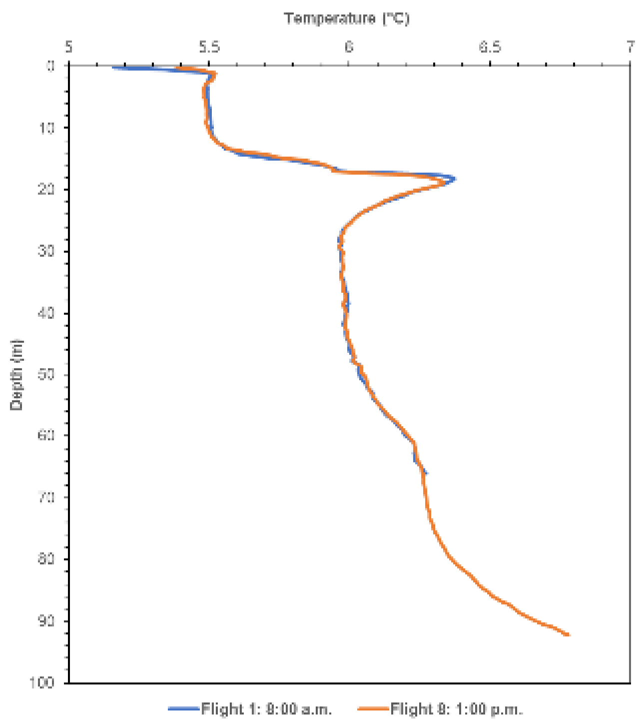
Pit Water Quality

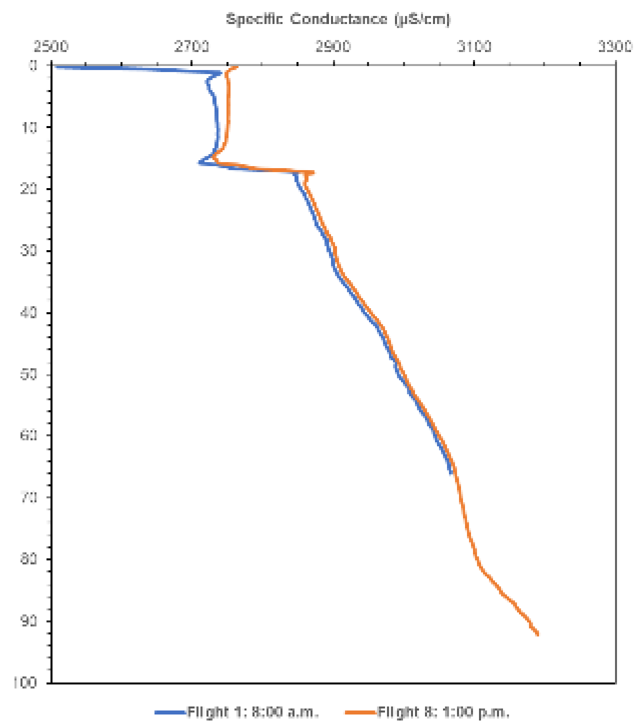
Reference	Sample Volume	Depth	Description
Ore et al., (2015)	20 mL	< 1 m	1-m-long tube with onboard pump
Cornell et al., (2016)	50 mL	0 m	Falcon tube dipped below surface
Koporan et al. (2018)	130 mL	0.6-0.8 m	Thief-style, messenger-triggered bottle
Terada et al. (2018)	250 mL	< 0.8 m	Sample tube with check-valve
Washburn et al., (2018)	500 mL	5 m	Bottle closes at a specific pressure
IRYS (2016)	1000 mL	0 m	Thin tray submerged in water
Castendyk et al., (2017a)	1250 mL	80 m	Niskin sample bottle
Williams et al., (2018)	2000 mL	83 m	Proprietary sampling device

- Numerous types of sampler can be used.
  - Choose based on your specific needs including volume, depth, UAV payload constraints, etc
- Sampling device used for our event ???
  - Proprietary sampling device constructed by Golder Associates.

Water Column Profile

Made 10 flights to a point on the water surface that was believed to overlie the deepest location.





- Flight 1 and Flight 8, the CTD probe was deployed.
- Flight 1 reached 66m while Flight 8 reached 92m.
- Both flights ID'd 3 distinct layers.
  - Shallow layer 0-13m
  - Transitional layer 13-26m
  - Deep layer 26-92m

Sample Depth Selection

Based on the variability within the water column samples were collected from each of the distinct layers:

- 2 from the shallow layer (0m and 10m)
- 1 from the transitional boundary (17m)
- 4 from the Deep layer (20m, 40m, 60m and 90m)

Initially 4 samples were submitted for laboratory analysis. These samples were collected from 3m, 15m, 40m and 83m (depth adjusted based on data collected with a Van Essen Micro-Diver DI610 pressure transducer to ensure the exact depth of sample collection was recorded).

- A comprehensive analysis including metals and other analytes of interest was performed. Summarized for this presentation are: Lab pH, major cations, Total Sulfide (S^-), Total Organic Carbon (TOC), and Total Dissolved Solids (TDS).

Depth	pH	Ca^{2+}	Mg^{2+}	Na^+	K^+	S^-	TOC	TDS
3 m	7.6	406	28	199	12	< 0.04	0.9	2220
15 m	7.6	401	29	204	12	< 0.04	1.1	2230
40 m	7.2	429	27	225	12	< 0.04	0.9	2400
83 m	7.2	464	26	236	11	< 0.04	0.9	2570

Sample Depth Selection

The Water Quality in the pit lake currently meets all effluent limits.

The water in the pit lake was treated prior to accumulation.

Prior treatment consisted of lime addition, clarification (flocculent and coagulant addition) and filtration using disk filters with equipped with 8 micron membranes. Additional settling time in the pit has further polished WQ (removed fine particles).

This water is ready for direct discharge.

	001 (Avg Monthly)		002 (Avg Monthly)		004 (Avg Monthly)		005 (Avg Monthly)		Pit Samples collected 11/13/18			
	<7cfs	>7cfs	<7cfs	>7cfs	<50cfs	>50cfs	<2000cfs	>2000cfs	3m	15m	40m	83m
Cadmium	56	1.4	8.5	5.5	5.8	13	6.2	15	**1.68**	**2.13**	**1.81**	**1.38**
Copper	150	20	22	26	24	37	59	160	**1.0**	**2.7**	**1.8**	**1.6**
Lead	73	5.4	23	13	26	19	10	25	**0.1**	**0.19**	**0.12**	**0.15**
Mercury	0.73	0.69	0.57	0.057	0.044	0.1	0.3	0.2	**ND**	**ND**	**ND**	**ND**
Selenium	0	41	27	11					**9**	**9**	**6**	**3**
Zinc	750	160	190	300	260	350	500	500	**60**	**73**	**61**	**47**
TSS	20	20	20	20	20	20	20	20	**<10**	**<10**	**<10**	**<10**
pH	6.5-9.0	6.5-9.0	6.5-9.0	6.5-9.0	6.5-9.0	6.5-9.0	6.5-9.0	6.5-9.0	**7.6**	**7.6**	**7.2**	**7.2**

Thank You for Your Attention

QUESTIONS?