Appendix 4-OO

Groundwater Working Group Meeting - December 2020

Groundwater Assessment
Crown Mountain Coking Coal Project

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December 16, 2020

NWP Coal Canada Ltd

srk consulting

Contents

Contents

Objectives and Scope

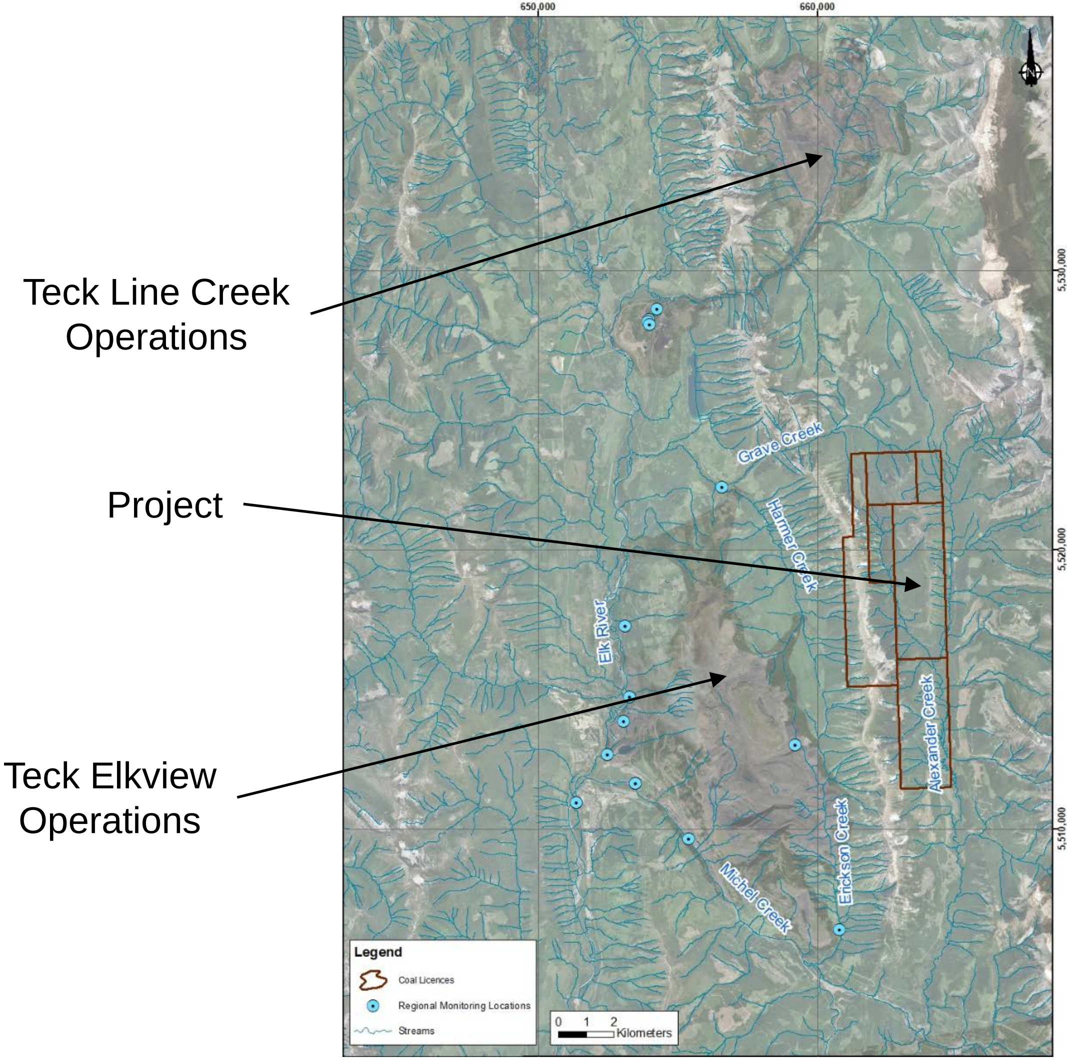
- Objective: To assess potential impacts of the project on groundwater quantity and quality

- Scope: Groundwater potentially affected by all pertinent mine components in Alexander Creek and Grave Creek catchments, including Baseline, End of Mining and Post-Closure periods.

- Impacts to surface water (quantity and quality) are covered elsewhere.

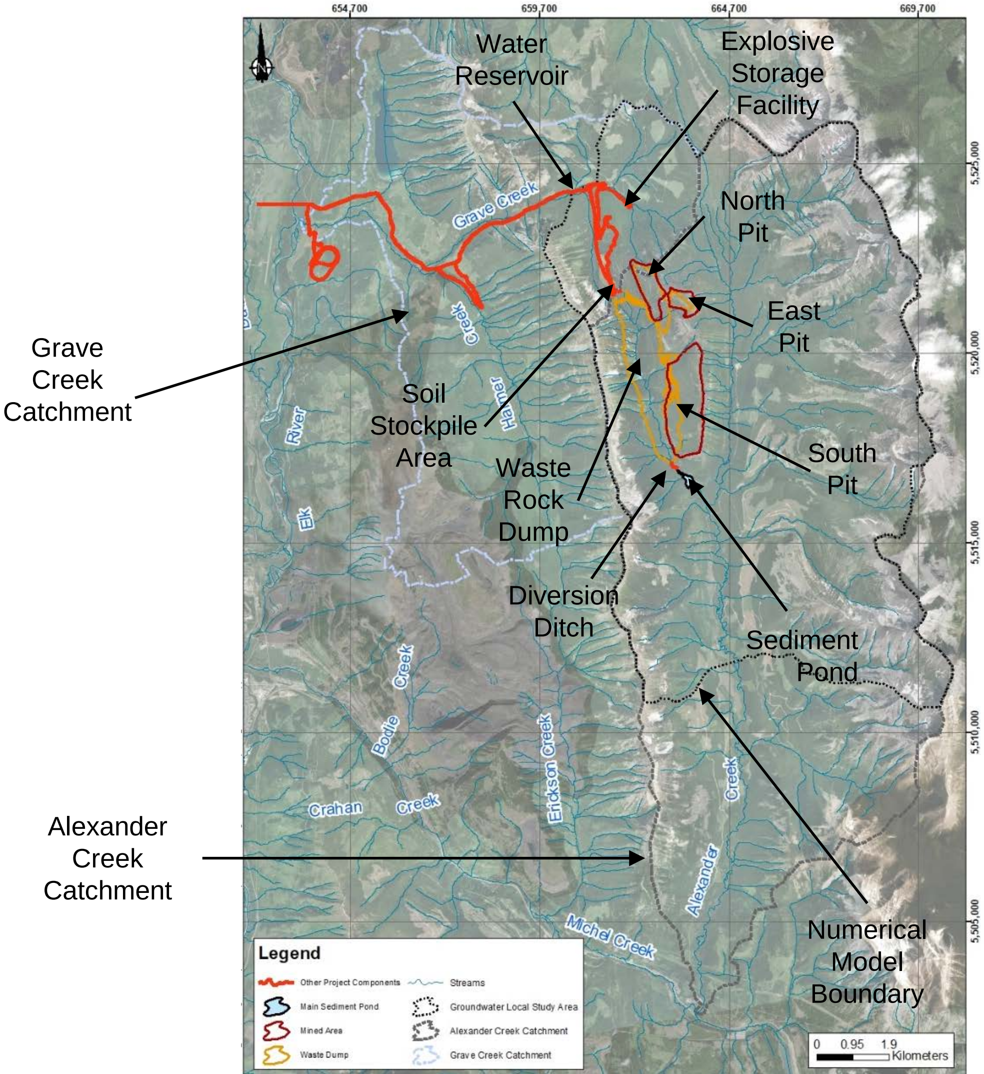
Contents

Project Overview
Regional Setting



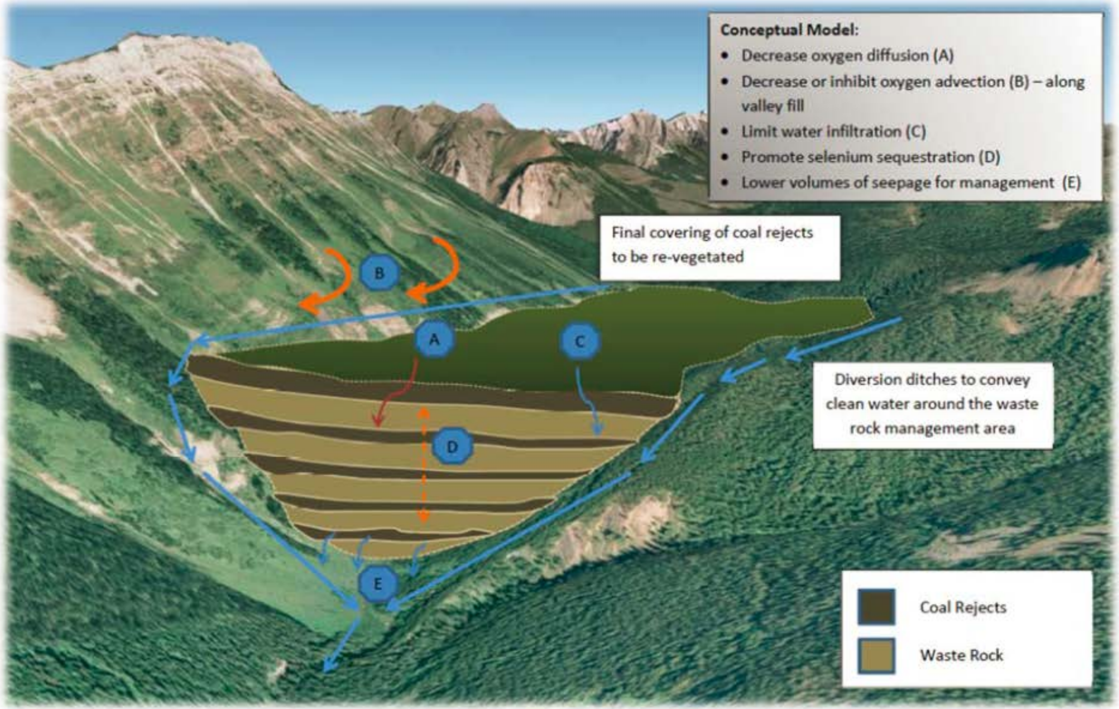
Project Overview
Regional Setting

- Nominal Production Rate (ROM) 4M tonnes/year
- Life of Mine 15 years
- Primary source of water will be the Interim Sedimentation Pond with Grave Creek Reservoir as a back up source



Project Overview – *Waste Rock Design*

Waste Rock Management: Layered Approach



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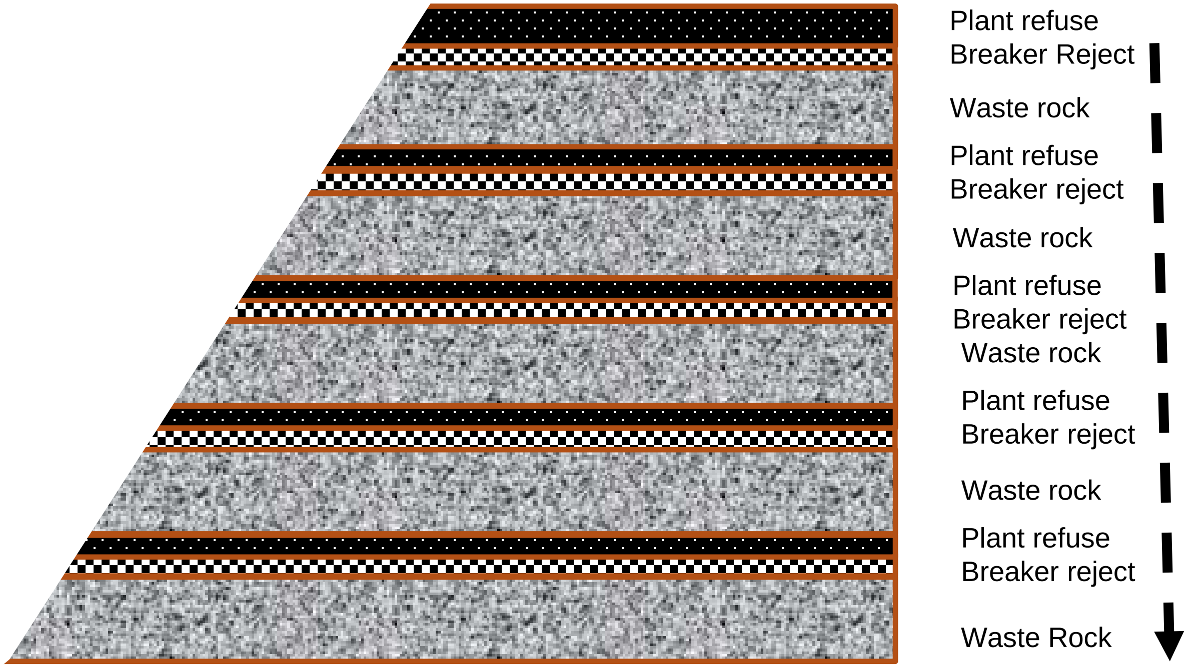
Project Overview – *Waste Rock Design*

Expected role of plant refuse layers:

- Retain moisture retarding oxygen transport.
- Generate dissolved organic carbon.
- Provide sub-oxic zones where reductive processes could occur.

Oxygen movement by diffusion not advection



Reductive Processes

O_2 decreasing

When DO<0.5 mg/L:

$NO_3^- \rightarrow N_2$

$SeO_4^{2-} \rightarrow Se^0$

Contents

Hydrogeological Data

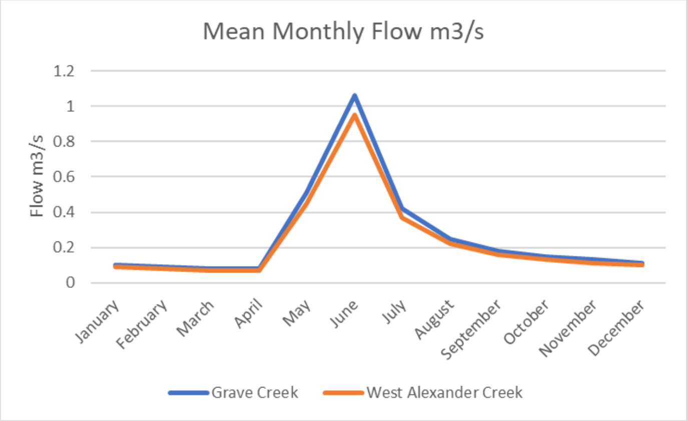
Climate and Hydrology

Month	Total Precipitation (1972–2018 Water Years) [mm]	Lake Evaporation (1971 – 2018) [mm]
January	59.8	0
February	48.6	0
March	57.1	0
April	49.3	0
May	67.1	72.3
June	73.1	88.9
July	52.6	115.3
August	47.1	104.5
September	51.9	65.6
October	57.4	0
November	81.6	0
December	71.1	0
Annual	717	446.5

Note: Lake Evaporation is 0 when it's frozen

Hydrogeological Data

Climate and Hydrology



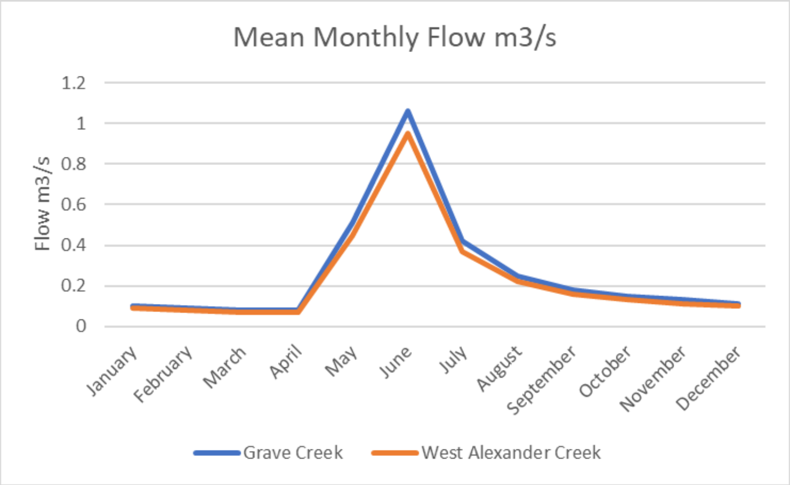
Average Monthly Flow of Grave Creek and West Alexander Creek

Month	Grave Creek Average Monthly Flow (m^3/s)			West Alexander Creek Average Monthly Flow (m^3/s)		
	Min	Mean	Max	Min	Mean	Max
January	0.04	0.10	0.19	0.04	0.09	0.17
February	0.04	0.09	0.17	0.03	0.08	0.15
March	0.03	0.08	0.15	0.03	0.07	0.13
April	0.03	0.08	0.19	0.03	0.07	0.17
May	0.18	0.51	1.48	0.16	0.45	1.32
June	0.39	1.06	3.23	0.35	0.95	2.88
July	0.20	0.42	1.22	0.17	0.37	1.10
August	0.13	0.25	0.64	0.12	0.22	0.57
September	0.10	0.18	0.39	0.09	0.16	0.35
October	0.08	0.15	0.29	0.07	0.13	0.26
November	0.07	0.13	0.24	0.07	0.11	0.22
December	0.06	0.11	0.21	0.06	0.10	0.19
Annual Total	**0.14**	**0.26**	**0.58**	**0.13**	**0.23**	**0.51**

Source: NWP, 2014

Hydrogeological Data

Climate and Hydrology



Creek	Baseflow (m^3/s)	Catchment Area (km^2)
West Alexander	0.07-0.10	14.7
Grave	0.08-0.10	80.9

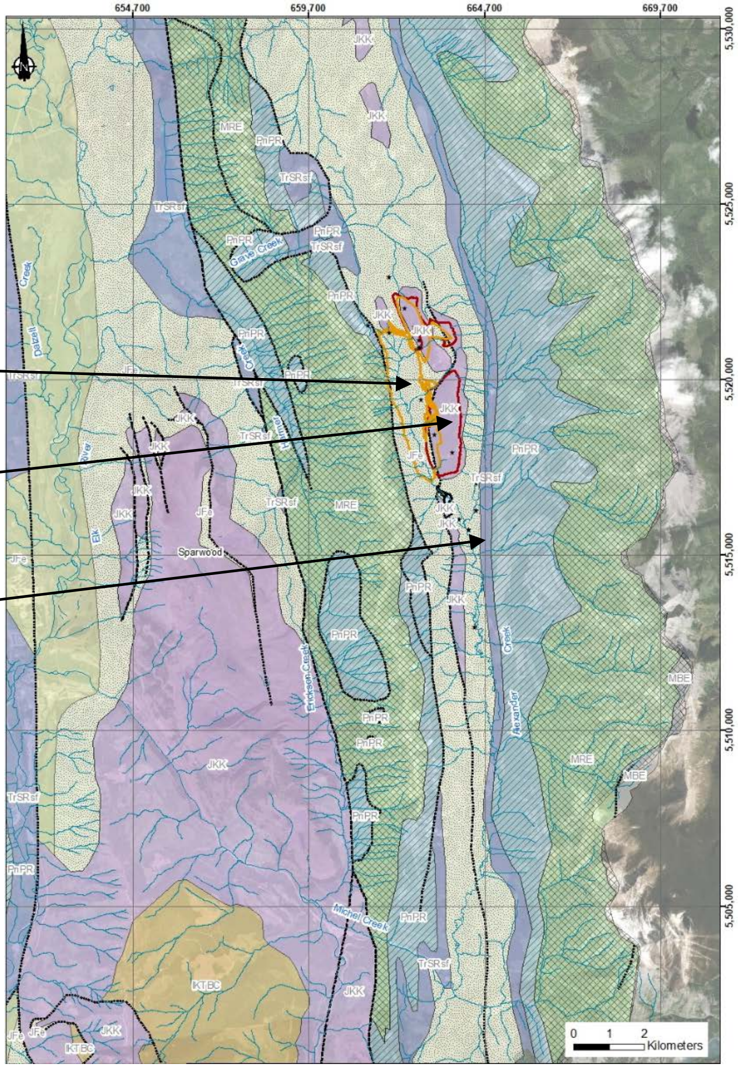
Source: NWP, 2014

Hydrogeological Data
Bedrock Geology

Fernie Formation

Kootenay Group

Spray River Group



Legend

- Streams
- Proposed Main Sediment Pond
- Proposed Open Pit
- Proposed Waste Dump

Faults

- Fault
- Normal Fault
- Thrust Fault

★ Drillholes

Bedrock Regional Geology

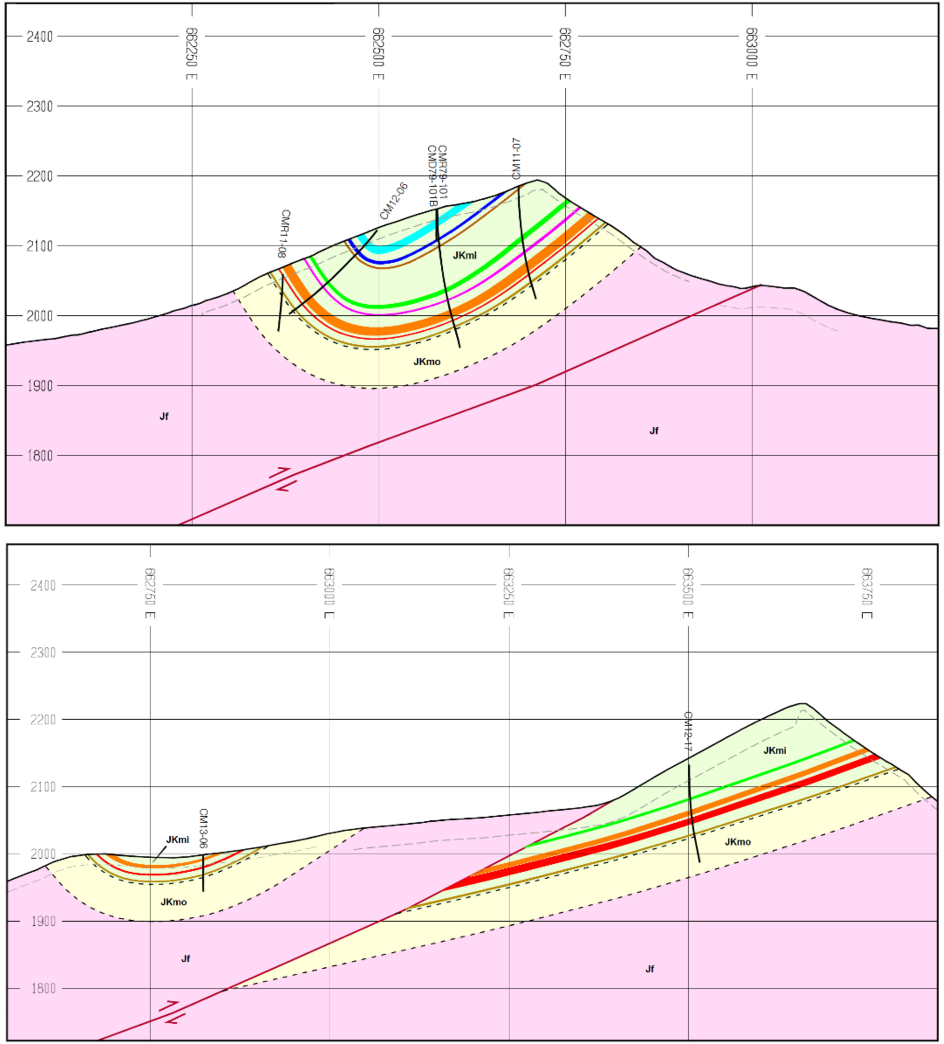
- lKTBC - Blairmore Group - Crowsnest Formation: Cretaceous to Neogene sandstone, siltstone and tuffs
- JKK - Kootenay Group: Jurassic to Cretaceous sandstone, siltstone and coal
- JFe - Fernie Formation: Jurassic shale, sandstone; limestone
- TrSRsf - Spray River Group: Triassic calcareous siltstone, orthoquartzite and shale
- MBE - Banff and Exshaw Formations: Carboniferous carbonate, shale
- PnPR - Rocky Mountain Group: Carboniferous to Permian dolomitic siltstone; sandy dolomite; orthoquartzite and limestone
- MRE - Rundle Group: Carboniferous Dolomite, limestone and chert

Source: BC EMPR, 2019

Hydrogeological Data
Bedrock Geology

LEGEND

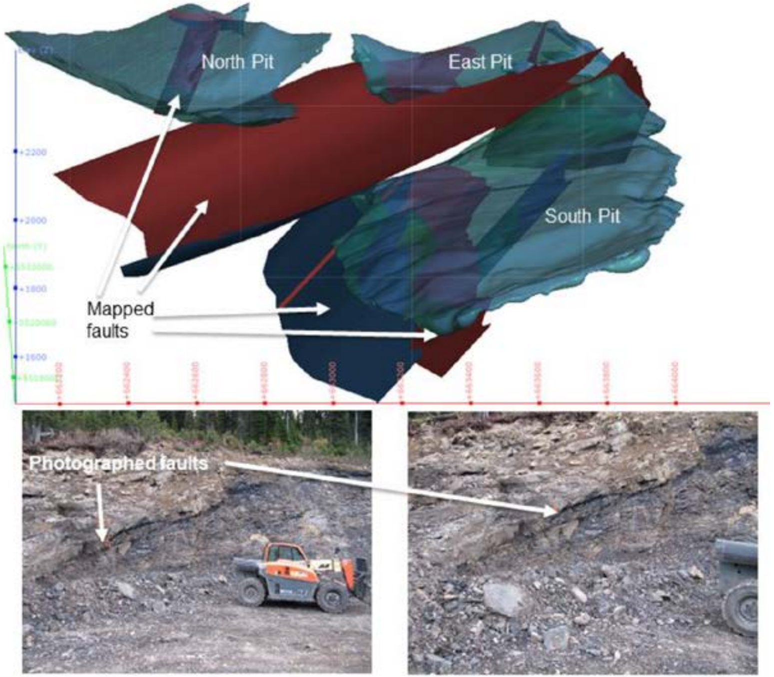
- Topography
- Contact
- Oxidation Depth
- Seam 8 Upper
- Seam 8 Middle
- Seam 8 Lower
- Seam 8 Rider
- Seam 9
- Seam 9 Rider
- Seam 10 Upper
- Seam 10 Middle
- Seam 10 M Rider
- Seam 10 Lower
- Mist Mountain Formation
- Morrissey Formation
- Fernie Formation



Source: NWP, 2014

Hydrogeological Data
Bedrock Geology

- There are mapped faults within pit areas
- Generally, trend sub-parallel to bedding strike
- Generally, intersect pits at base



Source: NWP, 2014

Hydrogeological Data
Karst potential

Legend

- Streams
- Proposed Main Sediment Pond
- Proposed Open Pit
- Proposed Waste Dump

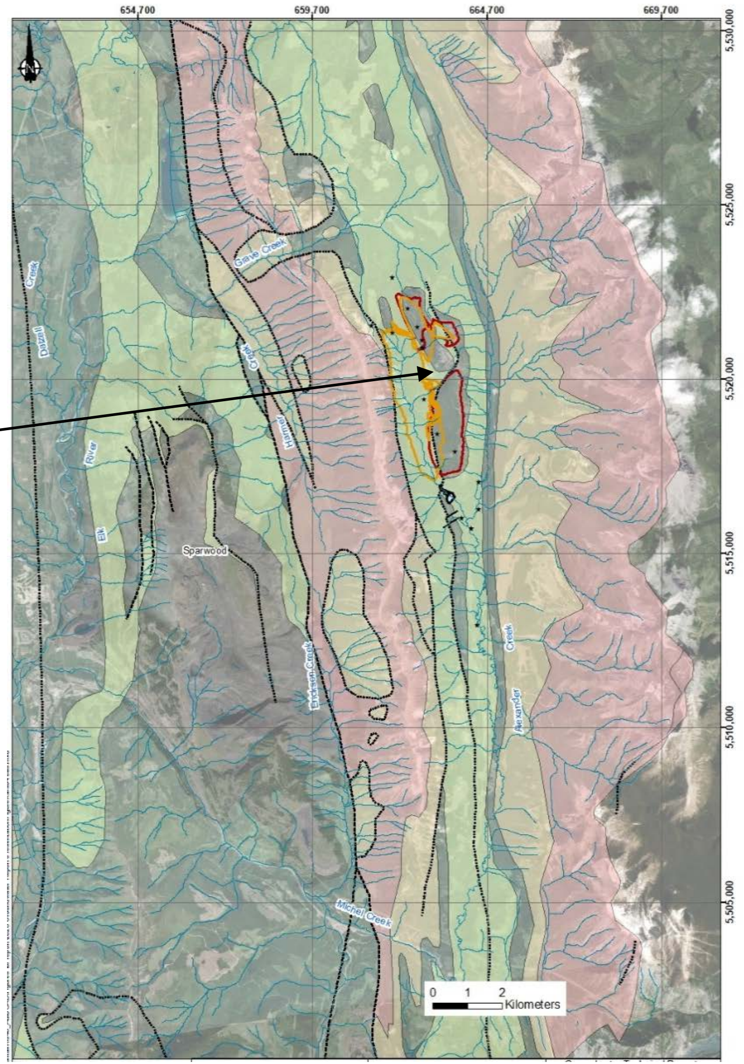
Faults

- Fault
- Normal Fault
- Thrust Fault

Karst Likelihood

- >50% soluble bedrock
- 20 to 49% soluble bedrock
- 5 to 19% soluble bedrock

Project



Source: BC EMPR, 2019

Hydrogeological Data
Overburden Geology

Legend

- Proposed Main Sediment Pond
- Proposed Open Pit
- Proposed Waste Dump
- Drillholes
- Topographic Contours
- Streams

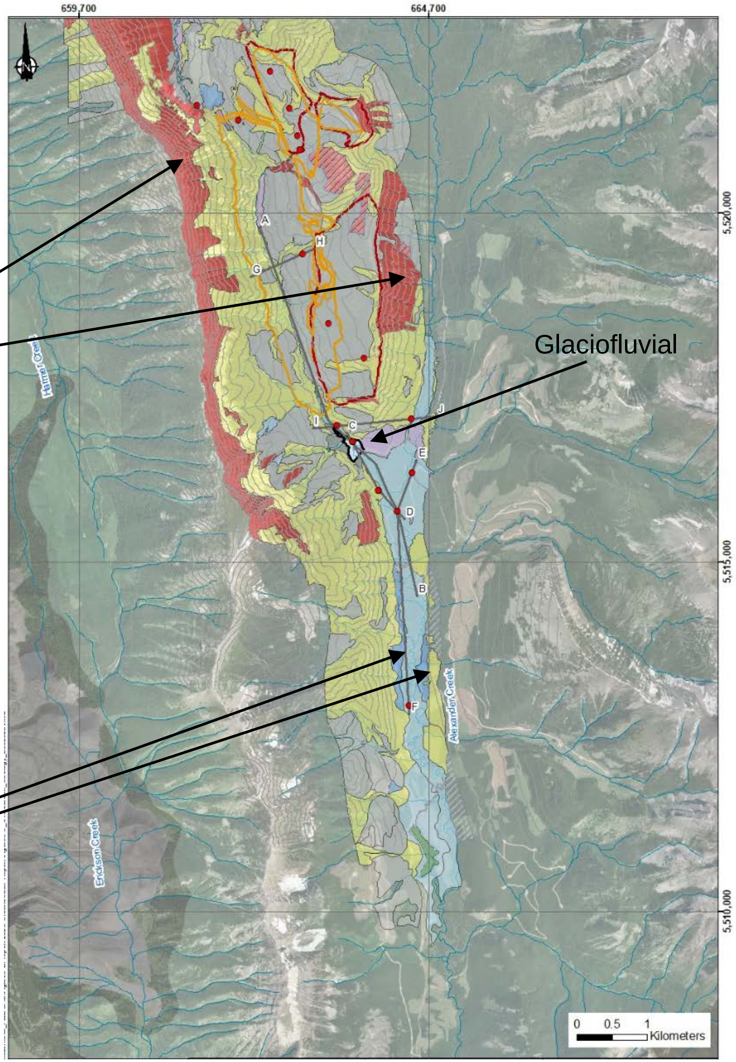
Overburden Geology

- Colluvium
- Fluvial
- Glaciofluvial
- Lacustrine
- Glaciolacustrine
- Till
- Organic Materials
- Weathered Bedrock
- Bedrock
- Undifferentiated Materials

Bedrock Outcrops

Glaciofluvial

Glaciolacustrine

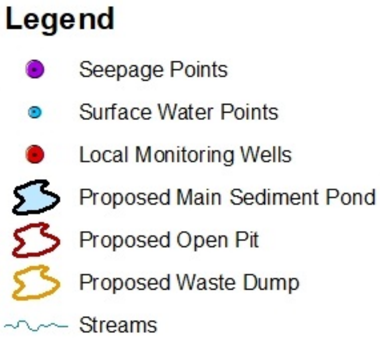


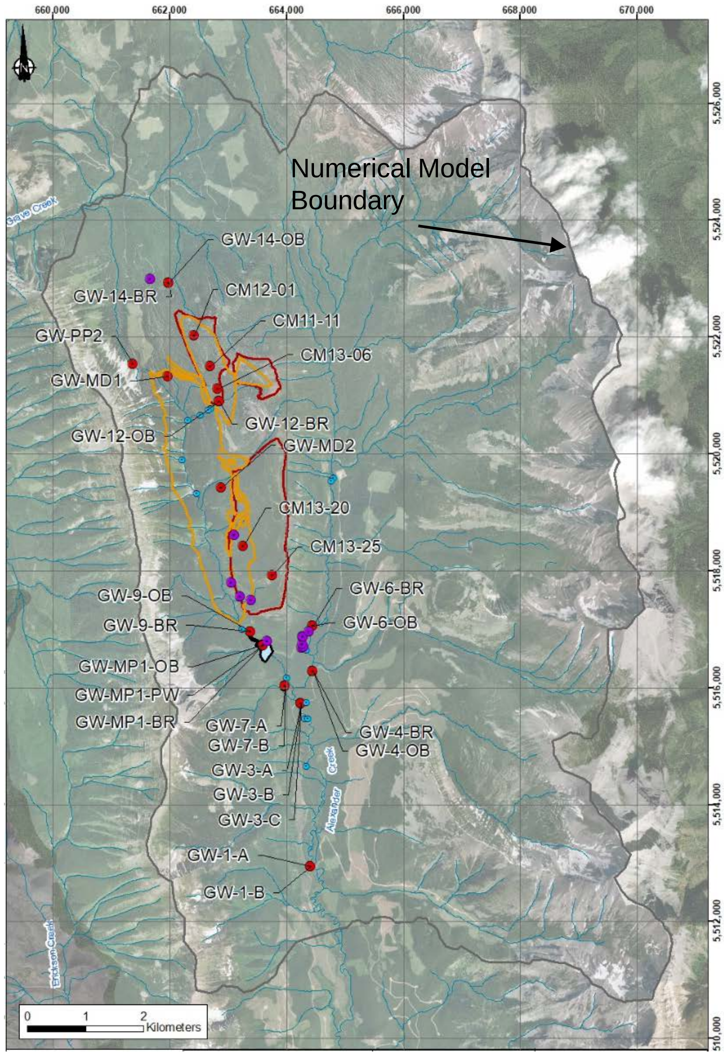
Source: BGC, 2019

Hydrogeological Data

Groundwater Monitoring Network

- 28 monitoring wells
  - stratigraphy, hydraulic parameters, groundwater levels and groundwater quality
- 12 seepage points
- 16 flow accretion survey points



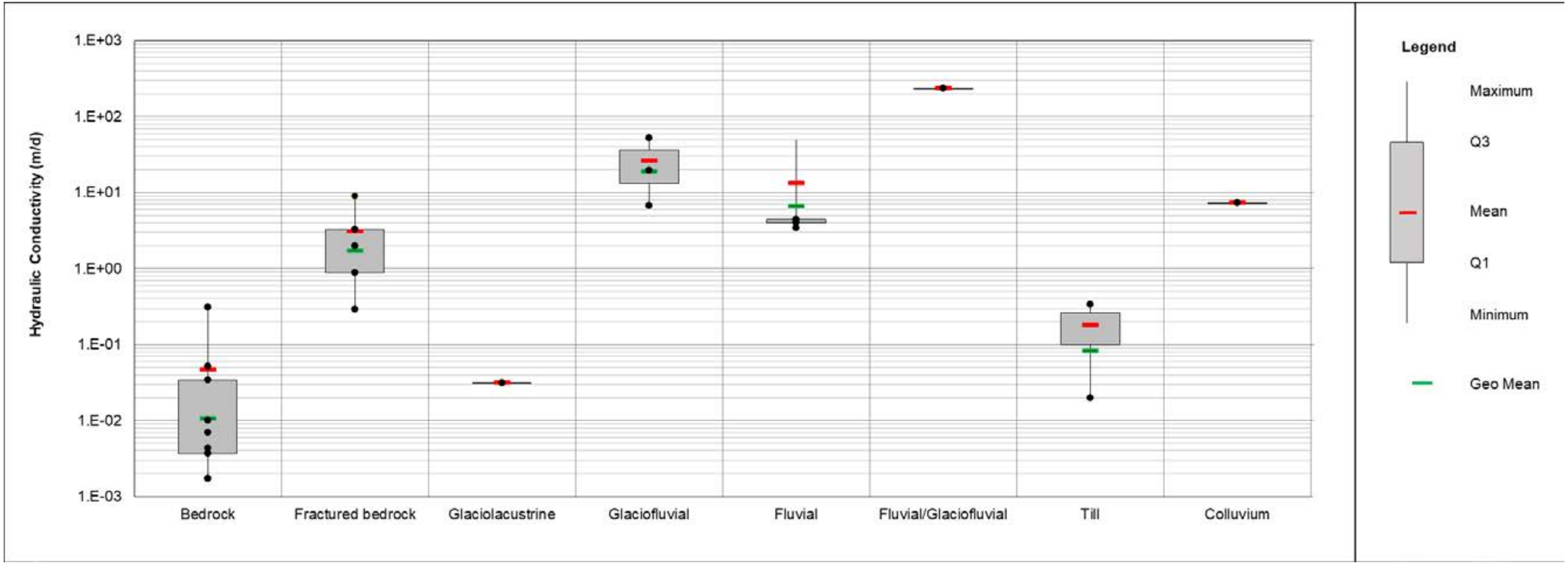


Hydrogeological Data

Hydraulic Parameters

Primary Hydrostratigraphic Unit	Secondary Hydrostratigraphic Unit	Description	Thickness (m)	Horizontal Hydraulic Conductivity (m/d)
Overburden Aquifer	Colluvium	Sands, gravels and cemented till lenses	10 - 20	7E+00 to 9E+00
	Fluvial	gravels interbedded with sands and silty sands	0 - 30	2E+00 to 5E+01
	Glaciofluvial	sand and gravel	0 - 34	1E+00 to 1E+04
Overburden Confining Layers	Till	pebbles, cobbles and boulders in a matrix of sand, silt and clay	<27	2E-01 to 6E-01
	Lacustrine	fine sand, silt and clay	-	4E-02
	Glaciolacustrine	silts and plastic clays but also include some fine sands	<18	2E-02 to 8E-02
Bedrock	Fractured or Weathered Bedrock	Fractured or weathered sandstone, mudstone and shale	<10	2E-01 to 8E+00
	Coal seams	Coal seams	-	2E-03 to 4E-01
	Competent Bedrock	Sandstone, mudstone and shale	-	2E-03 to 2E+00

Hydrogeological Data
Hydraulic Conductivity



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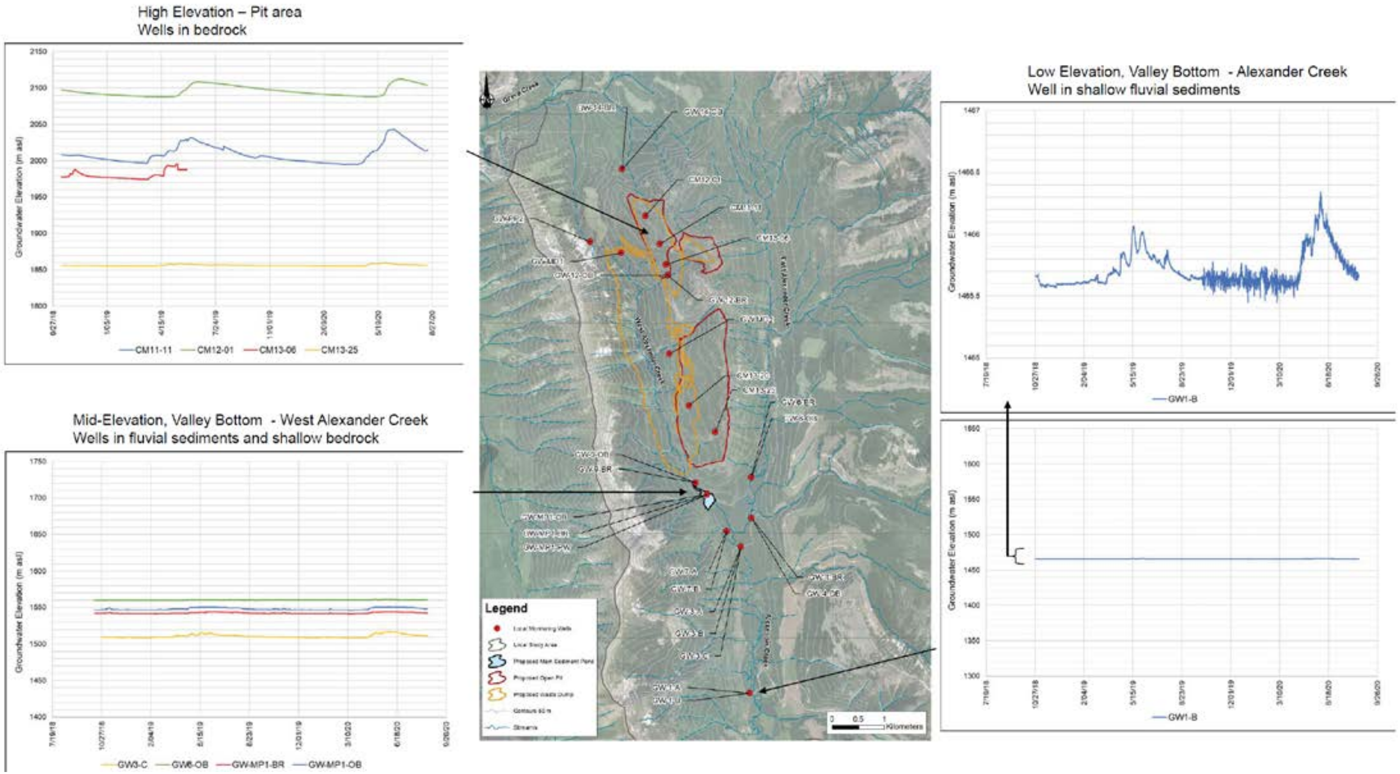
Hydrogeological Data
Water Levels

- Continuous data at nine stations
- Manual at all others



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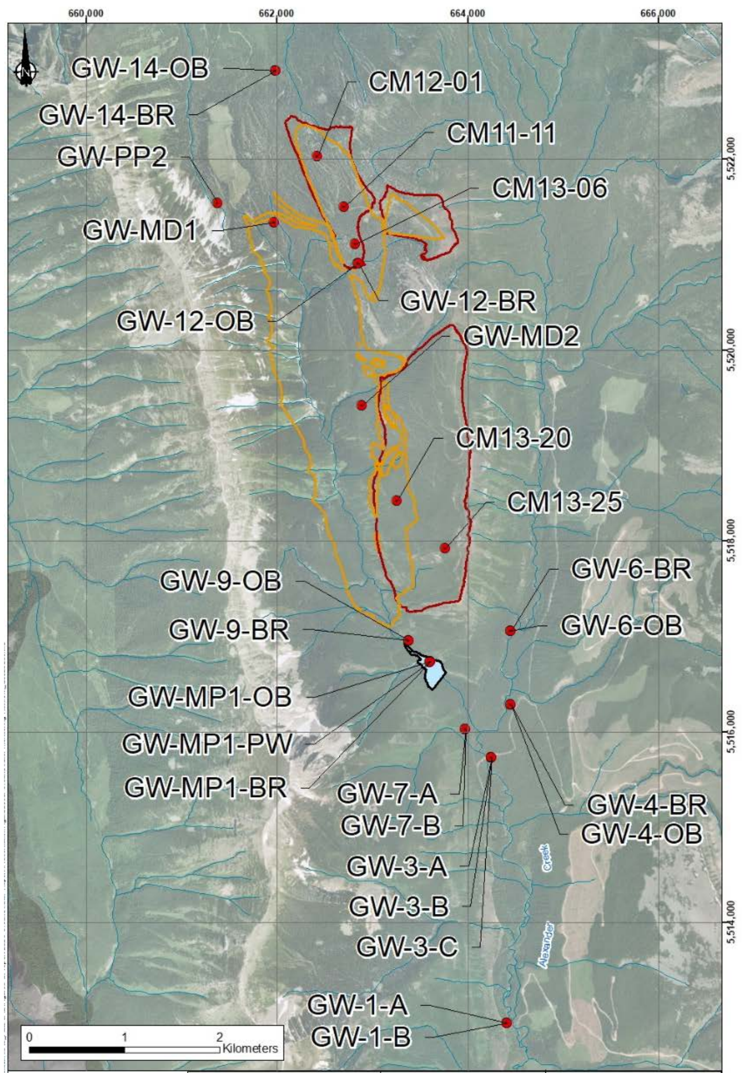
Hydrogeological Data

Groundwater Quality Monitoring

- Four wells in pit areas between 2013 and 2016 (23 samples)
- Quarterly sampling since fall 2018 to winter 2020 from 26 wells (146 samples)



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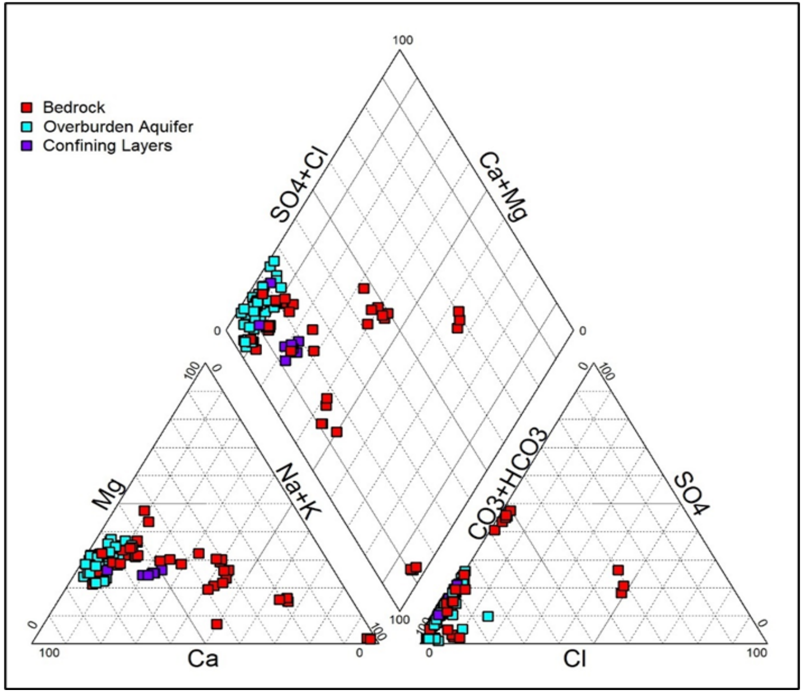
Hydrogeological Data
Groundwater quality

- Bedrock dominated by Ca-CO3 to Na-K-Cl water types with higher average electrical conductivity and TDS
- Overburden dominated by Ca-CO3 water types with lower average electrical conductivity and TDS



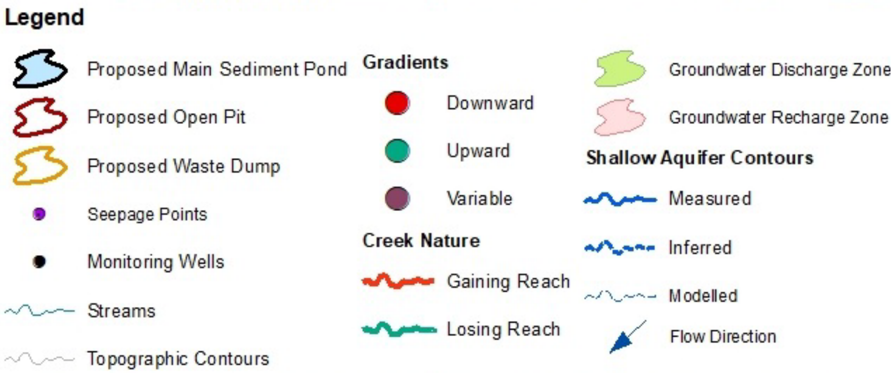
Hydrogeological Data
General characteristics for constituents of concern

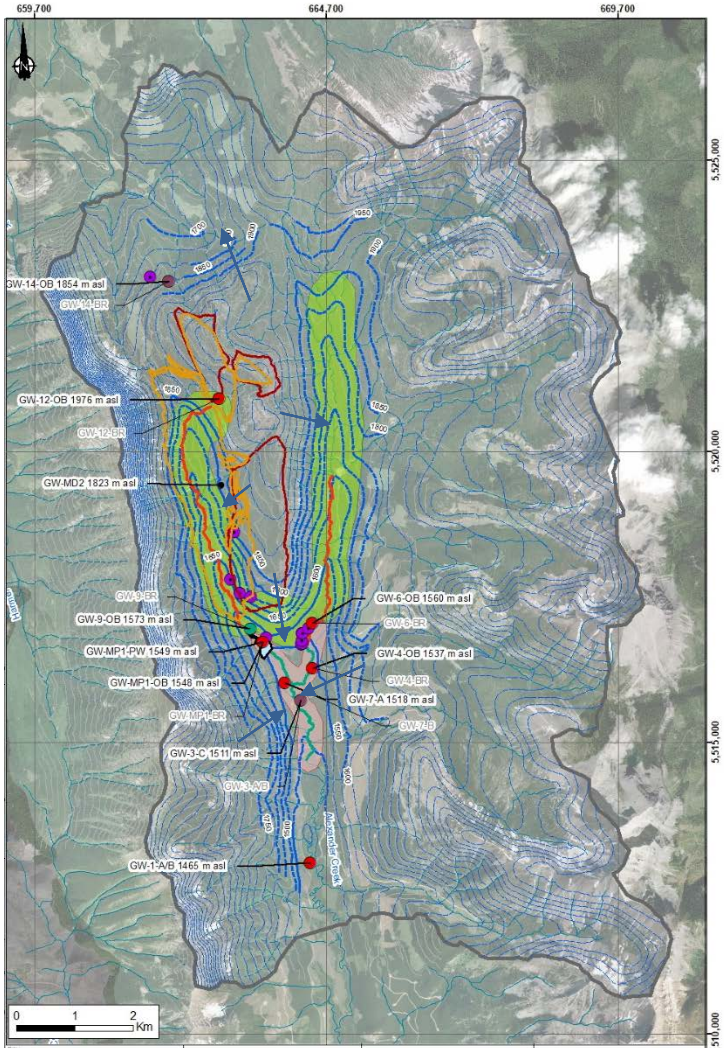
- Vast majority of groundwater quality at monitoring wells are below Aquatic Life and CSR guidelines for dissolved metals

- Only notable exceptions are:
  - Cobalt at GW-6-BR (Upper Alexander Creek)
  - Lithium at many wells (possible drilling artifact)

- Nitrate and nitrite are below all guidelines

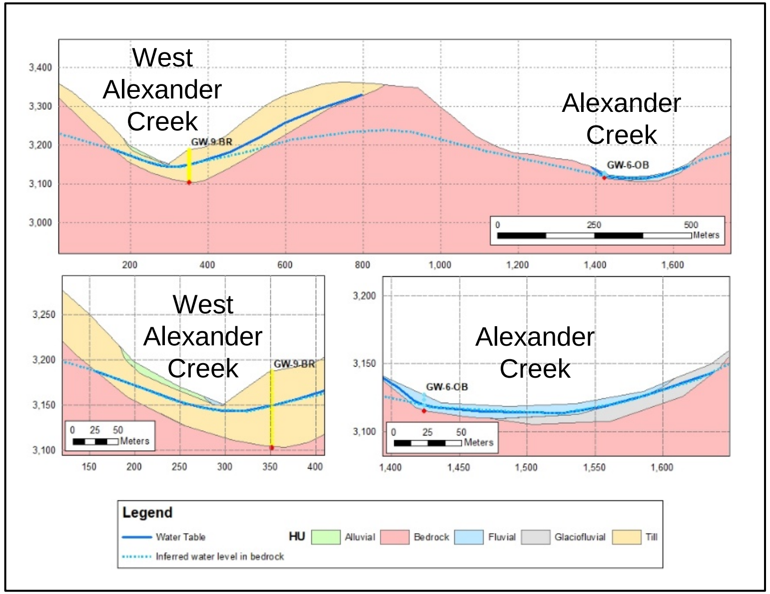
Hydrogeological Data
Groundwater-surface interaction

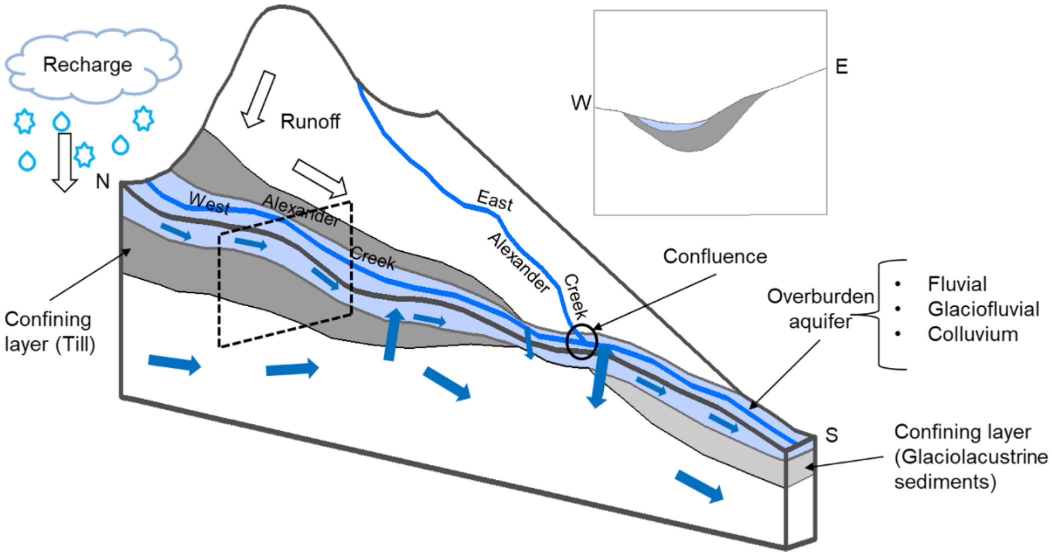




Contents

Conceptual Models
Current Conditions





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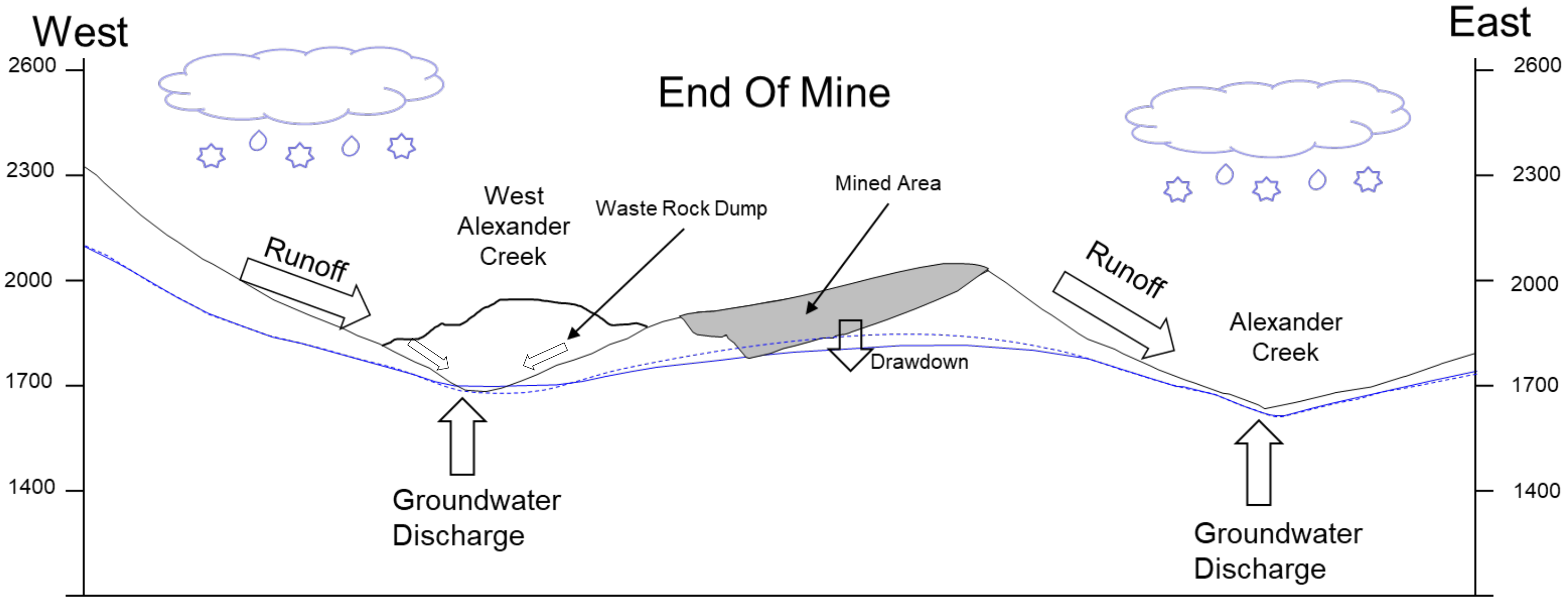
Conceptual Models
End of Mine



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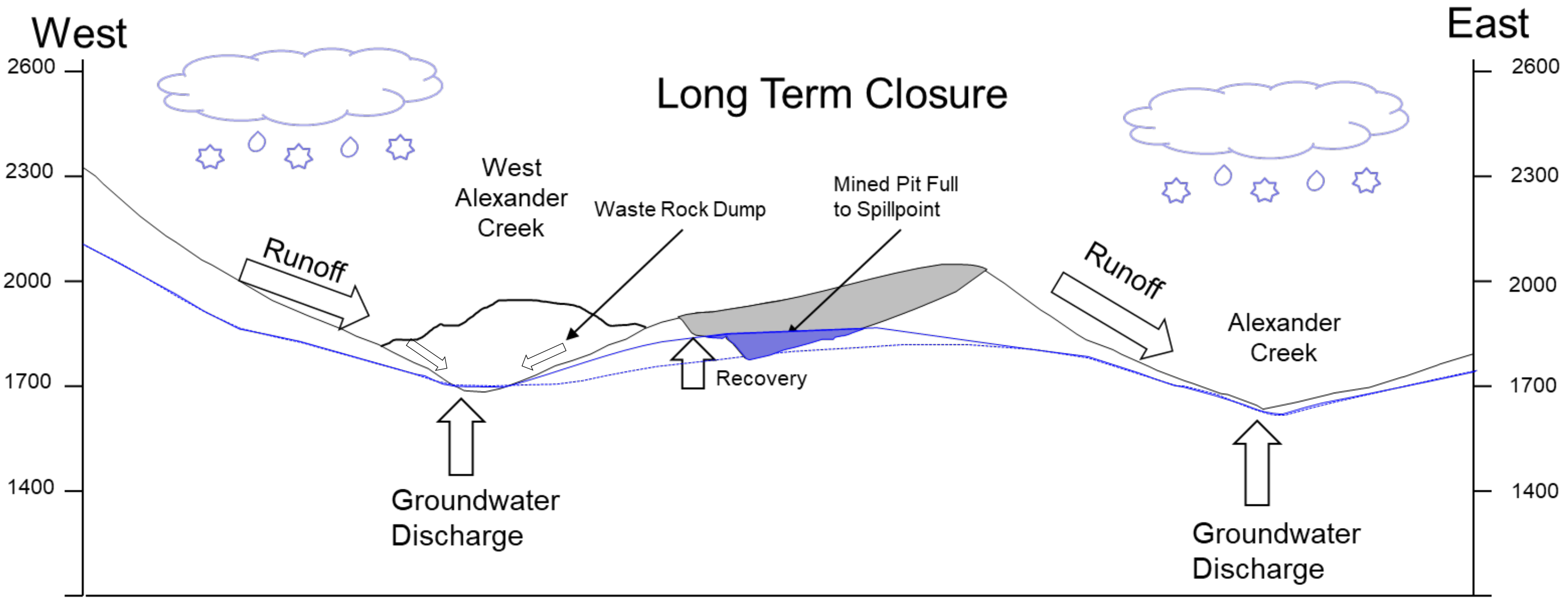
Conceptual Models
Long Term Closure



Contents

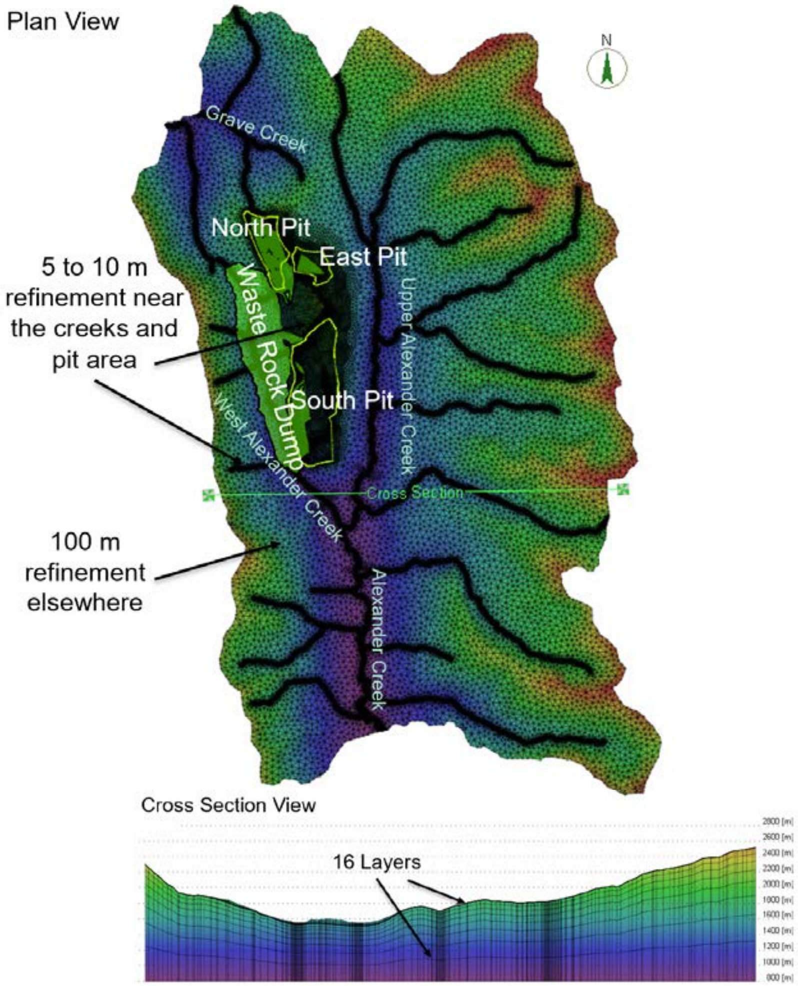
Potential Effects on Groundwater Methods

- Available hydrogeological data was used for the conceptual model
- A numerical model was developed to assess potential changes

- Numerical model calibrated to current (baseline) conditions and run for two predictive scenarios
  1. End of Mine (EoM)
  2. Long Term Closure (LTC)

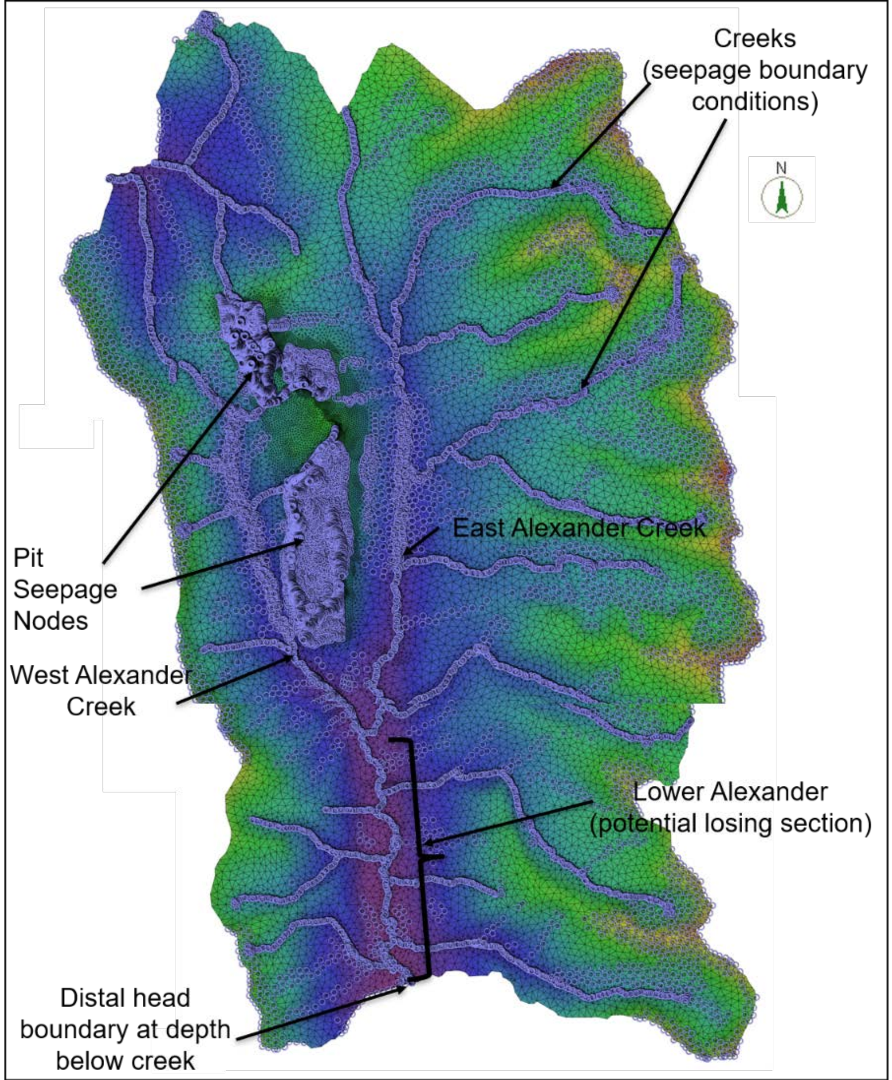
Potential Effects on Groundwater
Numerical model Set Up

- Feflow finite element model
- Includes all pits and dumps
- Steady-state simulations



Potential Effects on Groundwater
Numerical model Set Up

- Model boundary conditions



Potential Effects on Groundwater
Numerical model Set Up

- Model parameters

Zone	Geology	Approximate K Range from Field Data & Conceptual (m/s)	K1 & K2 (horizontal) (m/s)	K3 (perpendicular/ vertical) (m/s)	Specific Storage (1/m)	Specific Yield (-)
1	Bedrock	$2x10^{-8}$ to $2x10^{-5}$	$1x10^{-7}$ (decreasing with depth)	$4x10^{-8}$ (decreasing with depth)	$1x10^{-6}$	0.001
2	Till/Colluvium	$5x10^{-8}$ to $1x10^{-5}$	$1x10^{-7}$	$1x10^{-7}$	$5x10^{-5}$	0.01
3	Glaciofluvial (set = fluvial)	$1x10^{-4}$ to $2x10^{-3}$	$5x10^{-4}$	$5x10^{-5}$	$1x10^{-4}$	0.20
4	Glaciolacustrine	$2x10^{-7}$ to $1x10^{-6}$	$4x10^{-7}$	$4x10^{-7}$	$1x10^{-5}$	0.005
5	Fluvial	$5x10^{-5}$ to $5x10^{-4}$	$5x10^{-5}$	$5x10^{-6}$	$1x10^{-4}$	0.05

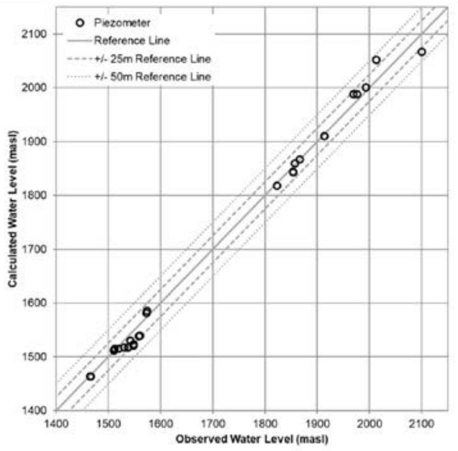
Model process

- Calibrated to heads and baseflow conditions
- Sensitivities (K, anisotropy, recharge)

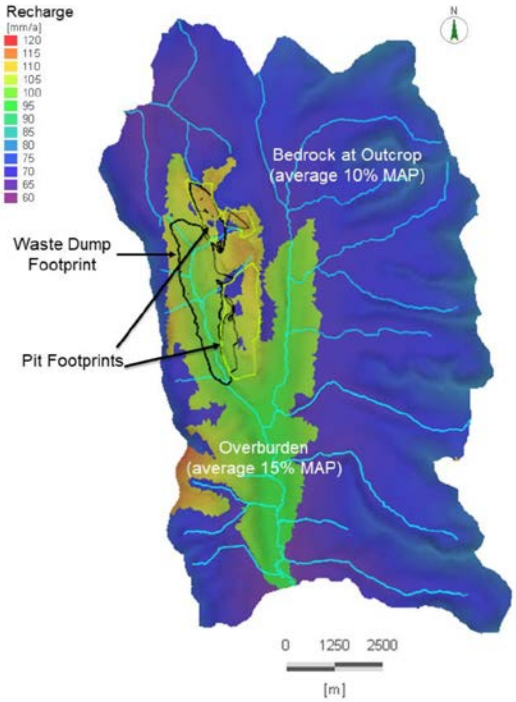
- Model run for predictive scenarios
  - End Of Mine
  - Long Term Closure

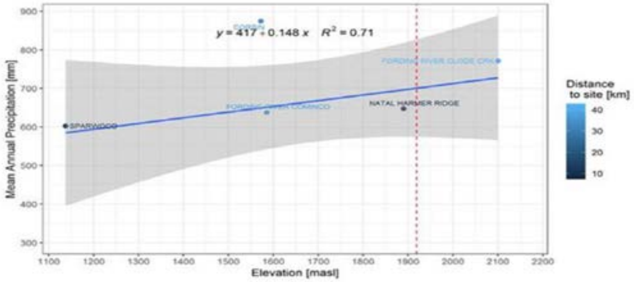
- Particle tracking and transport to assess flow directions and movement of potentially impacted water

Potential Effects on Groundwater
Numerical model Results



Model Statistics	
Mean Error	-3.19
Max. Absolute Error	39.25
Absolute Mean Error	2.28
Root Mean Squared Error	2.09
Norm. Root Mean Squared Error	0.3%
Coeff. Of Determination (R^2)	1.00





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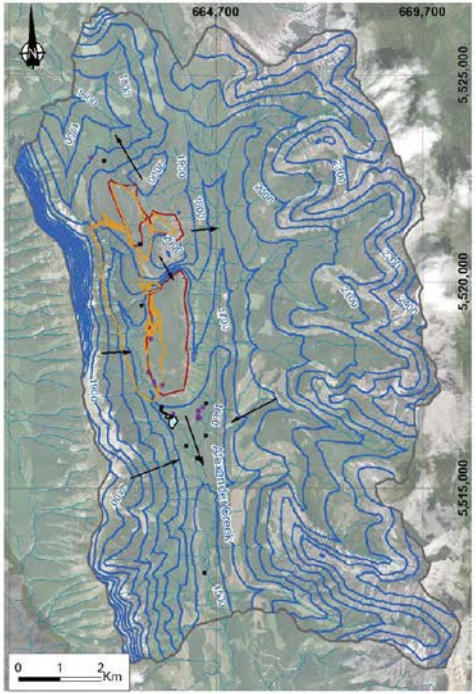
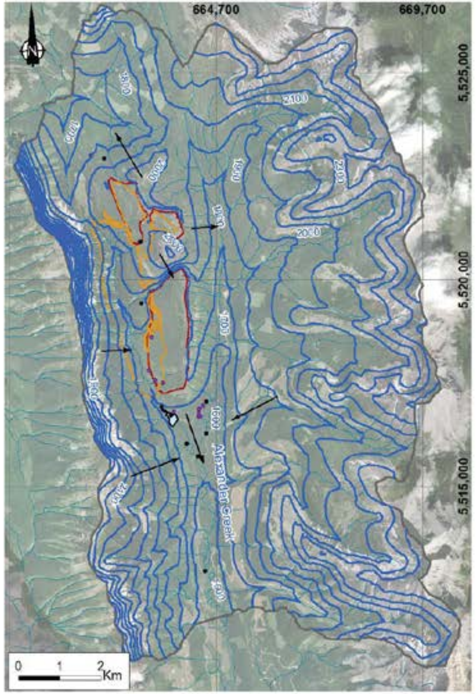
Potential Effects on Groundwater
Numerical model Results

Baseline Conditions

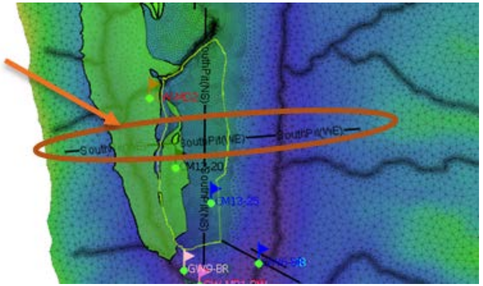
End Of Mine

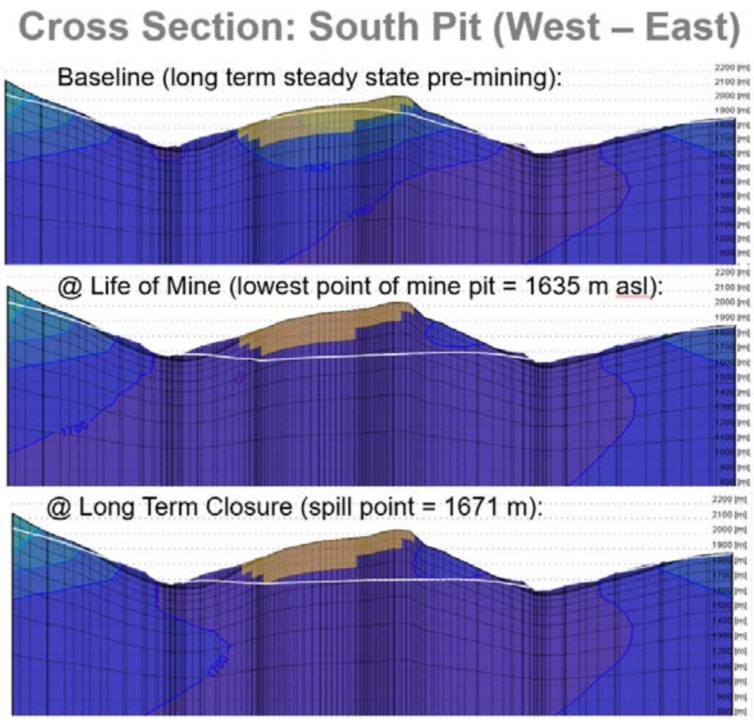


Long Term Closure



Potential Effects on Groundwater
Numerical model Results

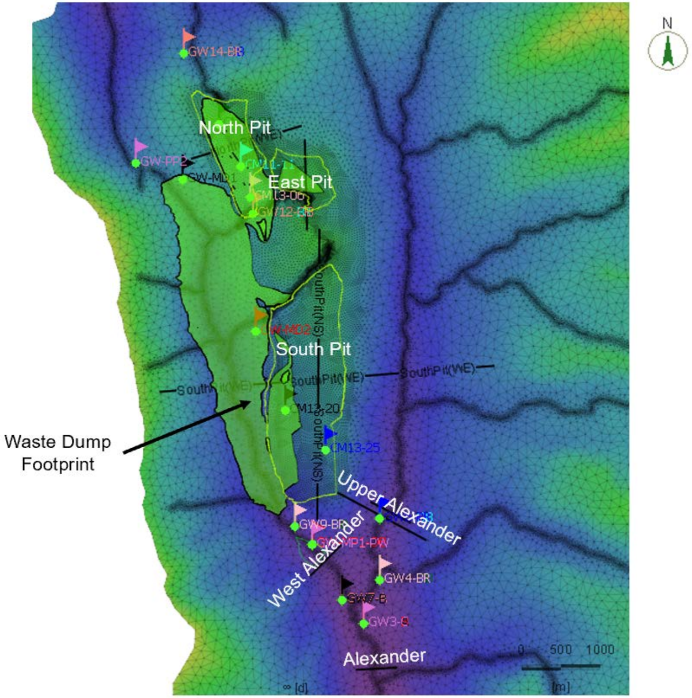




Potential Effects on Groundwater

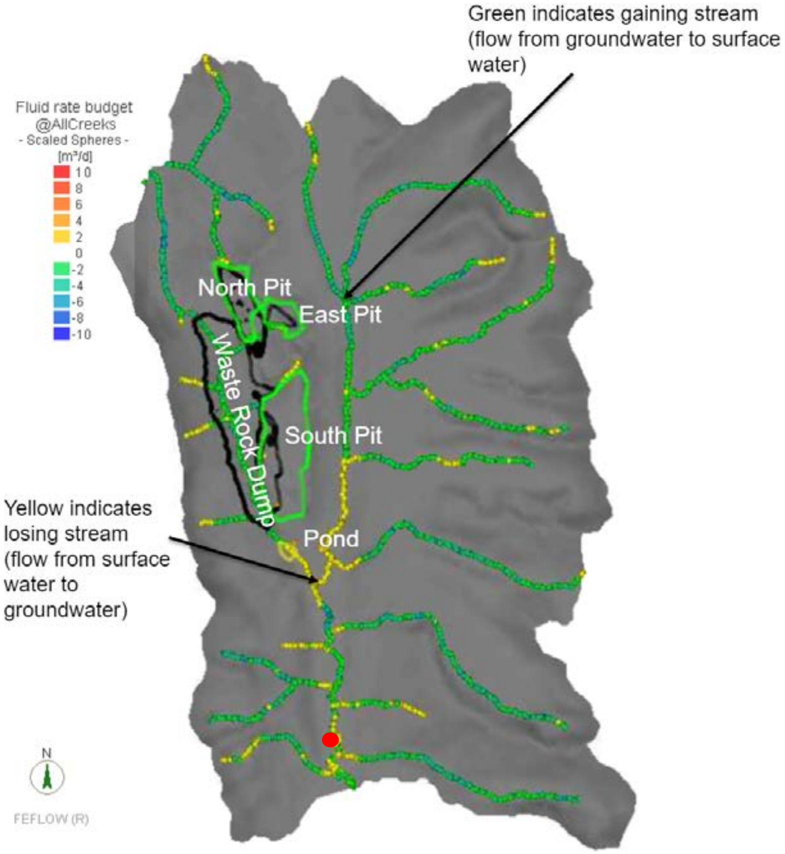
Numerical model Results

Pit	Inflow (m3/d)
North Pit	271
East Pit	130
South Pit	748



Potential Effects on Groundwater
Numerical model Results

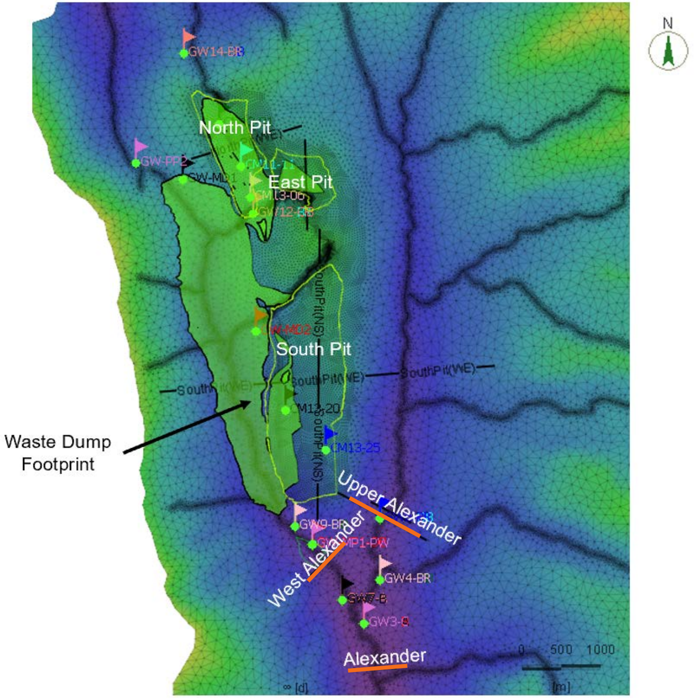
- Gaining stream under dumps
- Changes to losing stream at pond
- Uncertainty on gaining/losing reaches increases downstream of southern-most monitoring well (red dot)
  - In area between confluence and this well, overburden is thick with confining unit – any discharge is likely to be shallow GW



Potential Effects on Groundwater
Numerical model Results

- Baseline flux through creek valleys

Flux Section	Length (m)	Depth (m)	Total Flux (m3/d)	Total Flux (L/s)
West Alexander	500	50	215	2
Upper Alexander	600	50	796	9
Alexander	450	60	1001	12



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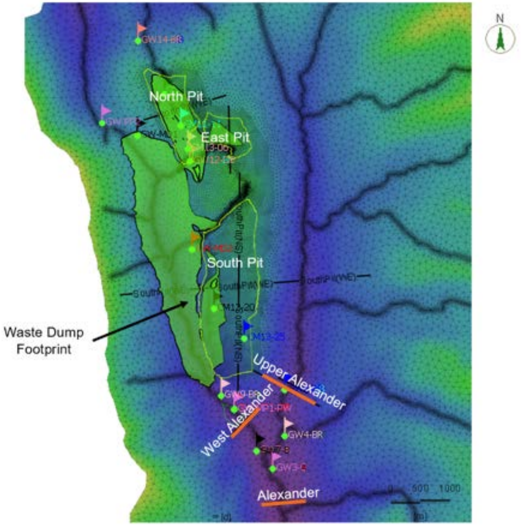
Potential Effects on Groundwater
Results – Expected changes on gw quantity

GW Flux Cross Section[1]	Baseline	EOM (most likely) % change from baseline	EOM (uncertainty range) % change from baseline	LTC (most likely) % change from baseline	LTC (uncertainty range) % change from baseline
West Alexander Creek	100%	-17%	-25% to -9%	-12%	-18% to -6%
Upper Alexander Creek	100%	-9%	-14% to -4%	-4%	-9% to 0%
Alexander Creek	100%	-4%	-7% to -1%	-3%	-6% to 0%



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Potential Effects on Groundwater

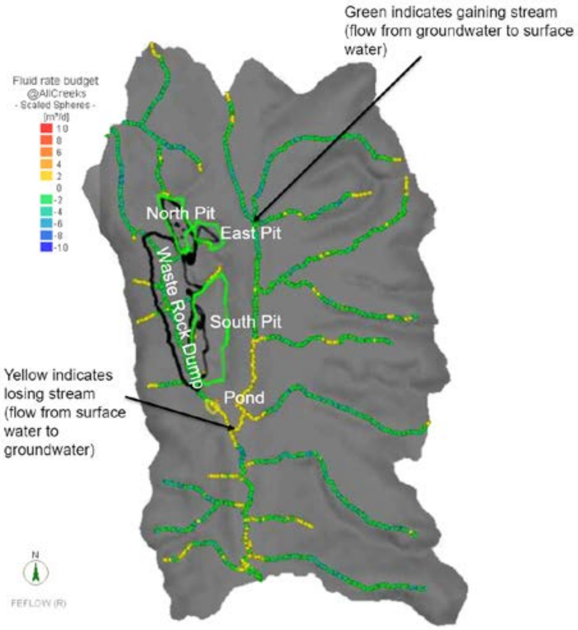
Results – Expected changes on baseflows

Mass Balance	Pre-mining		EOM	LTC
	Inflow (m³/d)	Outflow (m³/d)	% change from baseline*	% change from baseline
West Alexander Creek Baseflow	74	3,280	-30%	-21%
Upper Alexander Creek Baseflow	63	10,368	-5%	-4%
Alexander Creek Baseflow**	189	9,169	-2%	-1%
Alexander Creek Cumulative Change***	326	22,817	-7%	-5%
Grave Creek (Upper) Baseflow		2,893	-4%	-2%

*** A negative value represents a reduction with respect to baseline flow**

**** Alexander Creek below confluence to model boundary**

***** Includes West Alexander Creek, Upper Alexander Creek and Alexander Creek below confluence**



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Potential Effects on Groundwater

Considerations/Assumptions for groundwater quality

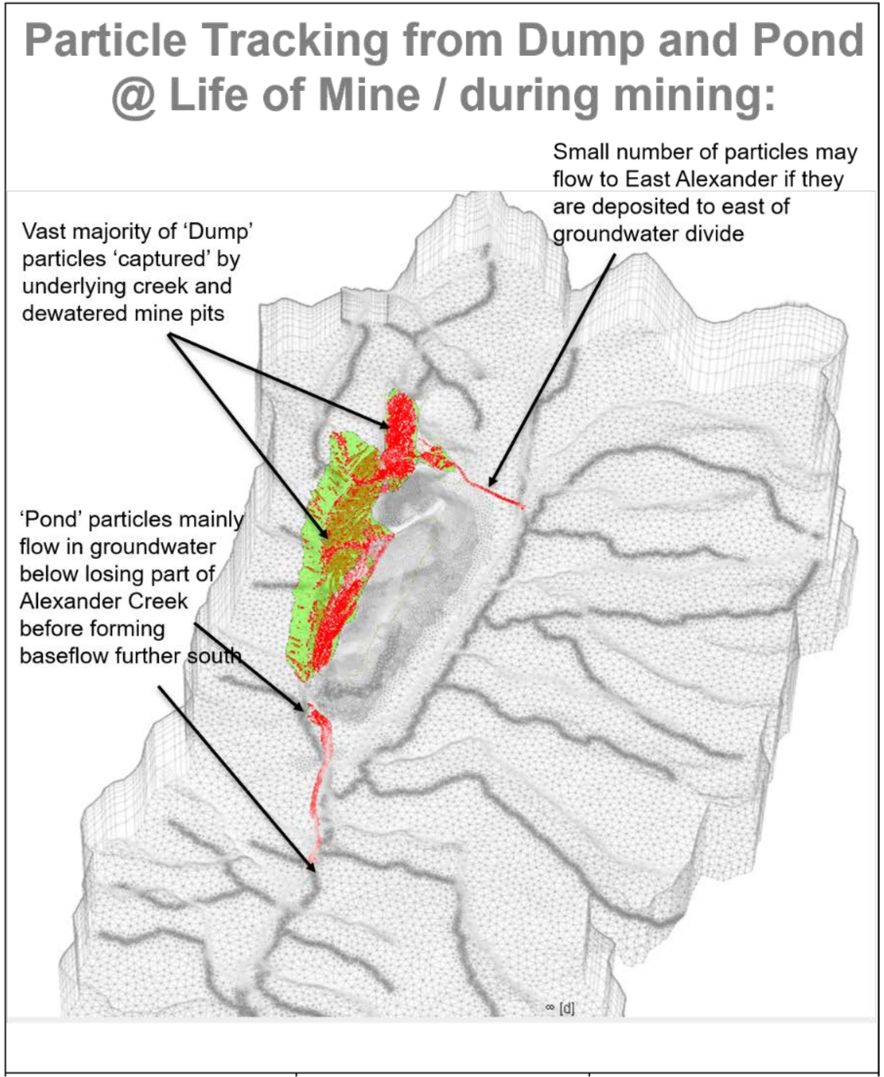
- Lined sedimentation pond

- WRD source control design

Potential Effects on Groundwater

Results – groundwater quality

- Particle tracking results indicate:
  - Almost all particles from mine directed towards West Alexander
    - Waste placed on Upper Alexander side of divide could move towards Upper Alexander, but anisotropy and control of waste placement can minimize risk
  - Particles started at dumps typically discharge to West Alexander locally
  - Only particles starting at sedimentation pond travel significant distances downgradient
    - for illustration – recall, pond lined

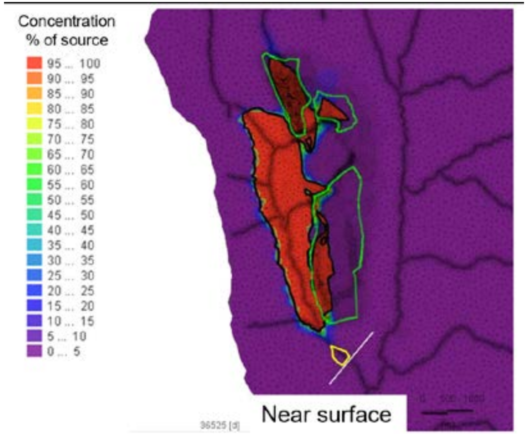


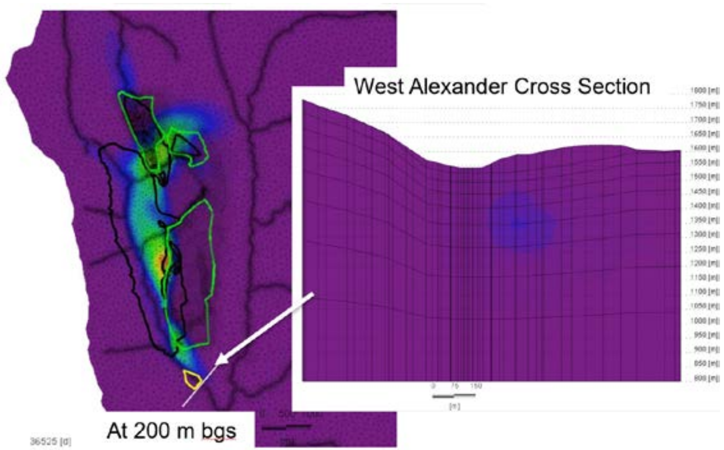
Potential Effects on Groundwater

Results – groundwater quality

Model run in transport mode, assuming a conservative parameter, for 100 years

- Load does not generally travel far from sources
- Near surface load in West Alexander creek does not migrate past sedimentation pond
- Anywhere, load transported to any appreciable distance is in bedrock, but will be lower in magnitude





Summary of Potential Effects

- No significant effects expected within Grave Creek catchment
  - Key mine components within Grave Creek catchment represents less than 1% of its total area.
- Potential reduction to baseflows in Alexander Creek catchment is most significant in West Alexander Creek but cumulative reduction in Alexander Creek is <10%
  - As much as 20-30% reduction in West Alexander
  - Reduces to 5-7% in Alexander Creek
  - Any long-term impacts reduced by surface flow returned to natural catchment
- Groundwater quality will be affected locally
  - Largest potential impact in West Alexander Creek valley
  - Load in shallow groundwater system estimated to discharge by sedimentation pond
  - Load in deeper bedrock could travel further, but at reduced concentrations

Mitigations

Mitigations built into mine plan:

- Design of the WRD to reduce source load
- Lining of sedimentation pond to minimize leakage

- If WRD source control does not meet water quality objects, the geological setting downgradient of the waste rock dump is well suited for groundwater collection
  - Narrow valley with low thickness of permeable (non-till) overburden (10-20m of relatively permeable shallow sediment overlying 15-20m of clayey till)
  - Low groundwater flux (on the order of a few L/s)

Contents

srk consulting

Discussion

Thank you