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Overcoming Challenges in Long-term Groundwater Interception

Lower Mine Yard, Former Sullivan Mine, Kimberley, BC

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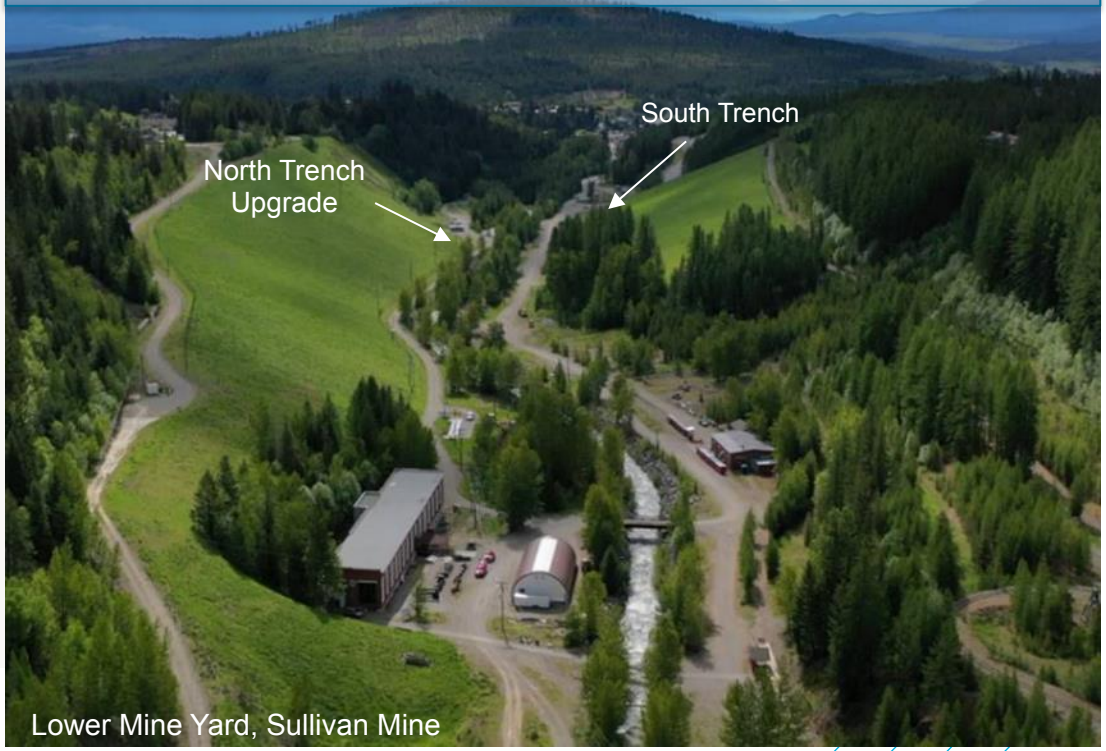
2020 BC MEND ML/ARD Virtual Workshop Challenges and Best Practices in Metal Leaching and Acid Rock Drainage

December 1, 2020

Outline of Presentation

- Site and Reclamation History
- Hydrogeological Characterization
- Collection System Design
- Construction Methods
- Operations and Maintenance
- Water Quality Improvements
- Overcoming Challenges

Overcoming Challenges in Long-term Groundwater Interception



Lower Mine Yard, Sullivan Mine

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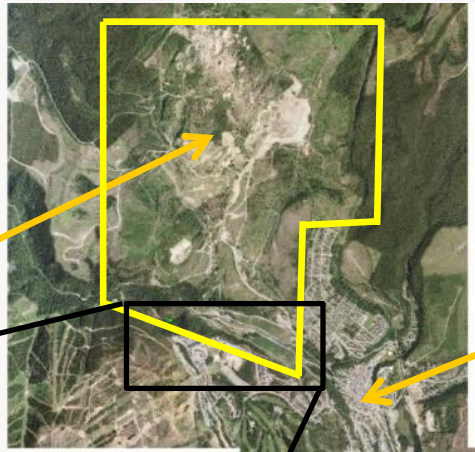
Sullivan Mine, Lower Mine Yard Location

Lower Mine Yard located in Mark Creek valley, west of Kimberley south of the Sullivan ore body.

Where is Kimberley, BC?

Former Mine and Waste Rock Areas

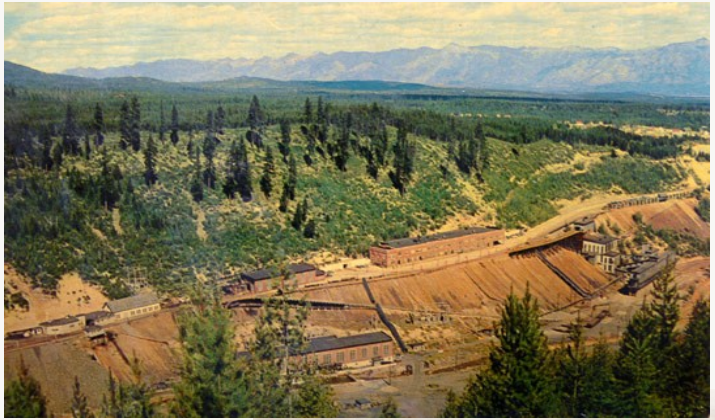
City of Kimberley



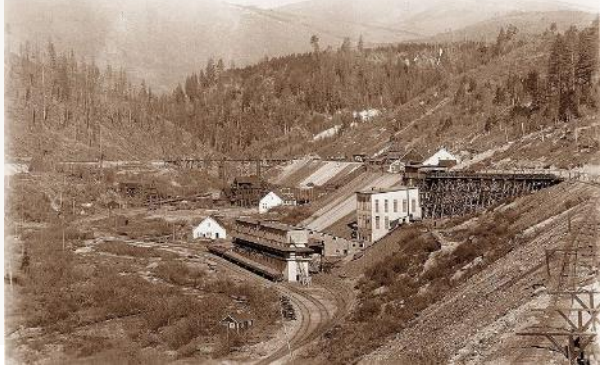
Former Mill Site and Tailings Areas (Marysville to south)

Lower Mine Yard History

- Once a highly industrialized portion of the Mark Creek valley
- Ore hauled to the Lower Mine Yard for handling until 1947
- Development rock from the 3900’ level placed on the north and south valley walls
- ~4.1 million tonnes of waste rock placed over 15 hectares of valley slope
- Iron-rich with some ore-grade zinc. Oxidation of pyrrhotite and pyrite resulted in ARD/ML



View to north

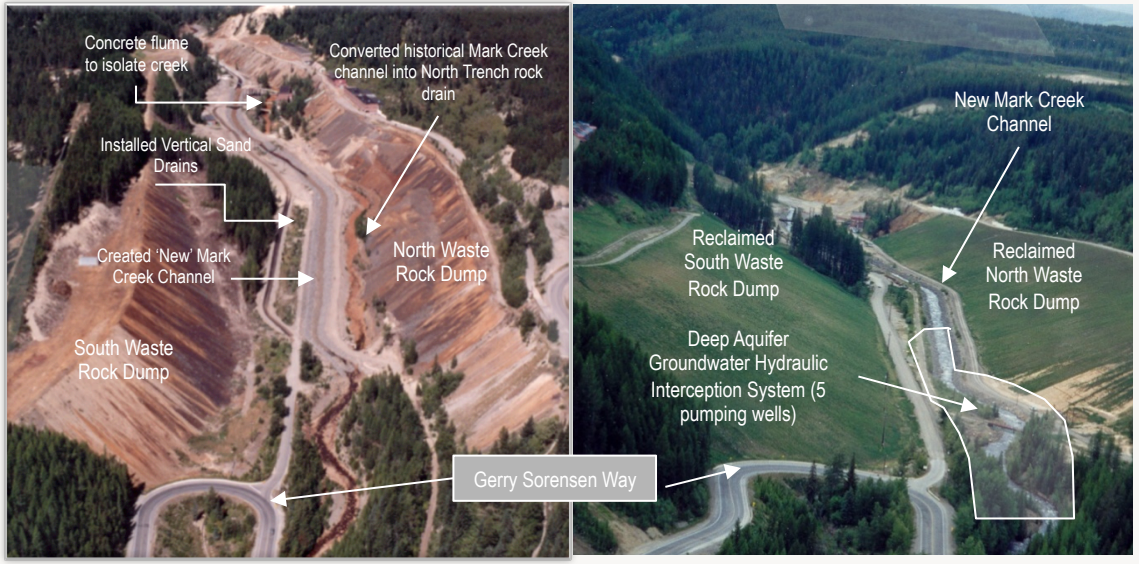


View to northwest

Major Reclamation – 1990s Groundwater/Surface Water Mitigation

Groundwater and Mark Creek surface water affected by ARD/ML. Measures taken in 1990s:

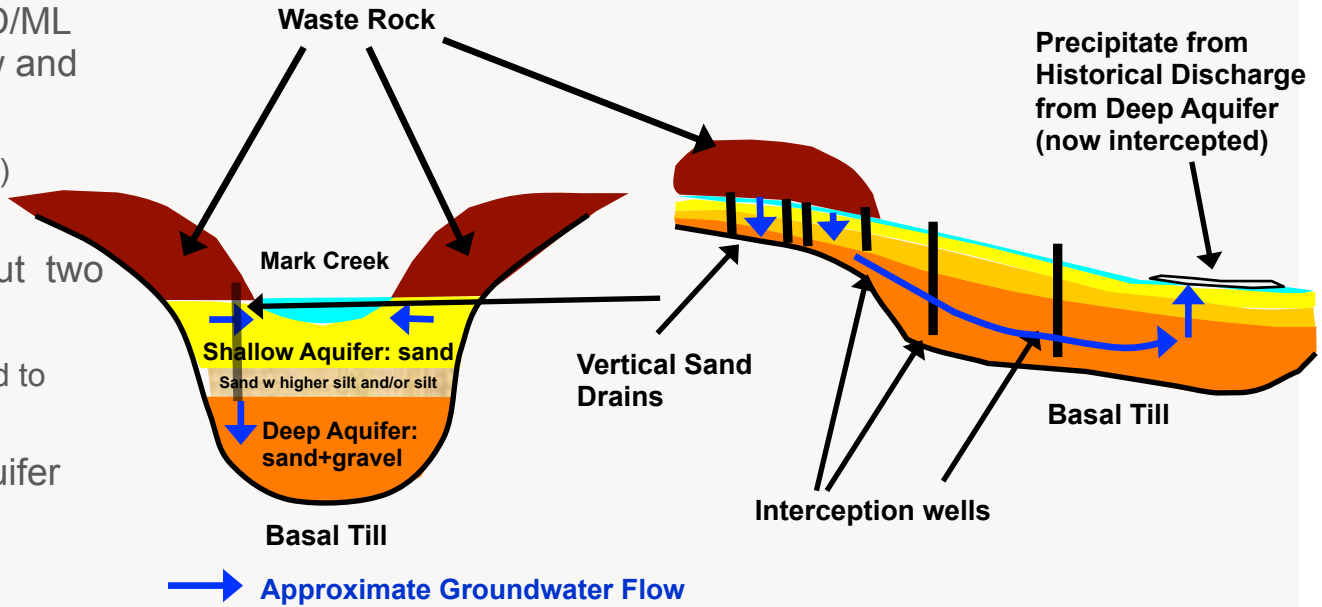
- Creek isolated
- North Dump: lined flow-through rock drain
- South Dump:
  - vertical sand drains to flow to deeper aquifer: limited space
- Hydraulic interception in deep aquifer (five interception wells)
  - Groundwater collected for treatment



Lower Mine Yard: Before and After 1990s Reclamation/Remediation

Challenge #1: Understanding Complex Hydrogeology to Develop Mitigation Strategies for Shallow and Deep Groundwater

- Groundwater affected by ARD/ML from waste rock: both shallow and deep aquifers
  - Historical (i.e., pre-mitigation) discharge into Mark Creek
- Shallow aquifer is perched, but two types of perching present
  - Vertical Sand Drains installed to promote downward flow
- Interception wells in deep aquifer



Challenge #2: Implement Temporary Mitigation in Short Timeframe

Since 1990s, groundwater and surface water monitoring under site wide Risk Management Plan

Monitoring

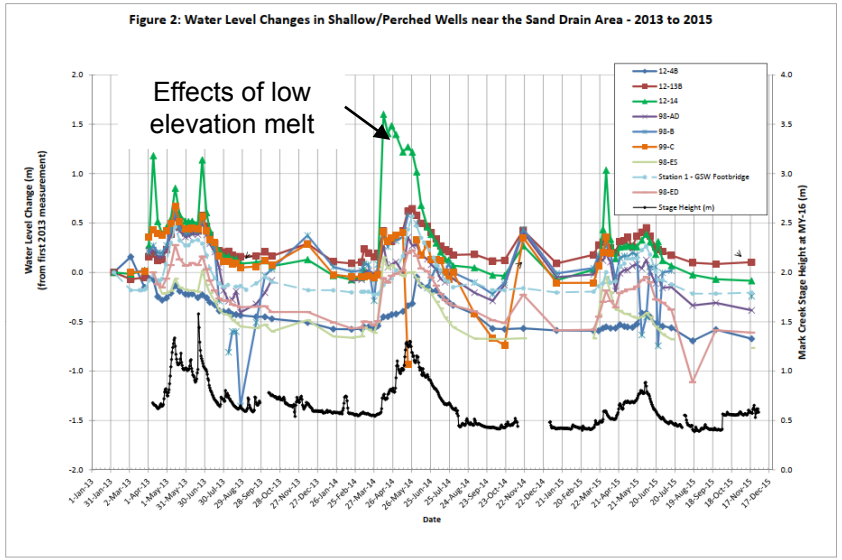
Monitoring identified Acid Rock Drainage bypass of collection system in 2012 (north/ south side), in 2018 (north side).

Challenge: *Temporary Mitigation Measures under short timeframe*

1) Pumping Wells (South Dump)
2) Collection point upgrade (North Trench)

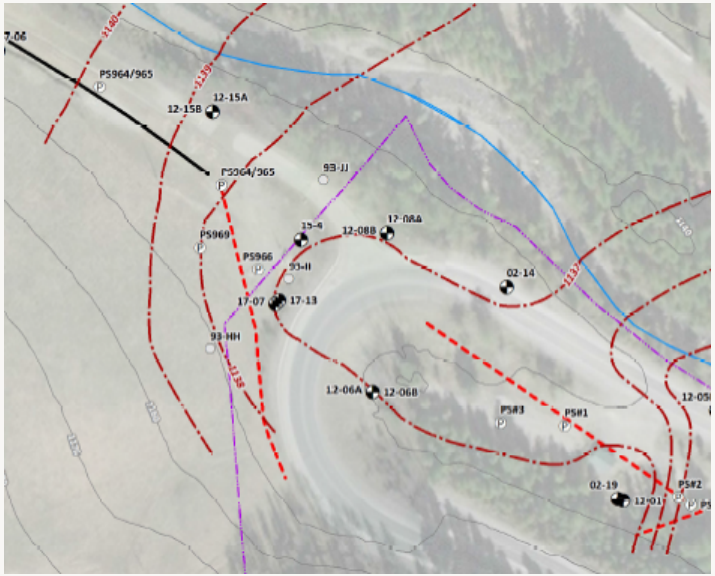
Challenge #3: Characterization under Time/Site Constraints.

South Dump - Sand Drain Area



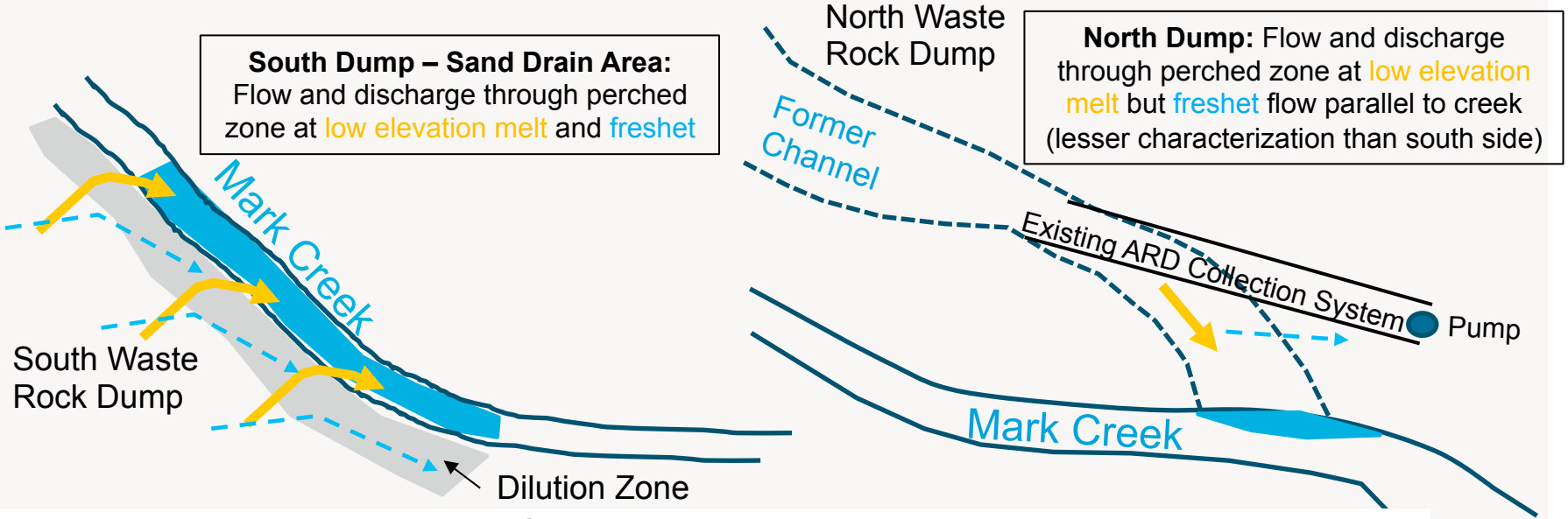
Challenge: *Detailed monitoring under short timeframe. Example: higher hydraulic gradients in shallow aquifer in Sand Drain Area during low elevation melt (i.e., pre-freshet)*

South Dump - Gerry Sorenson Way Area



Challenge: *Detailed characterization with site constraints. Example: indicated continuous shallow silt unit in Gerry Sorensen Way Area*

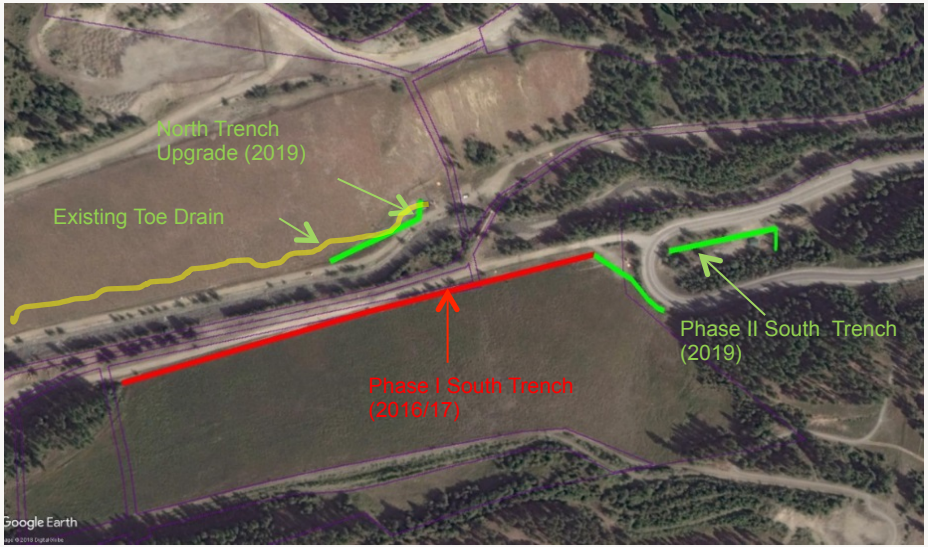
Challenge #3: Characterization under Complex Hydrogeological Setting



Factors in Discharge: variable flow regimes by season, low elevation melt

- South Dump – Sand Drain Area - vertical sand drains no longer functioning adequately
- North Dump: ARD collection system plugged, flow along former channel

Challenge #4: How do we Design Given Inherent Uncertainty?

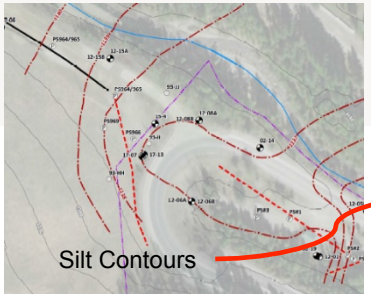


Area	Volumetric Estimates	Design Flow
South Dump: Sand Drain Area	140-175 L/Min	700-875 L/Min
South Dump: Gerry Sorenson Way	50-100 L/Min	250-500 L/Min
Total	**190-275 L/Min**	**950-1,375 L/Min**
North Trench: Collection Point Area	**5 - 70 L/min**	**350 L/Min**

Actual Volumes 50 – 100 L/Min, varies seasonally

Example Qs from an Engineer to Hydrogeologist

- How do we design for seasonality and non-perpendicular flow to creek in Sand Drain Area?
- Is silt unit in the Gerry Sorensen Way area fully continuous and if not, how do we address uncertainty?
- How do we deal with uncertainty of lesser characterization for North Dump?
- What depth and volumes?
- Will the trench fill with water if hydraulic barrier used?
- How do we develop a factor of safety?



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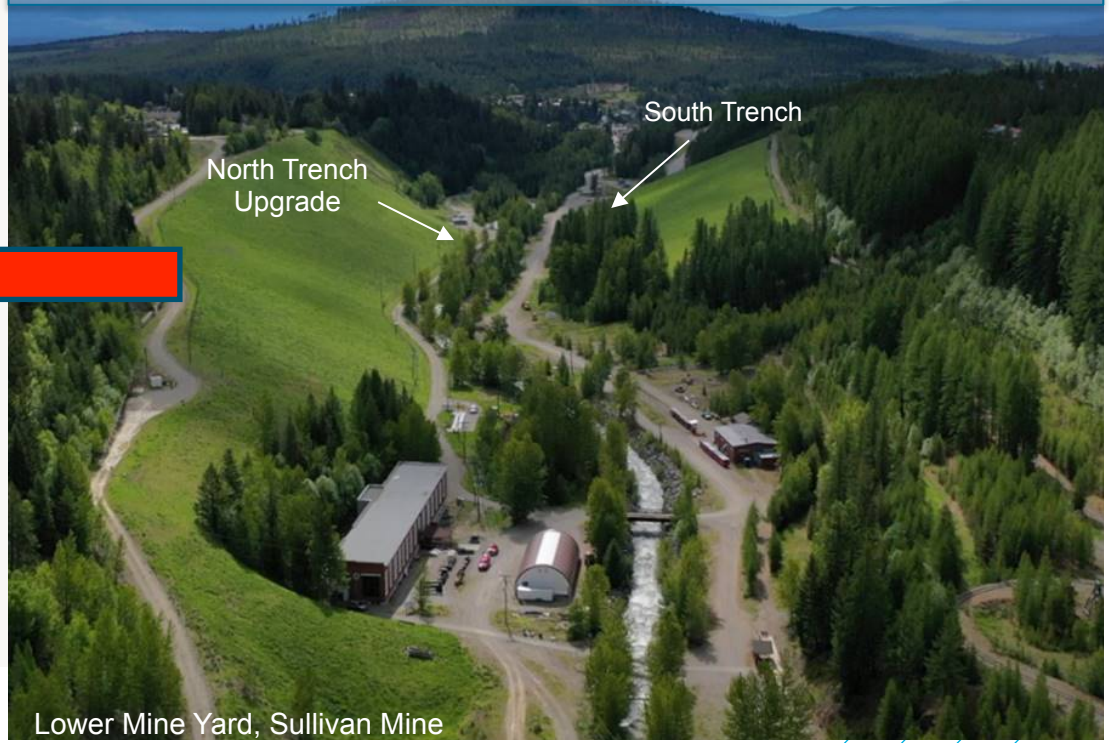
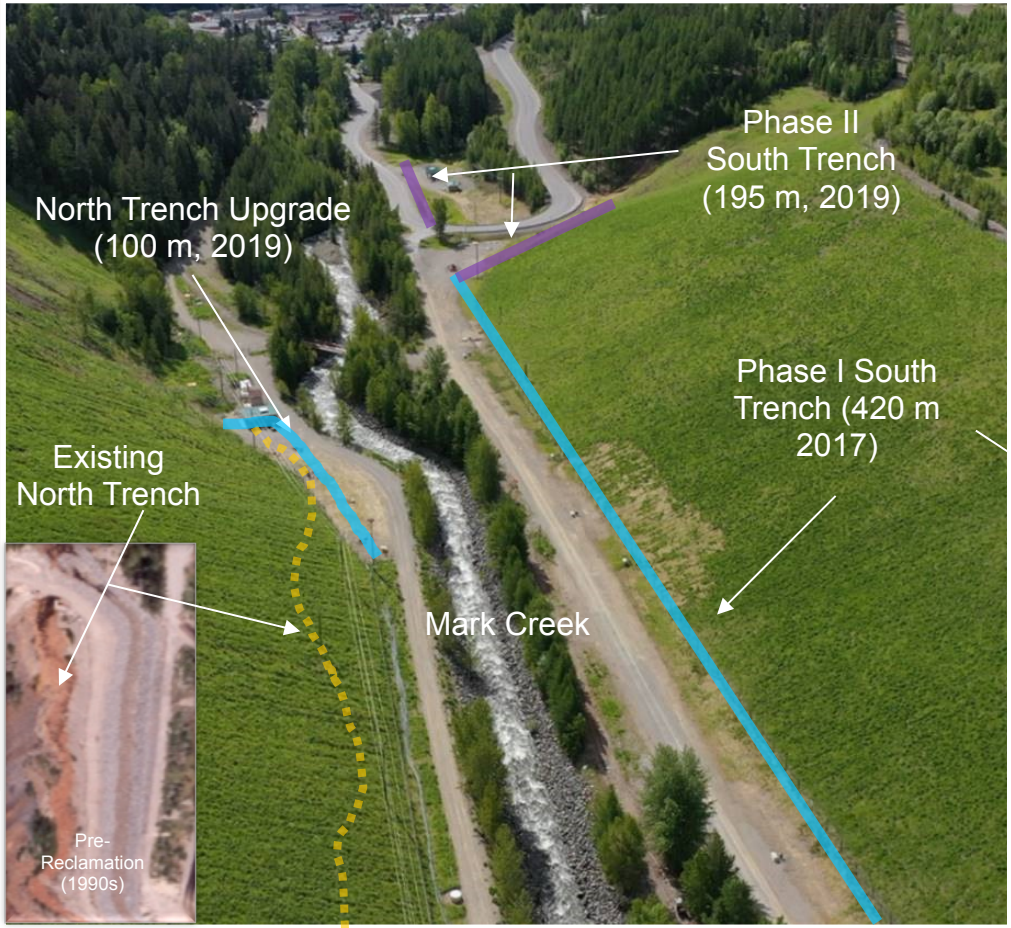
Overcoming Challenges in Long-term Groundwater Interception



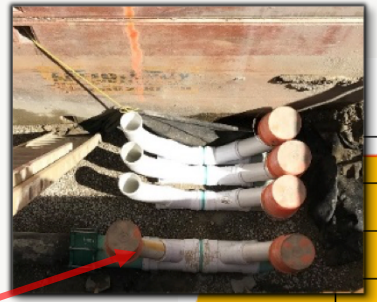
Design Setting & Timeline

- Complex Groundwater Regime
- Confined Valley, toe of waste rock dumps, Geotechnical Risks
- Creek adjacent
- Phase I South Trench – 420 m in **Sand Drain Area** (Winter 2017)
- Phase II South Trench: 195 m in **Gerry Sorenson Way Area** (Summer/Fall 2019);
- North Trench Upgrade: 100 m upgrade of existing 490 m collection system in old channel (Summer 2019)

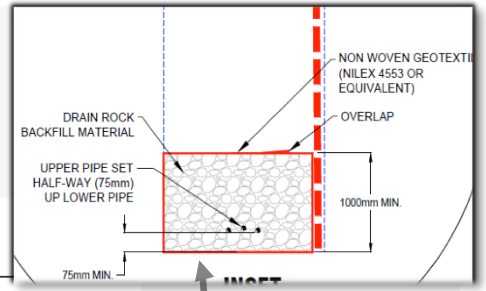


Challenge #5: Designing with Redundancy and for the Future Operations & Maintenance Program

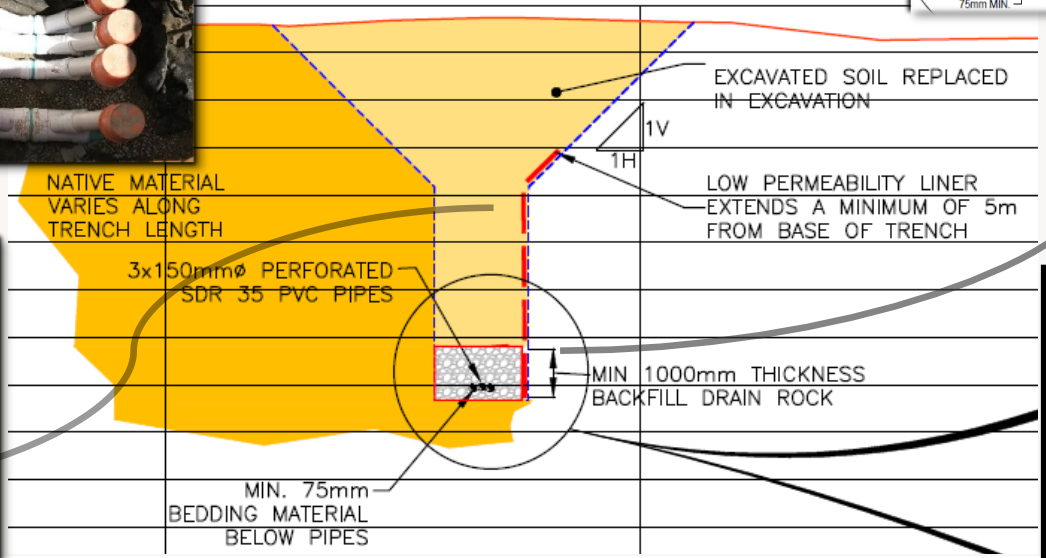
Bi directional Clean outs every 50 to 100 m for ***collection pipe maintenance***



250 mm Vault Connector Pipe



Geotextile *wrapped drain rock*



Liner on downgradient side of trench, directs seepage to perforated pipes, adds ***design redundancy***

Three 150 mm at 4.3 m length perforated PVC pipes for ***design redundancy***

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Innovative Design but is it Constructible?

Teck

MarWest Industries Ltd

R.W. Anderson Contracting

View of South Trench Southeast Arm Construction

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Challenge #6: Deep Trench Excavation up to 10 m depth….

Install Groundwater Collection Vault

Pre-excavation of trench, depths 6 m to 7 m, for shoring cage access, 15 m ‘segments’

Install liner outside access shoring cage, and set up for pipe fusing

Challenge #7: Installing Perforated Pipe and HDPE Liner Vertically in a Deep Trench

Pull access shoring cage access to next section, 60T machine

Place perforate pipes, pea gravel, geotextile wrap,

Backfill and compaction, excavated soil from next section

Process completed > 100 times, process refined

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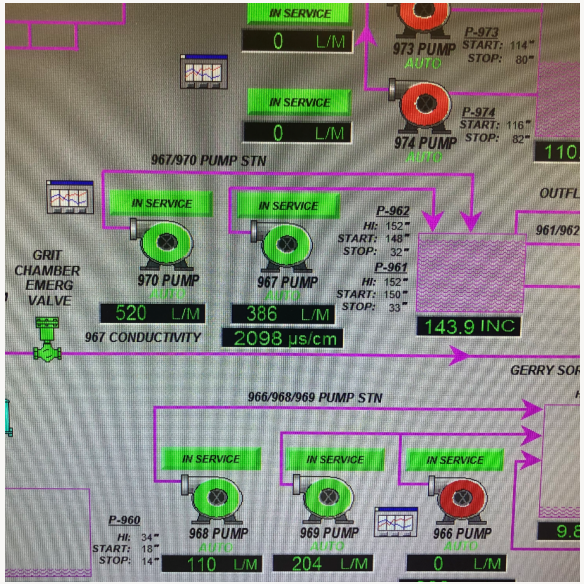
Field Engineer Onsite for Safety, Quality and Environmental Management

Daily field inspection and monitoring

North Trench Upgrade Vault Installation

Construction Activities on City Infrastructure

Challenge #8: Long Term Operations and Maintenance Program

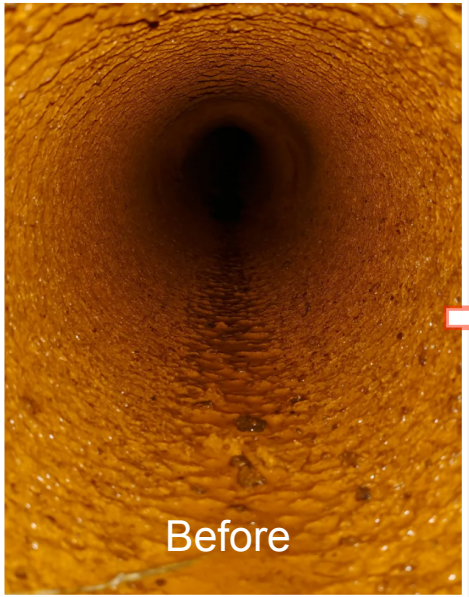


PLC Unit provides 24 hour monitoring of level sensors, pump sensors, and flow meters with alarms

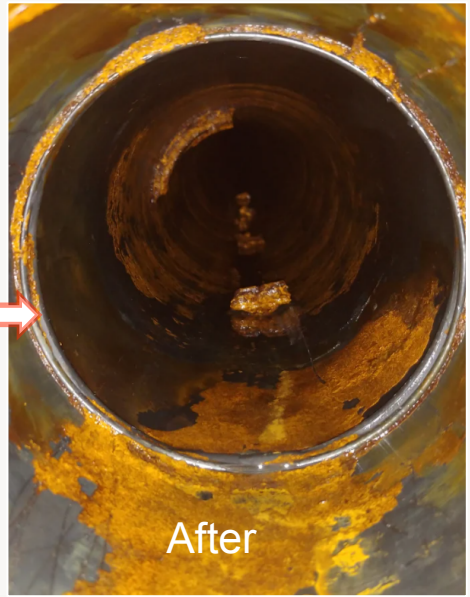
Seepage pump, gravitational flow within pipelines to storage ponds,

Phase I South Trench Stainless Pump Removal after 2 years (August 8, 2019); Phase II Vault Operational

Pipe Scaling Removal with Pipe Pig and Jet Rod Cleaning



973 discharge line < 1 year after installation



973 discharge line after jet rod maintenance 'switcher' head

3900 Line Before Annual Jet Rod and Pipe Pig Cleaning

3900 Mine Line After Jet Rod and Pipe Pig

Variety of scaling occurs, frequency of scaling maintenance varies by location geochemistry

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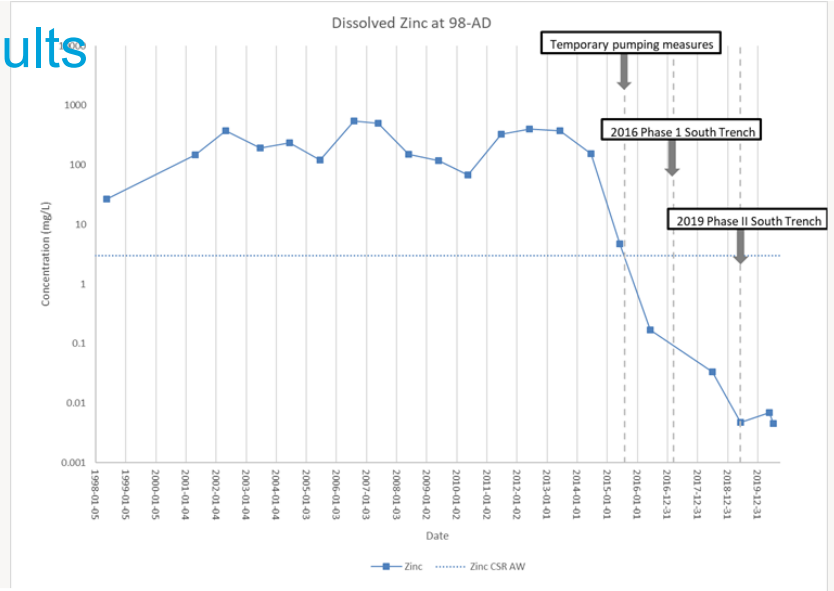
What have we covered?

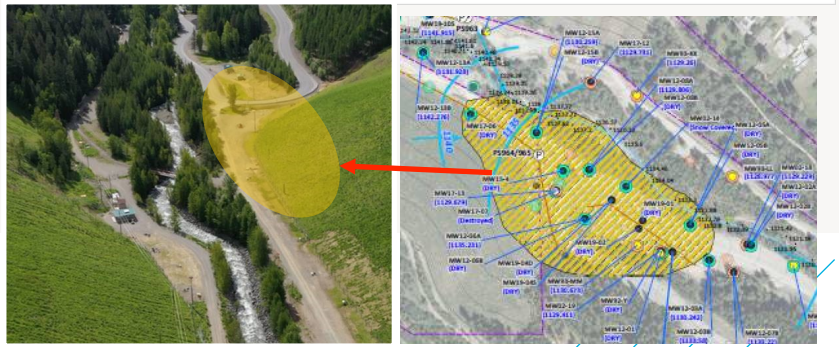
- ~~Site Location and History~~
- ~~Hydrogeological Characterization~~
- ~~Collection System Design~~
- ~~Construction Methods~~
- ~~Operations and Maintenance~~
- Performance Monitoring Results
- Overcoming Challenges

Overcoming Challenges in Long-term Groundwater Interception

Excellent Performance Monitoring Results

- Zinc concentration reduced 100x to 1000x upgradient vs. downgradient of trenches
- Large area of shallow aquifer effectively dewatered
- Deep Aquifer dissolved cadmium and zinc at historical lows
- Surface water sampling upgradient and down-gradient in 2020 indicates no significant source inputs to Mark Creek in Lower Mine Yard

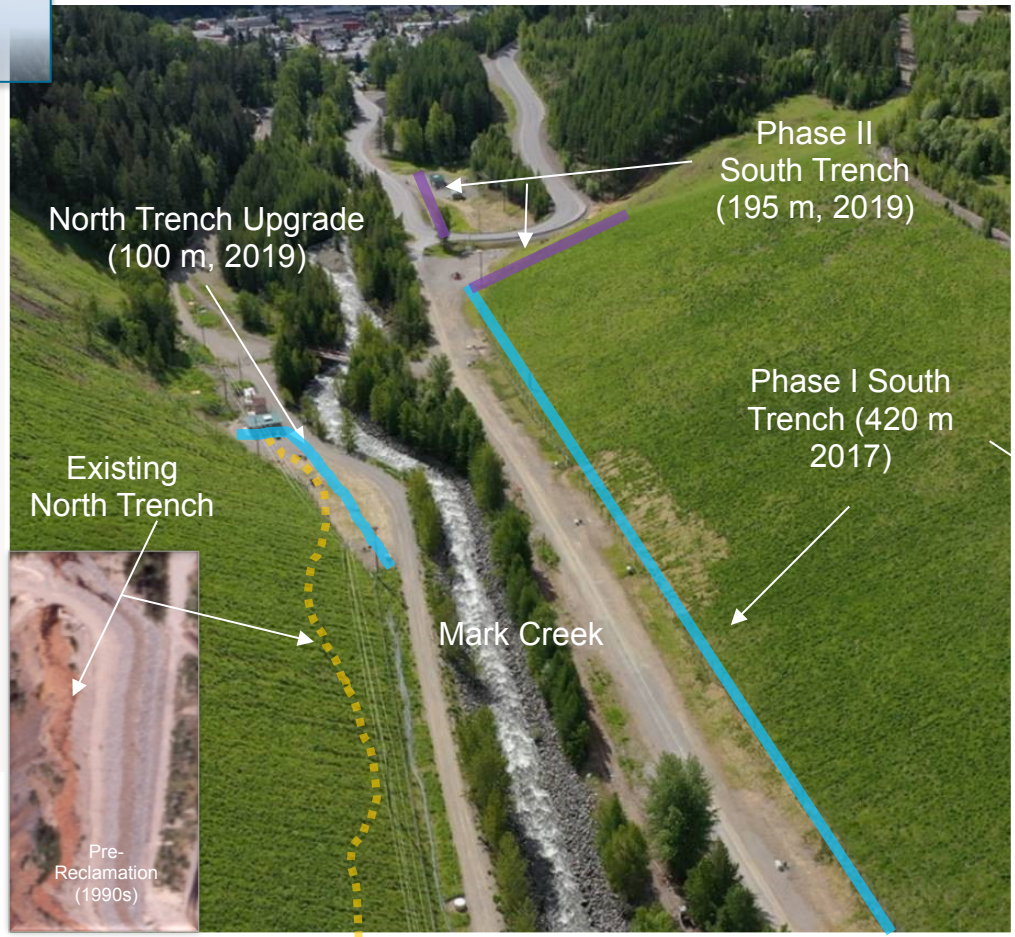




Shallow Groundwater Dewatered

Overcoming Challenges in Long-term Groundwater Interception

1. Complex hydrogeological environment requires detailed investigations.
2. We incorporated design redundancy and planned for long term monitoring and maintenance;
3. We engaged stakeholders, agencies and brought together multi-disciplinary team throughout planning, design and build phase
4. Teck has a world class operations and maintenance program and team.
5. We fostered an inclusive work culture across owner, design, build and operations teams; and with agency partners.



Acknowledgements

- **Contributors**
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Questions?
For more information, connect with Stefan & Daniel on LinkedIn & see 2019 BC TRCR Papers
Mark Creek