K4.18 WATER AND SEDIMENT QUALITY

This appendix contains additional technical information on the following topics related to mine site impacts to surface water, groundwater, and substrate/sediment quality described in Section 4.18, Water and Sediment Quality:

- Water quality modeling
- Water treatment plant (WTP) methodologies
- Dust deposition methodologies

K4.18.1 Water Quality Modeling

This section provides a description and analysis of modeling conducted at the mine site to estimate the chemical content of water stored in on-site facilities and provide source information for preliminary design of WTPs.

K4.18.1.1 Operations

Contact water at the mine site would be collected and held in various on-site facilities prior to treatment and reuse or discharge. These include the tailings storage facilities (TSFs), water management ponds (WMPs), seepage collection ponds (SCPs), open pit, process plant, and WTPs. The collection, storage, and movement of water around these facilities is described in Section 4.16, Surface Water Hydrology, and Section 4.18, Water and Sediment Quality, and is shown on figures in Section 4.16 and Appendix K4.16, Surface Water Hydrology. All mine facilities that collect, store, treat, and discharge water have been incorporated into mine site water balance and water quality models developed by Knight Piésold (2018a, 2019s) using both in-house and GoldSim Technology Group GoldSim® software. The models used for the operations phase of the project are based on the conceptual 20-year life of mine footprint shown on Section 4.16, Surface Water Hydrology; and Figure 4.16-1.

Comprehensive Water Modeling System

The comprehensive water modeling system (Knight Piésold 2019f) comprises three models: the watershed model, groundwater model, and mine site water balance model (Knight Piésold 2019f). The mine site water balance model is representative of the movement of water in the mine system, uses inputs from the watershed and groundwater models, and feeds information regarding anticipated treated water discharge back into the watershed model (Knight Piésold 2019f, 2019s; PLP 2019-RFI 109g). The water balance model was initially provided in an operations water management plan by Knight Piésold (2018a) and has since been updated in a water balance report by Knight Piésold (2019s; PLP 2019-RFI 021g) based on new groundwater model inputs (Section 4.17, Groundwater Hydrology).

The mine site water balance model estimates the amount of water to be managed at the mine site during the operations phase of the mine under a full range of historic climate conditions. As described in Section 3.16 and Appendix K3.16, Surface Water Hydrology, climate variability is incorporated in the model using a 76-year synthetic time series of monthly temperature and precipitation values to simulate the cyclical nature of the climate record. The climate model was developed using climate data from the nearby Iliamna Airport that has been recorded daily since 1940. The application of these data allowed for local climate trends and cycles to be calibrated and applied to the study area to create a more robust synthetic time series data. A 76-year model analysis period was used to resemble the 76-year dataset from Iliamna Airport used to create the model. Monthly outputs were examined to simulate seasonal trends and variability (AECOM 2018o; Knight Piésold 2018g, 2019s).

The water balance model was run with 20 years of consecutive data at a time. Seventy-six 20-year runs were made, each starting with a different year in the 76-year synthetic record. This method of analysis was used to preserve the inherent cyclical nature of the climate record (Knight Piésold 2018a, 2019s), and resulted in 76, 20-year-period evaluations of water flow and storage. Therefore, the model generated 76 unique sets of monthly water flow and storage results for each year. Additional details regarding the water balance model inputs and assumptions are provided in Knight Piésold (2018a, 2019s) and discussed in Section 3.16, Surface Water Hydrology.

Table K4.18-1 summarizes predicted monthly and annual total release from the WTPs to downstream of the mine site for the 1st, 10th, 50th, 90th, and 99th percentile climate scenarios. Discharge locations for treated water include the South Fork Koktuli (SFK) River, North Fork Koktuli (NFK) River, and Upper Talarik Creek (UTC) catchments (Knight Piésold 2018a, 2019s). WTP discharge locations are depicted in Section 4.18, Water and Sediment Quality, Figure 4.18-1.

Table K4.18-1: Predicted Water Release Quantity from WTPs

Operations					
Month	Total Release from WTPs (cfs)				
	1st Percentile	10th Percentile	50th Percentile	90th Percentile	99th Percentile
January	3	11	24	38	46
February	3	5	24	37	48
March	3	4	17	32	47
April	4	4	11	30	43
May	7	17	29	37	51
June	19	30	37	45	53
July	9	28	41	48	53
August	12	28	40	48	53
September	19	30	41	48	53
October	14	27	37	48	53
November	7	26	32	42	53
December	5	17	28	39	52
Annual Average	9	19	30	41	50

Notes:
cfs = cubic feet per second
WTP = water treatment plant
Source: Knight Piésold 2019s

The combined annual average WTP discharges from the WTPs for the 10th, 50th, and 90th percentile climate scenarios (i.e., dry, average, wet) are anticipated to be 19, 30, and 41 cubic feet per second (cfs), respectively (Knight Piésold 2019s). Discharge volumes may vary month-to-month based on the timing and magnitude of precipitation and snowmelt; however, in general on an annual basis, the dry scenario had the lowest total discharge and the wet scenario yielded the greatest total discharge. Higher discharge rates correspond to higher levels of precipitation, and lower discharge rates correspond to lower levels of precipitation.

A sensitivity analysis was conducted to assess the sensitivity and uncertainty of the water balance model as a result of varying seepage and groundwater flows due to varied bedrock hydraulic conductivity and variation in the course tailings extent in the groundwater model. Bedrock hydraulic conductivity was examined at 10 times the base case hydraulic conductivity (Base K × 10) (S7 scenario), and at one-tenth the base case hydraulic conductivity (Base K × 0.1) (S8 scenario). Sensitivity analysis indicates that the water balance model shows some sensitivity to variation in bedrock hydraulic conductivity in operations and closure phases. The S7 scenario resulted in a 20 percent increase in total release of treated water during operations, and 23 percent increase in closure phases. The S8 reduced hydraulic conductivity scenario yields a 3.3 percent decrease in total treated water released in operations, and no change in closure phases. Analysis of variations in course tailings extent indicates that the water balance model is not sensitive to this parameter (Knight Piésold 2019s). Additional details pertaining to model sensitivity analysis, as well as data pertaining to model sensitivity runs, are available in Knight Piésold (2019s) and associated appendices and described in Section 4.17, Groundwater Hydrology).

Geochemical Source Terms and Water Quality Model

The water quality model for the end of mine (operations phase) developed in GoldSim® uses a mass balance approach, which leverages conservation of mass in the system for material entering and leaving the system to ensure all water is all accounted for in the model. This model was used to estimate constituent loading in and out of each of the mine facilities based on geochemical source terms and flow path information from the water balance model. The water quality model is coupled with the water balance model to estimate constituent loads under completely mixed, steady-state conditions. The model considers the inflow, outflow, storage volumes, and constituent concentrations to calculate constituent loads for all contact water facilities; and predicts water quality in on-site water storage facilities and influent water quality to the WTPs under varying climate conditions. The water quality model was initially run using water balance values provided in the Knight Piésold (2018a) operations water management plan, and has since been updated by Knight Piésold (2019s; PLP 2019-RFI 021g) based on new groundwater model inputs (described in Section 4.17, Groundwater Hydrology) and revised geochemical source terms described below.

Geochemical source term inputs for the water quality model were developed by SRK Consulting (Canada) Inc. (SRK 2018a, 2019e). The source terms were developed using a combination of data from humidity cell tests, barrel tests, and shake flask tests in the Pebble East Zone and Pebble West Zone, as well as pilot test supernatant analyses (SRK 2018f). Source term-specific adjustments were made for oxygen available, temperature, particle surface area, and water contact to adjust to field conditions, and included consideration of explosive residues (SRK 2018a, 2019e).

Detailed methods and assumptions used to calculate the source terms are provided in SRK (2018a), and were updated for certain sources (quarries, pyritic TSF) in SRK (2019e). In general, upside inputs for contact water source terms were developed and provided as single values using assessments of statistical variability appropriate to each input parameter and its intended use, while attempting to avoid unrealistic conditions:

- Where the mean would be considered the best representation of the most likely condition, and extreme low and high values offset each other, the input was calculated as the upper 95 percent confidence limit on the mean (i.e., representing the statistical uncertainty on the mean).
- Where high values in a dataset are considered a reasonable representation of variability about an expected condition, the 95th percentile value was used, which is an approximation of inputs that would occur 1 time in 20.
- Where datasets are used to evaluate solubility of ions in solution, upper values provided the best representation of the expected value, because lower values are probably affected by dilution. In this case, the 99th percentile was used mainly to screen anomalously high values not offset by low values.
- For non-contact terms, median values were used as an appropriate indicator of central tendency in datasets. Due to the low chemical loads provided by these sources, the overall model outcomes are not sensitive to this assumption.

Table K4.18-2 provides the predicted constituent concentrations and physical parameters expected to be produced from various geochemical sources at the mine site that would be captured on site, such as waste rock, pit wall runoff, tailings, existing streams, and groundwater. These concentrations were used as conservative (95th percentile) inputs to the water quality model to predict the water quality in various mine site facilities and analyze water treatment processes.

Water quality model mass loading data for the final year of mining operations is provided in Table K4.18-3. The relative contributions of inflow loads from the geochemical sources to several mine site facilities are depicted in Figure K4.18-1 through Figure K4.18-5 (from Knight Piésold 2019a) for the following constituents: total dissolved solids (TDS), copper, sulfate, arsenic, mercury, and molybdenum). For example, about half of the arsenic entering the main WMP (Figure K4.18-5) would come from the main SCP, about a quarter from the bulk TSF pond, less than a quarter from the pyritic TSF pond, and smaller amounts from other sources such as embankment and mill site runoff. Although Figure K4.18-1 through Figure K4.18-5 represent predictions from the water quality model prior to the update of Knight Piésold (2019s), the relative contributions to water quality shown in the figures are anticipated to be roughly similar to those reported in model updates based on water balance model flowpaths and source terms.

Sensitivity analyses were performed on the water quality model to assess model uncertainty due to variations in hydraulic conductivity, varied source terms for the bulk TSF, and varied source terms for the pyritic tailings and exposed waste rock. The sensitivity analysis indicates that the predicted water quality of the open pit WMP and WTP #1 are most sensitive to changes in bedrock hydraulic conductivity. The analyses indicate that water quality varies proportionally to the increased/decreased volume of water entering the system as a result of varied bedrock hydraulic conductivity (S7 and S8 scenarios). The S7 scenario, a 10 times increase in bedrock hydraulic conductivity, yielded a decrease in water quality concentrations as a result of increased groundwater and seepage flow rates. Conversely, the S8 scenario decreased bedrock hydraulic conductivity by a factor of 0.1, which resulted in an increase in water quality concentrations due to a decrease in groundwater and seepage flow (Knight Piésold 2019s).

Applying bulk tailings void concentrations to seepage beneath the bulk TSF generally resulted in decreased water quality concentrations. Sensitivity analysis indicates that this effect is more prominent in operational phases than in closure phases. When high pyritic tailings source terms were applied (as opposed to the low pyritic tailings source terms) to exposed waste rock in the pyritic TSF and in the open pit, the resultant predicted water quality concentrations are impacted in closure phase 1. Water quality in other phases of the project are relatively independent of this source term application (Knight Piésold 2019s). Additional details pertaining to model sensitivity analysis, as well as data pertaining to model sensitivity runs, are available in Knight Piésold (2019s) and associated appendices.

Geochemical source terms were developed as annual averages in dissolved concentrations based on geochemical weathering and leaching rates (SRK 2018a). Data presented in this technical appendix for geochemical source terms are dissolved concentrations. Additionally, the GoldSim mass balance model represents dissolved water concentrations in flow pathways for project facilities (Knight Piésold 2019s). In water management and treatment, it is anticipated that non-dissolved (suspended) constituents would largely settle out in the tailings impoundments, and water would be filtered as part of the water treatment process. As a result, the data presented in this technical appendix from the mass balance model are dissolved water concentrations, which are equivalent to whole water concentrations.

Table K4.18-2: Predicted Water Quality from Mine Site Geochemical Sources[a]—Part 1

Parameters	Background				Overburden	Other Rock		Open Pit				
	Direct Precipitation[b]	Non-Contact Surface Water	Non-Contact Surface Water	Groundwater	Stockpiles	Quarried Rock Fill (Dams)	Quarried Rock Fill (Dams)	Wall	Wall Runoff	Wall Runoff	In-Pit Stockpile	In-Pit Stockpile
		NFK (NK119A)	SFK SK100F	Pit Area		Non-Acidic	Non-Acidic	Runoff Pre-Tertiary Non-Acidic	Pre-Tertiary Acidic	Tertiary—Non-Acidic	Non-Acidic	Non-Acidic
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/t of new rock	mg/L	mg/L	mg/L	mg/L	mg/t of new rock
pH (pH Units)	**5.5[c]**	6.5	6.8	6.7	6.8	6.8	—	8.1	**3.5**	8.2	8	—
Alkalinity	**0**	**15**	**18**	33	**18**	**18**	—	49	**0**	69	800	—
Chlorine	0	0.62	0.71	0.8	0.71	0.71	—	2.2	6.9	2.3	23	—
Fluorine	0	0.032	0.04	0.072	0.04	0.04	—	0.32	0.45	0.11	1.8	—
Sulfate	0	1.2	7.8	4.9	7.8	7.8	—	88	**280**	29	**2,400**	—
Aluminum	0	0.036	0.054	0.0034	0.054	0.054	—	0.0011	**23**	0.0015	**2.6**	—
Antimony	0	0.00011	0.000064	0.000031	0.000064	0.000064	—	0.0022	0.001	**0.018**	**0.2**	—
Arsenic	0	0.00015	0.00038	0.00045	0.00038	0.00038	—	**0.02**	**0.034**	**0.043**	**0.4**	—
Barium	0	0.0025	0.0049	0.0064	0.0049	0.0049	—	0.14	0.06	1	0.36	—
Cadmium	0	0.000011	0.000013	<0.00002	0.000013	0.000013	—	**0.002**	**0.026**	**0.00023**	**0.22**	—
Calcium	0	3.9	6.1	14	6.1	6.1	—	30	9.9	25	940	—
Chromium	0	0.00022	0.00027	0.00051	0.00027	0.00027	—	0.00082	0.0017	0.0011	**0.02**	—
Cobalt	0	0.000076	0.00011	0.0001	0.00011	0.00011	—	0.02	0.25	0.00061	**0.88**	—
Copper	0	0.00037	0.0021	0.00044	0.0021	0.0021	—	**0.0064**	**6.4**	**0.0041**	**1.3**	—
Iron	0	0.15	0.55	0.02	0.55	0.55	—	0.002	**39**	0.002	**16**	—
Lead	0	0.00016	0.00028	0.0001	0.00028	0.00028	—	0.000091	**0.0081**	**0.00047**	**0.062**	—
Magnesium	0	0.73	1.5	1.1	1.5	1.5	—	10	1.9	2.5	120	—
Manganese	0	0.009	0.049	**0.44**	0.049	0.049	—	**1.9**	**13**	**0.14**	**6.2**	—
Mercury	0	0.0000011	0.0000011	<0.0000009	0.0000011	0.0000011	—	0.0000035	0.000011	0.0000027	**0.0062**	—
Molybdenum	0	0.00016	0.00051	0.00026	0.00051	0.00051	—	**0.051**	0.0084	**0.15**	**7.8**	—
Nickel	0	0.00022	0.00035	0.00065	0.00035	0.00035	—	**0.013**	**0.2**	0.0023	**0.32**	—
Potassium	0	0.21	0.37	0.34	0.37	0.37	2,600	4.7	0.0004	4.7	—	2,600
Selenium	0	0.00014	0.00041	0.0011	0.00041	0.00041	—	**0.016**	**0.13**	**0.016**	**0.048**	—
Silver	0	0.0000046	0.0000043	<0.000006	0.0000043	0.0000043	—	0.00003	0.000092	0.000042	**0.01**	—
Sodium	0	2	2.4	2.5	2.4	2.4	4,000	8.7	0.008	9.8	—	4,000
Thallium	0	0.0000056	0.0000078	0.0000073	0.0000078	0.0000078	—	0.0008	**0.0022**	0.00046	0.001	—
Zinc	0	0.0017	0.0032	0.0015	0.0032	0.0032	—	**0.36**	**2**	0.0078	**8.8**	—
Nitrate (as N)	0	0.081	—	—	0.21	—	4,700	—	—	—	0	390

Notes:

a. Values in table represent the 95th percentile geochemical source terms
b. Rows indicate source and sub-source
c. Bold values indicate exceedances of the most stringent water quality criteria (Appendix K3.18, Table K3.18-1). In the case of alkalinity, values less than the minimum criterion (>20 mg/L) are bolded
d. Adjustments made for specific location and orographic effects. Tailings Pond Adjustment values were applied for Al, SO_4, Fe, Cu and Mn in the Bulk TSF and Pyritic TSF
e. The 50th percentile (or median) supernatant mercury concentration (10 micrograms per liter [µg/L]) was used for the bulk tailings water given that about 70 percent of the results were not detected at <10 ng/L.

Nitrate-N = Nitrate as nitrogen; the concentration of nitrogen in solution due to nitrates
mg/L = milligrams per liter
mg/t = milligrams per ton
NFK = North Fork Koktuli
SFK = South Fork Koktuli
WR = waste rock
— = no data
Source: SRK 2018a, 2019e

Table K4.18-2: Predicted Water Quality from Mine Site Geochemical Sources[a]—Part 2

Parameters	Tailings						Pyritic TSF Waste Rock—Operations		Pyritic TSF Waste Rock—De-Commissioning		Open Pit—Closure	
	Bulk TSF Water[b]	Fresh Ore Leaching + Reagent	Pyritic Tailings	Ore	Tailings Pond Adjustment[d]	Pyritic Tailings Sand Wedge	PAG WR	Leached WR	Exposed Waste Rock	Exposed Waste Rock	Backfilled Waste Rock	Backfilled Waste Rock
	Supernatant[b]	—	Runoff	Entrained moisture	Pond	Seepage	Infiltration	Infiltration	Low Pyritic Tailings	High Pyritic Tailings	Low Pyritic Tailings	High Pyritic Tailings
	mg/L	mg/t of ore	$mg/m^2/week$	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
pH (pH units)	8.0	—	—	6.7	8	**8.6[c]**	8	**3.5**	8	**3**	8	**3**
Alkalinity	97.4	220,000	220	33	—	770	**18**	**14**	800	**14**	800	**14**
Chlorine	17.0	2,100	1.7	0.8	—	9.3	4.5	6.9	23	6.9	23	6.9
Fluorine	0.48	0	0.55	0.072	—	0.9	**1.8**	**2.8**	**1.8**	**2.8**	**1.8**	**2.8**
Sulfate	159.5	920,000	67	4.9	**2,400**	**2,400**	**600**	**4,000**	**2,400**	**31,000**	**2,400**	**31,000**
Aluminum	0.0109	480	0.38	0.0034	0.0006	**2.5**	**0.74**	**47**	**2.6**	**750**	**2.6**	**750**
Antimony	0.0025	2.4	0.021	0.000031	—	**0.2**	**0.057**	**0.015**	**0.2**	**0.036**	**0.2**	**0.036**
Arsenic	0.0020	3.3	0.096	0.00045	—	**0.26**	**0.05**	**0.76**	**0.4**	**0.9**	**0.4**	**0.9**
Barium	0.0226	42	0.043	0.0064	—	0.15	0.28	0.07	0.36	0.07	0.36	0.07
Cadmium	0.00006	14	0.00017	<0.00002	—	**0.01**	**0.0054**	**0.08**	**0.22**	**1.1**	**0.22**	**1.1**
Calcium	66.2	150,000	72	14	—	770	220	140	940	800	940	800
Chromium	0.005	3.1	0.0016	0.00051	—	0.02	0.0046	**0.041**	**0.02**	**0.19**	**0.02**	**0.19**
Cobalt	0.006	31	0.00033	0.0001	—	**0.05**	0.041	**0.51**	**0.88**	**3.2**	**0.88**	**3.2**
Copper	**0.0102**	30,000	0.017	0.00044	0.01	**0.37**	**1.3**	**99**	**1.3**	**640**	**1.3**	**640**
Iron	0.030	11,000	0.1	0.02	0.002	**1.8**	0.28	**1,100**	**16**	**1,800**	**16**	**1,800**
Lead	0.001	21	0.00021	0.0001	—	**0.05**	**0.0026**	**0.016**	**0.062**	**0.049**	**0.062**	**0.049**
Magnesium	15.6	85,000	18	1.1	—	99	69	190	120	190	120	190
Manganese	**0.56**	18,000	0.21	**0.44**	**2**	**2.9**	**3.9**	**36**	**6.2**	**56**	**6.2**	**56**
Mercury	0.00001[e]	0.1	0.000036	<0.0000009	—	**0.0005**	**0.0001**	**0.00009**	**0.0062**	**0.001**	**0.0062**	**0.001**
Molybdenum	0.0383	7.5	0.068	0.00026	—	**12**	**0.1**	**0.017**	**7.8**	**1.9**	**7.8**	**1.9**
Nickel	0.00212	92	0.0019	0.00065	—	**0.05**	**0.027**	**0.4**	**0.32**	**20**	**0.32**	**20**
Potassium	31.3	35,000	21	0.34	—	36	15	23	50	140	50	140
Selenium	**0.006**	20	0.0034	0.0011	—	**0.055**	**0.032**	**0.12**	**0.048**	**0.12**	**0.048**	**0.12**
Silver	0.000017	0.069	0.000032	<0.000006	—	**0.01**	**0.00011**	**0.0013**	**0.01**	**0.013**	**0.01**	**0.013**
Sodium	28.4	100,000	6.9	2.5	—	130	23	18	750	41	750	41
Thallium	0.00007	0.62	0.00017	0.0000073	—	0.0005	0.001	**0.005**	0.001	**0.005**	0.001	**0.005**
Zinc	0.0029	1,800	0.0046	0.0015	—	**1.9**	**0.95**	**21**	**8.8**	**170**	**8.8**	**170**
Nitrate (as N)	—	0	—	—	—	0	27	27	0	0	0	0

Notes:
[a] Values in table represent 95th percentile geochemical source terms
[b] Rows indicate source and sub-source
[c] Bold values indicate exceedances of the most stringent water quality criteria (Appendix K3.18, Table K3.18-1). In the case of alkalinity, values less than the minimum criterion (>20 mg/L) are bolded
[d] Adjustments made for specific location and orographic effects. Tailings Pond Adjustment values were applied for Al, SO_4, Fe, Cu and Mn in the Bulk TSF and Pyritic TSF
[e] The 50th percentile (or median) supernatant mercury concentration (10 nanogram per liter [ng/L]) was used for the bulk tailings water given that about 70 percent of the results were not detected at <10 ng/L
[f] Metals values presented represent dissolved water concentrations.
Nitrate-N = Nitrate as nitrogen; the concentration of nitrogen in solution due to nitrates.
kg = kilogram
mg/L = milligrams/liter
mg/m^2 = milligrams/square meters
mg/t = milligrams/tonne
PAG = potentially acid-generating
TSF = tailings storage facility
WR = waste rock
— = no data
Source: SRK 2018a, 2019e

Table K4.18-3: 50th Percentile Modeled Mass Loads—Final Year of Operations

Parameter[c]	WTP #1 Inflows	WTP #2 Inflows	Open Pit Water Management Pond	Bulk TSF[a]	Main Embankment Seepage Collection Pond	Pyritic TSF[a,b]	Main Water Management Pond
	Maximum Monthly Load[d] (kg)	Maximum Monthly Load (kg)	Maximum Monthly Load (kg)	Maximum Monthly Load (kg)	Maximum Monthly Load (kg)	Maximum Monthly Load (kg)	Maximum Monthly Load (kg)
TDS[e]	23,1093	35,724,296	231,093	3,257,142	2,836,152	9,942,757	35,724,296
Alkalinity	39,506	5,524,000	39,506	474,239	531,203	1,181,000	5,524,000
Acidity	52,322	104,988	52,322	5,143	8,830	20,594	104,988
Chloride	2,437	634,926	2,437	31,567	7,049	614,276	634,926
Fluoride	199.5	5,806	199.5	364	642.9	1,507	5,806
Sulfate	124,465	18,840,000	124,465	1,757,000	1,560,000	4,837,000	18,840,000
Aluminum	3,795	21.38	3,795	18.58	1,712	6.12	21.38
Antimony	5.70	900	5.7	57.63	132.6	104.4	900
Arsenic	16.38	1,166	16.38	74.26	172.4	123.3	1,166
Barium	30.06	1,450	30.06	135.3	103.6	396	1,450
Beryllium	1.52	173.6	1.52	23.23	3.33	45.55	173.6
Bismuth	5.13	470.3	5.13	31.34	66.38	59.62	470.3
Boron	52.25	10,140	52.25	1,125	346.5	2,390	10,140
Cadmium	9.90	106.6	9.9	11.47	6.64	21.47	106.6
Calcium	35,085	5,680,000	35,085	488,676	515,932	1,485,000	,5680,000
Chromium	1.09	123	1.09	10.42	13.57	19.18	123
Cobalt	63.2	438.2	63.2	42.36	33.22	88.55	438.2
Copper	1,064	339.5	1064	661.1	246.1	147	339.5
Iron	6,777	74.36	6,777	248	1,538	50.16	74.36
Lead	2.99	304	2.99	26.28	33.37	45.77	304
Magnesium	5,876	1,172,000	5,876	127,713	66,825	294,297	1,172,000
Manganese	2,402	50,880	2,402	3,436	1,947	9,536	50880
Mercury	0.16	3.16	0.16	0.27	0.33	0.48	3.16
Molybdenum	201.9	51,198	201.9	3,147	7,946	4,995	51,198.00
Nickel	40.28	777.80	40.28	91.47	33.46	186.70	777.80
Potassium	7,688	880,139	7,688	81,779	29,666	412,968	880,139
Selenium	22.99	443.1	22.99	41.16	36.71	94.89	443.1
Silver	0.28	43.61	0.28	2.74	6.63	4.42	43.61
Sodium	12,935	2,698,000	12,935	275,260	97,275	1,070,000	2,698,000
Thallium	0.42	7.93	0.42	0.89	0.34	2.17	7.93
Silicon	3,101	295,231	3101	20,908	28,202	48,216.00	295,231
Tin	0.85	857.4	0.85	53.25	132.50	84.86	857.40
Vanadium	1.34	178.2	1.34	14.65	20.33	26.42	178.20
Zinc	554.5	16,276	554.5	1,645	1,261	3,065	16,276

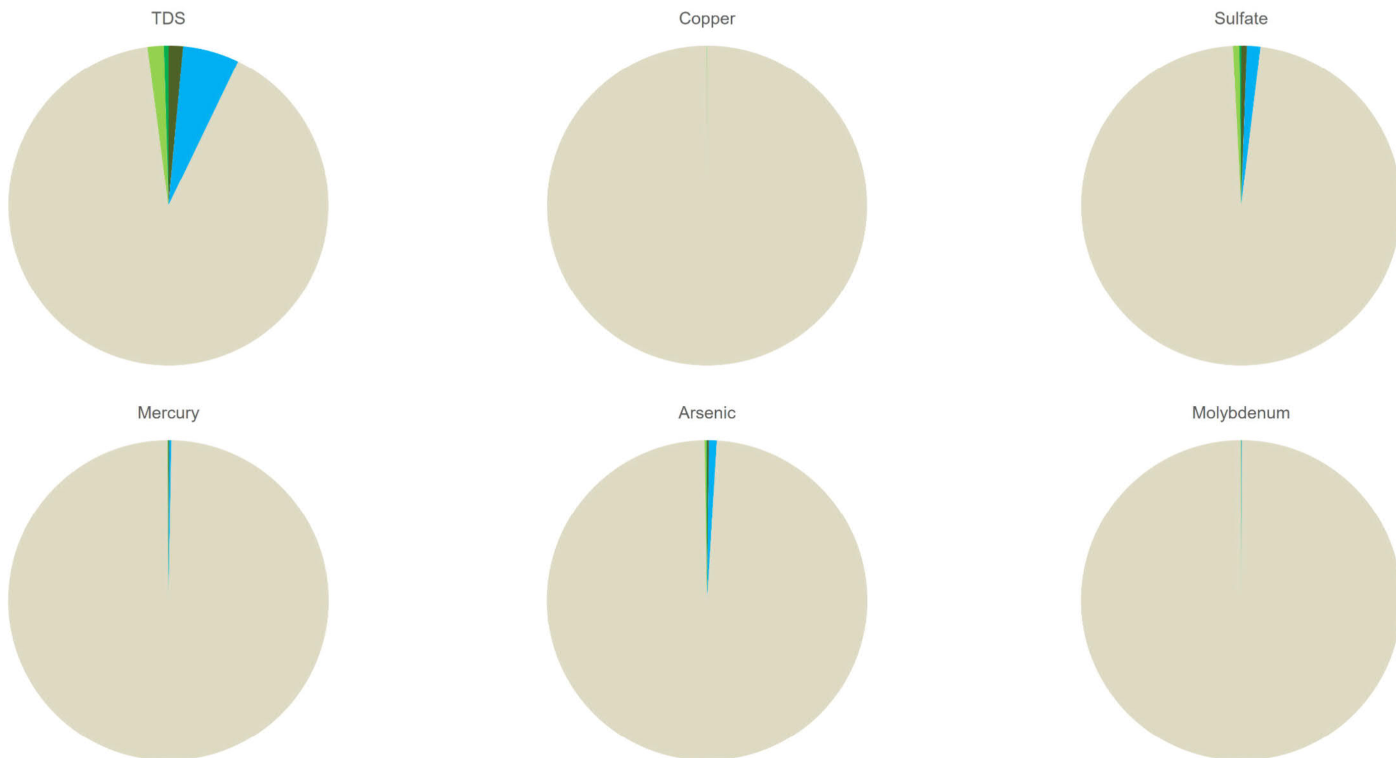
Table K4.18-3: 50th Percentile Modeled Mass Loads—Final Year of Operations

Parameter[c]	WTP #1 Inflows	WTP #2 Inflows	Open Pit Water Management Pond	Bulk TSF[a]	Main Embankment Seepage Collection Pond	Pyritic TSF[a,b]	Main Water Management Pond
	Maximum Monthly Load[d] (kg)	Maximum Monthly Load (kg)	Maximum Monthly Load (kg)	Maximum Monthly Load (kg)	Maximum Monthly Load (kg)	Maximum Monthly Load (kg)	Maximum Monthly Load (kg)
Nitrate_N	1,052	144,065	1,052	5,701	10,009	41,117	144,065
Nitrate (ion)	4,365	601,245	4,365	20,610	44,307	175,760	601,245
Nitrite	87.29	11,980	87.29	409.90	886.10	3,488	11,980
Ammonia	98.6	15,189	98.6	638.90	1,001	4,569	15,189

Notes:

a. Tailings pond adjustment values were applied for Al, SO_4, Fe, Cu, and Mn in the Bulk TSF and Pyritic TSF
b. WTP reject flows report to the pyritic TSF in operations and to the open pit in closure
c. pH was not modeled
d. Results are presented as the seasonal maximum load for the final year of operation; the maximum month with the load is not necessarily the same as the month with the maximum concentration
e. TDS values were calculated by summing alkalinity, Cl, F, SO_4, Ca, Mg, K, Na, and Si

kg = kilogram
TDS = total dissolved solids
TSF = tailings storage facility
WTP = water treatment plant
Source: Knight Piésold 2019s



Legend

- OPWMP Undiverted Runoff (SFK Source Term)
- OP Groundwater (Groundwater Source Term)
- OP Pitwall Runoff (Pre-Tertiary Non-Acidic, Pre-Tertiary Acidic, Tertiary Non-Acidic Source Terms)
- OP Undiverted Runoff (SFK Source Term)
- OP Diversion Leakage (SFK Source Term)

NOTES:

1. LOADS ARE SHOWN AS TOTAL ANNUAL INPUTS FOR THE END OF MINE AND ARE BASED ON THE 50TH PERCENTILE RESULTS FOR THE BASE CASE SCENARIO FROM 76 MODEL REALIZATIONS FROM THE CLIMATE VARIABLE MODEL (REF. NO. VA101-00176/60-3 REV 1. 8JAN'20).

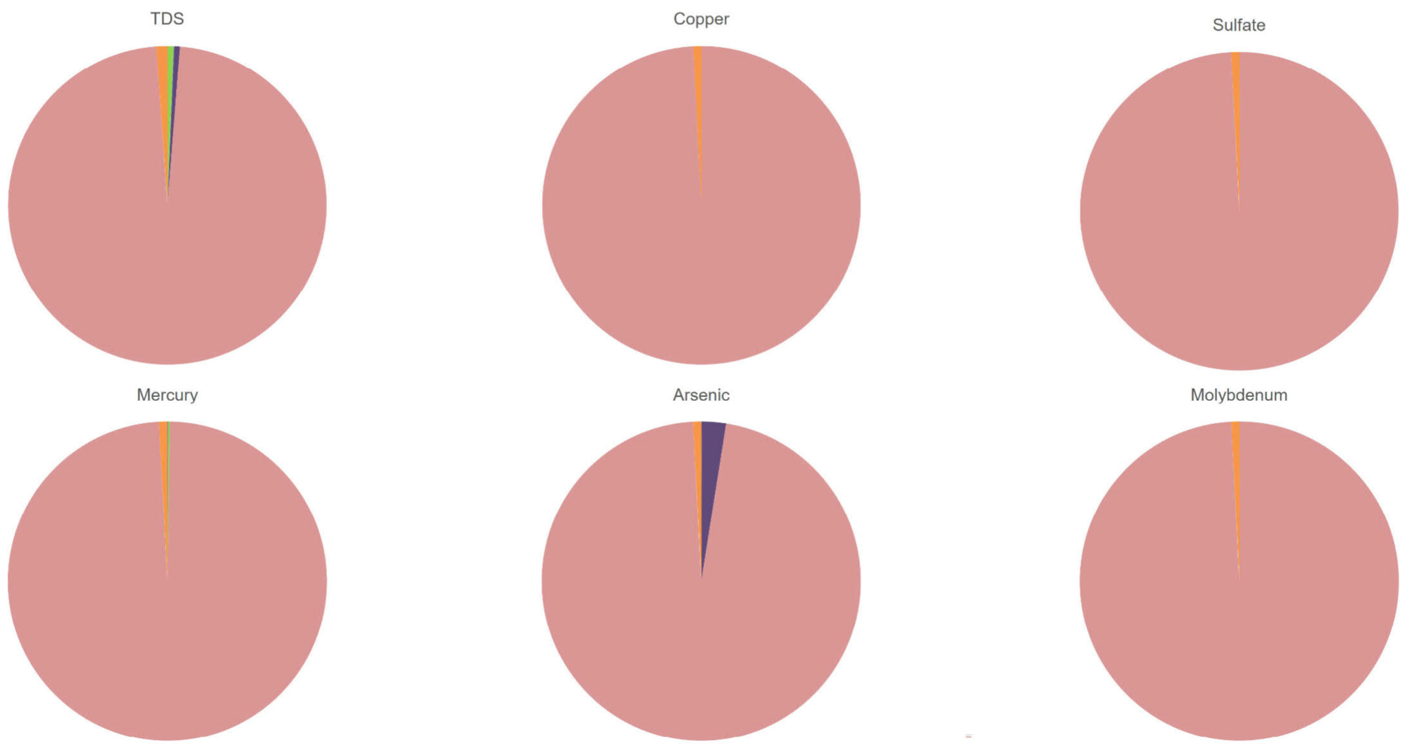
Sources: PLP 2020-RFI 106a

US Army Corps of Engineers®

INFLOW LOADS – OPEN PIT WATER MANAGEMENT POND

PEBBLE PROJECT EIS

FIGURE K4.18-1



Legend

- Undiverted Runoff (NFK Source Term)
- Diversion Leakage (NFK Source Term)
- Beach Runoff (Rougher Tailings Source Term)
- Tailings Slurry (Concentration in Mill after Tailings Pond Adjustment)
- Recycle from South SCP (Concentration in SCP)

NOTES:

1. LOADS ARE SHOWN AS TOTAL ANNUAL INPUTS FOR THE END OF MINE AND ARE BASED ON THE 50TH PERCENTILE RESULTS FOR THE BASE CASE SCENARIO FROM 76 MODEL REALIZATIONS FROM THE CLIMATE VARIABLE MODEL (REF. NO. VA101-00176/60-3 REV 1. 8JAN'20).

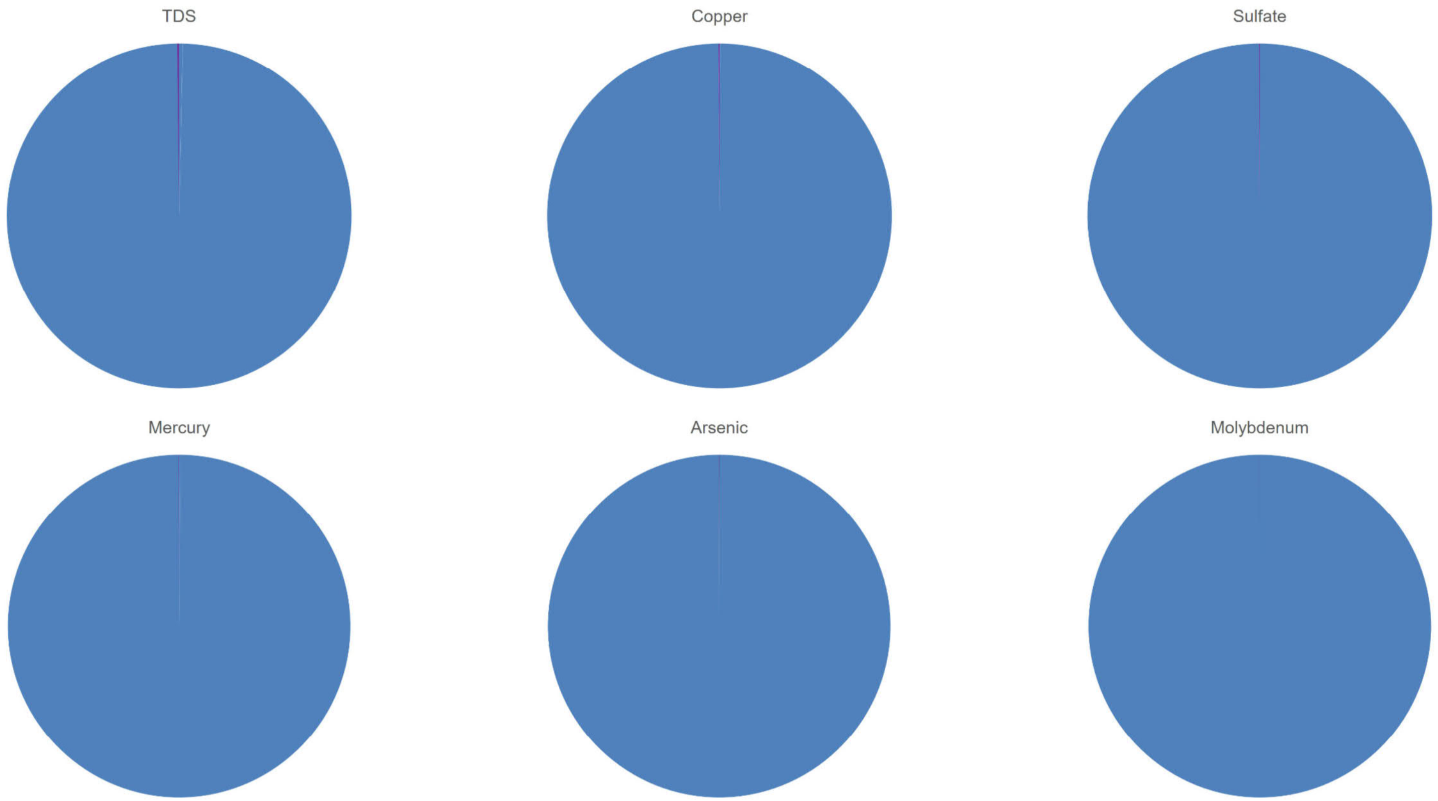
Sources: PLP 2020-RFI 106a

US Army Corps of Engineers®

INFLOW LOADS – BULK TSF

PEBBLE PROJECT EIS

FIGURE K4.18-2



NOTES:

1. LOADS ARE SHOWN AS TOTAL ANNUAL INPUTS FOR THE END OF MINE AND ARE BASED ON THE 50TH PERCENTILE RESULTS FOR THE BASE CASE SCENARIO FROM 76 MODEL REALIZATIONS FROM THE CLIMATE VARIABLE MODEL (REF. NO. VA101-00176/60-3 REV 1. 8JAN'20).

Legend

- Undiverted Runoff (NFK Source Term)
- Diversion Leakage (NFK Source Term)
- Seepage to Underdrains (Rougher Tails Seepage Source Term)
- Embankment Runoff (Quarried Rockfill Source Term)

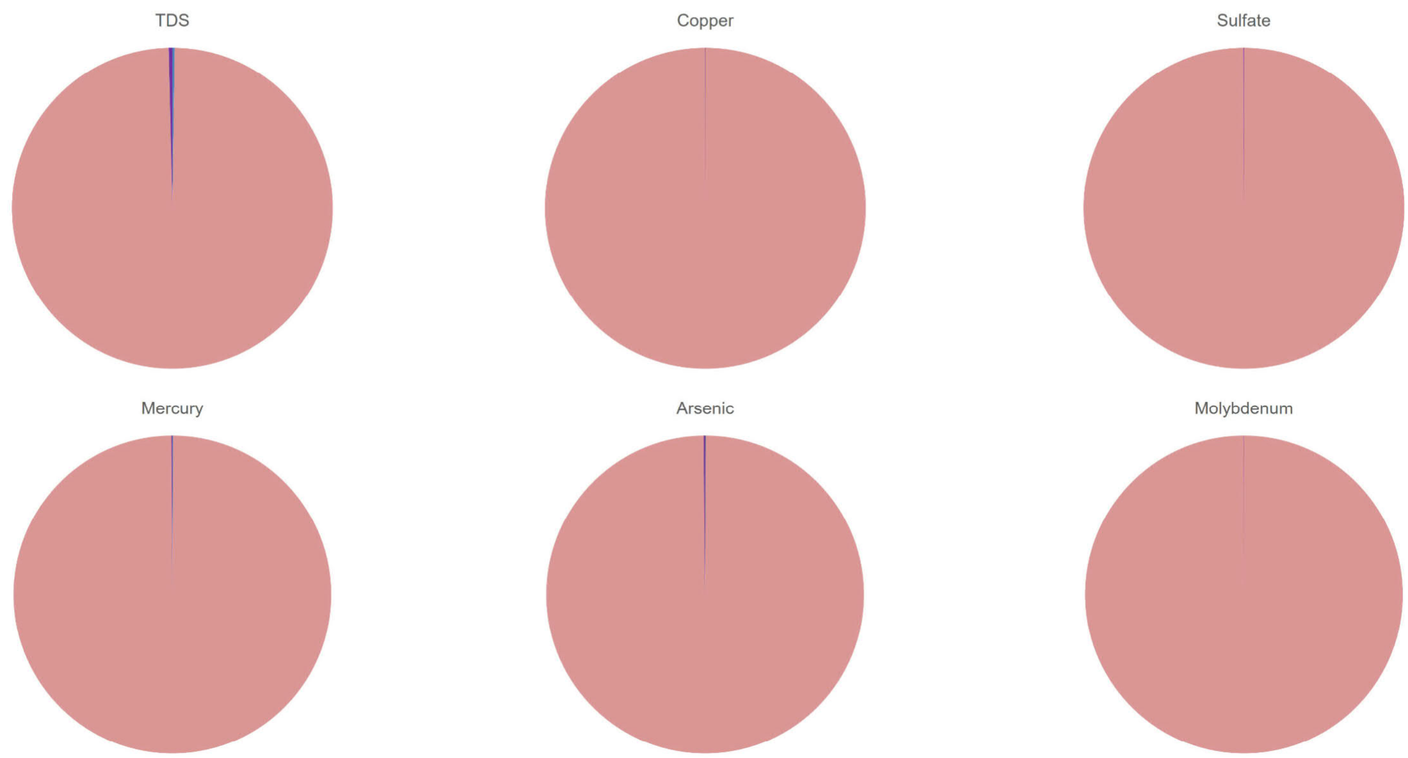
Sources: PLP 2020-RFI 106a

US Army Corps of Engineers®

INFLOW LOADS – MAIN EMBANKMENT SEEPAGE COLLECTION POND

PEBBLE PROJECT EIS

FIGURE K4.18-3



Legend

- Diversion Leakage (NFK Source Term)
- Undiverted Runoff (NFK Source Term)
- Pyritic Slurry (Ore Source Term, Plus Reclaim Loads and WTP Sludge and Reject
- Recycle from East/South SCRPs (Concentration in SCRPs)
- PAG Waste Rock (PAG WR Source Term)

NOTES:

1. LOADS ARE SHOWN AS TOTAL ANNUAL INPUTS FOR THE END OF MINE AND ARE BASED ON THE 50TH PERCENTILE RESULTS FOR THE BASE CASE SCENARIO FROM 76 MODEL REALIZATIONS FROM THE CLIMATE VARIABLE MODEL (REF. NO. VA101-00176/60-REV 1. 8JAN'20).

Sources: PLP 2020-RFI 106a

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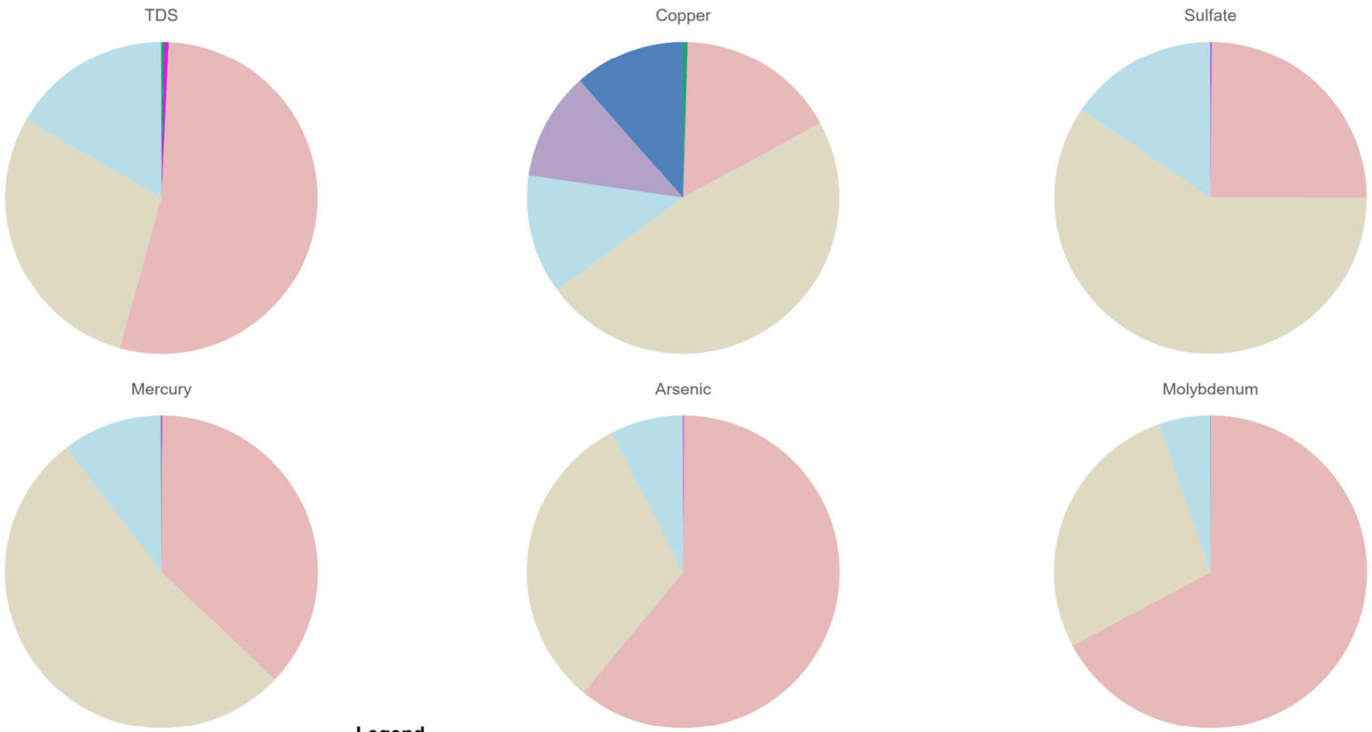
INFLOW LOADS – PYRITIC TSF

PEBBLE PROJECT EIS

FIGURE K4.18-4



Legend

- Diversion Leakage (NFK Source Term)
- Undiverted Runoff (NFK Source Term)
- Blow Down Water (WTP Effluent Source Term)
- Pyritic TSF Embankment Runoff (Quarry Source Term)
- Mill Site Runoff (Quarry Source Term)
- MESCP Surplus (Concentration of the MESCP)
- Bulk TSF Surplus (Concentration of the Bulk TSF)
- Pyritic TSF Surplus (Concentration of the Pyritic TSF)
- Open Pit WMP Surplus (Concentration of the OP WMP)
- Pyritic TSF Liner Leakage (Concentration of the Pyritic Tailings Voids)
- Recycle from North SCP (Concentration in SCP)

NOTES:

1. LOADS ARE SHOWN AS TOTAL ANNUAL INPUTS FOR THE END OF MINE AND ARE BASED ON THE 50TH PERCENTILE RESULTS FOR THE BASE CASE SCENARIO FROM 76 MODEL REALIZATIONS FROM THE CLIMATE VARIABLE MODEL (REF. NO. VA101-00176/60-3 REV 1. 8JAN'20).

Sources: PLP 2020-RFI 106a

US Army Corps of Engineers®

INFLOW LOADS – MAIN WATER MANAGEMENT POND

Predicted Water Quality

Table K4.18-4 shows the predicted water quality in mine site facility ponds during the final year of operations from the Knight Piésold (2019s) water quality model. Values in the table represent the maximum monthly predicted concentrations for the 10th, 50th, and 90th percentile flow values, using the 95th percentile source term concentrations, for waste streams going to the WTPs from each facility. As described above, the 95th percentile represents a source term input to the water quality model that would be greater than 95 percent of all possible inputs to the WTP, thereby ensuring a conservative range of estimates from the water quality model.

The mass balance model used to predict water quality cannot explicitly model pH. Instead, a range of values was indirectly accounted for based on acidic and non-acidic source terms provided by SRK (2018a; 2019a, e) (Table K4.18-2) and relative flow contributions to the facilities. Although mine site surface soils are acidic (SLR et al. 2011a), the assumed pH values (7 to 8) are consistent with those of mine site groundwaters, as groundwaters in both overburden and bedrock are mostly circumneutral (Table K3.18-18).

SRK (2019a) clarified that pH is accounted for indirectly by adopting different pH-related constituent source terms for weathering under “non-acidic” or “acid” oxygen-limited conditions. Because the weathering reactions are controlled by carbonate minerals, the distinction between these conditions is very strong. The source terms used in the water quality model were applied on a mass conservation basis, with the exception of the tailings ponds, where elevated pH values due to the use of lime in the process plant are assumed to partially remove aluminum, copper, and iron. Elsewhere, the model does not allow for any pH- or Eh-dependent mechanisms that might occur, although most of the site waters are non-acidic and oxic due to the waste management approach.

SRK (2019e) developed two new source terms to describe the behavior of PAG waste rock disposed in the pyritic TSF before it is submerged. The source terms replaced those reported in SRK (2018a). One source term was developed for lower NP, near surface, naturally weathered “leached” rock, which was assumed to be acidic. The other source term was developed for deeper PAG bedrock assumed to be non-acidic. Both source terms were assigned chemistry using SRK’s porphyry mine database for the Canadian cordillera, and account for pH differences indirectly.

SRK (2019e) also developed source terms for the decommissioning of the pyritic TSF, which would be temporarily exposed to weathering during desaturation and subsequent handling as the materials are moved to the open pit for final storage. The range in water chemistry for these materials was accounted for by non-acidic and acidic source terms. The chemistries of both source terms were assigned using SRK’s porphyry database, and account for pH differences indirectly.

SRK (2019a) also constrained constituent concentrations in the source terms by applying solubility limits where appropriate. Mineral solubility is governed by the same processes, such as pH, that are accounted for indirectly in the source terms.

Modeled water quality for inflow into WTP #1 and WTP #2 in operations are provided in Table K4.18-5. Water quality feeding the WTPs would be primarily controlled by constituent concentrations from the open pit WMP for WTP #1 and the main WMP for WTP #2. Water quality predictions for WTP #1 are dominated by loading from open pit dewatering. The maximum predicted concentrations in the open pit WMP would occur during the summer months because of the in-pit stockpile loads from the open pit. The influent water quality to WTP #1 would be expected to gradually worsen with each year of mine activity as more pre-Tertiary age rock is exposed to oxygen and water. Therefore, pit wall runoff in early years of mining would be expected to be of better quality than at the end of mine life (i.e., after 20 years). To be conservative, the water quality estimate for end of mine life was used in all simulations to represent all years of mining.

Table K4.18-4: Predicted Water Quality in Mine Site Storage Ponds in Operations

Parameters (mg/L)	Open Pit Water Management Pond			Bulk TSF			Main Embankment Seepage Collection Pond			Pyritic TSF			Main Water Management Pond		
	Maximum Monthly			Maximum Monthly			Maximum Monthly			Maximum Monthly			Maximum Monthly		
	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile
pH	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8
TDS	325	404	421	**3,376**	**3,928**	**4,233**	**4,196**	**4,196**	**4,196**	**2,625**	**3,016**	**3,276**	**1,951**	**2,564**	**3,088**
Alkalinity	46.1	49.1	50.2	497	587	680	770	770	770	326	384	418	301	400	488
Acidity	55.8	67.8	72.8	13.8	15.7	17.2	7.49	7.49	7.49	52.1	57.0	61.2	15.7	17.3	18.9
Chloride	2.63	3.09	3.27	19.73	24.15	27.21	9.30	9.30	9.30	112.70	132.30	153.90	21.52	25.98	29.29
Fluoride	0.218	0.254	0.268	0.224	0.292	0.348	0.900	0.900	0.900	0.344	0.379	0.407	0.247	0.319	0.375
Sulfate	128	158	171	**1,980**	**2,291**	**2,350**	**2,350**	**2,350**	**2,350**	**1,402**	**1,624**	**1,760**	**1,108**	**1,460**	**1,747**
Aluminum	**3.87**	**4.83**	**5.23**	0.000600	0.000600	0.000600	0.000600	0.000600	0.000600	0.000600	0.000600	0.000600	0.000600	0.000600	0.000600
Antimony	0.00581	**0.00726**	**0.00783**	**0.0317**	**0.0453**	**0.0576**	**0.200**	**0.200**	**0.200**	**0.0180**	**0.0243**	**0.0291**	**0.0377**	**0.0523**	**0.0645**
Arsenic	**0.0202**	**0.0251**	**0.0271**	**0.0443**	**0.0624**	**0.0780**	**0.260**	**0.260**	**0.260**	**0.0287**	**0.0381**	**0.0456**	**0.0519**	**0.0711**	**0.0869**
Barium	0.0506	0.0616	0.0659	0.106	0.125	0.143	0.150	0.150	0.150	0.0899	0.1020	0.1094	0.0663	0.0863	0.1040
Beryllium	0.00155	0.00193	0.00209	**0.0583**	**0.0649**	**0.0723**	**0.00500**	**0.00500**	**0.00500**	**0.0291**	**0.0359**	**0.0407**	**0.0232**	**0.0307**	**0.0372**
Bismuth	0.00523	0.00654	0.00705	0.0189	0.0260	0.0325	0.100	0.100	0.100	0.0108	0.0142	0.0168	0.0200	0.0277	0.0340
Boron	0.0602	0.0749	0.0808	**0.89**	**1.03**	**1.18**	0.520	0.520	0.520	0.514	0.620	0.693	0.462	0.619	**0.754**
Cadmium	**0.0105**	**0.0131**	**0.0141**	**0.0253**	**0.0284**	**0.0318**	**0.0100**	**0.0100**	**0.0100**	**0.0133**	**0.0163**	**0.0185**	**0.0113**	**0.0148**	**0.0179**
Calcium	38.2	44.1	46.5	392	471	552	770	770	770	345	386	411	266	352	430
Chromium	0.00120	0.00137	0.00144	0.0083	0.0101	0.0120	0.0200	0.0200	0.0200	0.00446	0.00575	0.00668	0.00585	0.00791	0.00965
Cobalt	**0.0683**	**0.0854**	**0.0924**	**0.065**	**0.074**	**0.083**	**0.0500**	**0.0500**	**0.0500**	0.0376	0.0455	**0.0516**	0.0333	0.0431	**0.0515**
Copper	**1.08**	**1.35**	**1.47**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**
Iron	**6.90**	**8.63**	**9.35**	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200
Lead	**0.00306**	**0.00381**	**0.00411**	**0.042**	**0.049**	**0.057**	**0.0500**	**0.0500**	**0.0500**	**0.0207**	**0.0264**	**0.0304**	**0.0226**	**0.0305**	**0.0372**
Magnesium	6.17	7.45	7.95	163	185	209	99.0	99.0	99.0	96	114	127	77	102	124
Manganese	**2.89**	**3.49**	**3.74**	**2.00**	**2.00**	**2.00**	**2.00**	**2.00**	**2.00**	**2.00**	**2.00**	**2.00**	**1.68**	**1.78**	**1.85**
Mercury	**0.000164**	**0.000204**	**0.000220**	**0.000246**	**0.000296**	**0.000346**	**0.000500**	**0.000500**	**0.000500**	**0.000121**	**0.000157**	**0.000182**	**0.000160**	**0.000215**	**0.000262**
Molybdenum	**0.214**	**0.268**	**0.289**	**1.59**	**2.38**	**3.09**	**12.0**	**12.0**	**12.0**	**0.77**	**1.09**	**1.38**	**2.11**	**2.96**	**3.65**
Nickel	**0.0434**	**0.0540**	**0.0584**	**0.168**	**0.188**	**0.210**	**0.0500**	**0.0500**	**0.0500**	**0.089**	**0.108**	**0.123**	**0.0727**	**0.0954**	**0.1153**
Potassium	38.5	53.1	53.1	76	87	97	36.0	36.0	36.0	93.3	102.1	111.9	42.3	52.4	62.5
Selenium	**0.0256**	**0.0317**	**0.0342**	**0.044**	**0.051**	**0.058**	**0.0550**	**0.0550**	**0.0550**	**0.0273**	**0.0326**	**0.0361**	**0.0249**	**0.0328**	**0.0397**
Silver	0.000283	0.000353	0.000380	**0.00144**	**0.00211**	**0.00271**	**0.0100**	**0.0100**	**0.0100**	0.000703	0.000988	**0.001236**	**0.00181**	**0.00253**	**0.00311**
Sodium	60.7	83.3	83.3	233	265	298	130	130	130	240	262	281	124	158	190
Thallium	0.000546	0.000680	0.000735	0.00119	0.00134	0.00150	0.000500	0.000500	0.000500	0.000746	0.000882	0.000973	0.000556	0.000719	0.000865

Table K4.18-4: Predicted Water Quality in Mine Site Storage Ponds in Operations

Parameters (mg/L)	Open Pit Water Management Pond			Bulk TSF			Main Embankment Seepage Collection Pond			Pyritic TSF			Main Water Management Pond		
	Maximum Monthly			Maximum Monthly			Maximum Monthly			Maximum Monthly			Maximum Monthly		
	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile
Silicon	4.62	5.86	5.87	14.9	17.7	20.6	32.0	32.0	32.0	9.73	11.55	12.84	11.5	14.6	17.3
Tin	0.00088	0.00108	0.00116	0.0277	0.0409	0.0528	0.200	0.200	0.200	0.0140	0.0198	0.0246	0.0357	0.0500	0.0616
Vanadium	0.00146	0.00168	0.00177	0.0109	0.0136	0.0161	0.0300	0.0300	0.0300	0.00583	0.00758	0.00884	0.0082	0.0111	0.0136
Zinc	**0.637**	**0.796**	**0.860**	**3.50**	**3.95**	**4.45**	**1.90**	**1.90**	**1.90**	**1.92**	**2.36**	**2.68**	**1.64**	**2.16**	**2.61**
Nitrate_N	5.75	8.08	8.08	3.61	4.30	5.14	1.78	5.35	**11.19**	7.38	8.86	**10.83**	3.64	4.51	5.95
Nitrate (ion)	24.9	35.0	35.0	12.8	15.9	19.4	7.9	23.7	49.6	31.5	37.8	46.5	15.0	18.8	24.8
Nitrite	0.498	0.700	0.701	0.256	0.316	0.386	0.158	0.474	0.991	0.613	0.741	0.927	0.297	0.375	0.495
Ammonia	0.563	0.791	0.791	0.406	0.476	0.565	0.178	0.535	1.119	0.857	0.990	1.170	0.394	0.476	0.626
Hardness as $CaCO_3$	121	141	149	1,650	1,937	2,238	2,330	2,330	2,330	1,255	1,435	1,550	982	1,299	1,585

Notes:
End of mine life maximum monthly 10th, 50th, and 90th percentile results based on 76 realizations of model simulations
Model input concentrations provided by SRK (2018a, 2019e)
Tailings pond adjustment values were applied for Al, SO_4, Fe, Cu, and Mn in the TSFs, main SCP, and main WMP
Model assumes return of WTP reject flows to the pyritic TSF via the pyritic tailings line. WTP reject concentrations were provided by HDR (2019g)
TDS values were calculated by summing alkalinity, Cl, F, SO_4, Ca, Mg, K, Na, and Si
Bold values indicate exceedances of most stringent water quality parameters (Appendix K3.18, Table K3.18-1)
Hardness values were calculated based on the equation, hardness (CaCO3) = calcium concentration (mg/L) × 2.497 + magnesium concentration (mg/L) × 4.118
pH was not modeled; pH values are based on the range of pH source terms provided by SRK (2018a, 2019e) (Knight Piésold 2019s)
$CaCo_3$ = calcium carbonate
TDS = total dissolved solids
TSF = tailings storage facility
mg/L = milligrams per liter
WMP = water management pond
WTP = water treatment plant
Source: Knight Piésold 2019s

Table K4.18-5: Predicted Water Quality Inflows for WTPs in Operations

Parameters (mg/L)	WTP #1			WTP #2		
	Maximum Monthly			Maximum Monthly		
	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile
pH	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8
TDS	325	404	421	**1,951**	**2,564**	**3,088**
Alkalinity	46.1	49.1	50.2	301	400	488
Acidity	55.8	67.8	72.8	15.7	17.3	18.9
Chloride	2.63	3.09	3.27	21.52	25.98	29.29
Fluoride	0.218	0.254	0.268	0.247	0.319	0.375
Sulfate	128	158	171	1,108	1,460	1,747
Aluminum	**3.87**	**4.83**	**5.23**	0.000600	0.000600	0.000600
Antimony	0.00581	**0.00726**	**0.00783**	**0.0377**	**0.0523**	**0.0645**
Arsenic	**0.0202**	**0.0251**	**0.0271**	**0.0519**	**0.0711**	**0.0869**
Barium	0.0506	0.0616	0.0659	0.0663	0.0863	0.1040
Beryllium	0.00155	0.00193	0.00209	**0.0232**	**0.0307**	**0.0372**
Bismuth	0.00523	0.00654	0.00705	0.0200	0.0277	0.0340
Boron	0.0602	0.0749	0.0808	0.462	0.619	**0.754**
Cadmium	**0.0105**	**0.0131**	**0.0141**	**0.0113**	**0.0148**	**0.0179**
Calcium	38.2	44.1	46.5	266	352	430
Chromium	0.00120	0.00137	0.00144	0.00585	0.00791	0.00965
Cobalt	**0.0683**	**0.0854**	**0.0924**	0.0333	0.0431	**0.0515**
Copper	**1.08**	**1.35**	**1.47**	**0.0100**	**0.0100**	**0.0100**
Iron	**6.90**	**8.63**	**9.35**	0.00200	0.00200	0.00200
Lead	**0.00306**	**0.00381**	**0.00411**	**0.0226**	**0.0305**	**0.0372**
Magnesium	6.17	7.45	7.95	77	102	124
Manganese	**2.89**	**3.49**	**3.74**	**1.68**	**1.78**	**1.85**
Mercury	**0.000164**	**0.000204**	**0.000220**	**0.000160**	**0.000215**	**0.000262**

Table K4.18-5: Predicted Water Quality Inflows for WTPs in Operations

Parameters (mg/L)	WTP #1			WTP #2		
	Maximum Monthly			Maximum Monthly		
	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile
Molybdenum	**0.214**	**0.268**	**0.289**	**2.11**	**2.96**	**3.65**
Nickel	**0.0434**	**0.0540**	**0.0584**	**0.0727**	**0.0954**	**0.1153**
Potassium	38.5	53.1	53.1	42.3	52.4	62.5
Selenium	**0.0256**	**0.0317**	**0.0342**	**0.0249**	**0.0328**	**0.0397**
Silver	0.000283	0.000353	0.000380	**0.00181**	**0.00253**	**0.00311**
Sodium	60.7	83.3	83.3	124	158	190
Thallium	0.000546	0.000680	0.000735	0.000556	0.000719	0.000865
Silicon	4.62	5.86	5.87	11.5	14.6	17.3
Tin	0.00088	0.00108	0.00116	0.0357	0.0500	0.0616
Vanadium	0.00146	0.00168	0.00177	0.0082	0.0111	0.0136
Zinc	**0.637**	**0.796**	**0.860**	**1.64**	**2.16**	**2.61**
Nitrate_N	5.75	8.08	8.08	3.64	4.51	5.95
Nitrate (ion)	24.9	35.0	35.0	15.0	18.8	24.8
Nitrite	0.498	0.700	0.701	0.297	0.375	0.495
Ammonia	0.563	0.791	0.791	0.394	0.476	0.626
Hardness as $CaCO_3$	121	141	149	982	1,299	1,585

Notes:
End of mine life maximum monthly 10th, 50th, and 90th percentile results based on 76 realizations of model simulations
TDS values were calculated by summing alkalinity, Cl, F, SO_4, Ca, Mg, K, Na, and Si
Bold values indicate exceedances of the most stringent water quality criteria (Appendix K3.18, Table K3.18-1)
Hardness values were calculated based on the following: Hardness ($CaCO_3$) = Calcium Concentration (mg/L)*2.497+Magnesium Concentration (mg/L)*4.118
pH was not modeled; pH values are based on the range of pH source terms provided by SRK (2018a, 2019e) (Knight Piésold 2019s)
$CaCo_3$ = calcium carbonate
mg/L = milligrams/liter
TDS = total dissolved solids
WTP = water treatment plant
Source: Knight Piésold 2019s

The main WMP manages surplus water from the mine site. The majority of loading to the main WMP would be primarily from the bulk and pyritic TSFs. However, the maximum predicted concentrations in the main WMP would be less than in the bulk and pyritic TSFs because of the continuous removal of loads from the main WMP via reclaimed water that is directed to the process plant and to WTP #2. The bulk tailings slurry water drives the loading in the bulk TSF supernatant pond. Similarly, the pyritic tailings slurry water drives the majority of loading in the pyritic TSF, with both sludge reject and reverse osmosis (RO) reject flows from the WTPs contributing to the loading. The flushing load from potentially acid generating (PAG) waste rock in the pyritic TSF provides loading to the pyritic TSF supernatant pond; however, the load from the PAG waste rock is not as great as that from the tailings slurry water.

As described below, water collected at the mine site that does not meet discharge water quality criteria would be treated in the WTPs prior to discharge to the environment. Treated water in excess of process requirements would be released to the environment in the NFK, SFK, and UTC watersheds at flows protective of the environment to the extent possible, given the capacities of the WTPs and need for process water use on site. Impacts on flows in these watersheds are discussed in Section 4.16, Surface Water Hydrology, and Section 4.24, Fish Values.

Process Water Toxicity Testing

In a separate study from the geochemical modeling predictions described above, aquatic toxicity testing was conducted on samples of process water generated during plant water testing by Nautilus (2012). Samples of "non-gold" process plant water in the study are considered representative of process water that would be pumped from the mill to the TSFs and main WMP, undiluted by precipitation or other inflows (such as tailings beach runoff, SCP return water, WTP reject flows) (Knight Piésold 2019s). The results indicated no acute toxicity effects in the 96-hour rainbow trout and fathead minnow tests, and no chronic toxicity effects to survival or growth in the 7-day fathead minnow tests, with 100 percent survival rates and no growth impairment in undiluted process water. The results using *Ceriodaphnia dubia* (a daphnid or water flea) indicated 50 percent survival in undiluted process water after 48 hours, and chronic reproductive effects of 55.8 and 89.6 percent at IC25 and IC50[1], respectively, after 7 days. Potential effects on aquatic life in the event of a release from mine site facilities are further discussed in Section 4.27, Spill Risk.

K4.18.1.2 Closure and Post-Closure

The closure strategy for the mine site is to decommission and reclaim facilities that leave the mine site in a stable condition that complies with regulations and closure criteria, and prevents unnecessary degradation of land and water resources. To assess closure effectiveness, water balance, water quality, and pit lake models for the closure and post-closure periods of the mine were based on a four-phase closure plan as outlined below:

- **Phase 1**—reclamation of quarries and bulk TSF; backfilling of open pit by closure year 15
- **Phase 2**—bulk TSF and quarries reclaimed; backfilling of open pit complete; reclamation of pyritic TSF and main WMP; pit dewatering ceases; water flow into the pit creating a lake; no water treatment needed in closure years 16 through approximately 23 as the pit fills to its maximum maintenance level (WTP #3 used for

[1] IC = Inhibition Concentration; IC25 and IC50 represent concentrations which result in 25 and 50 percent reductions in reproductive output, respectively.

treatment if necessary to meet downstream flows based on adaptive management and monitoring)

- **Phase 3**—pyritic TSF and main WMP reclaimed; ongoing treatment of surplus water in open pit in closure years 23 through 50 to maintain pit as hydraulic sink to capture groundwater and mitigate potential for contaminant release along subsurface pathways
- **Phase 4**—post-closure long-term conditions

The mine layout during each of the closure phases is described and shown on figures in Section 4.16, Surface Water Hydrology, and reclamation of project facilities is described in more detail in Knight Piésold (2018d, 2019s).

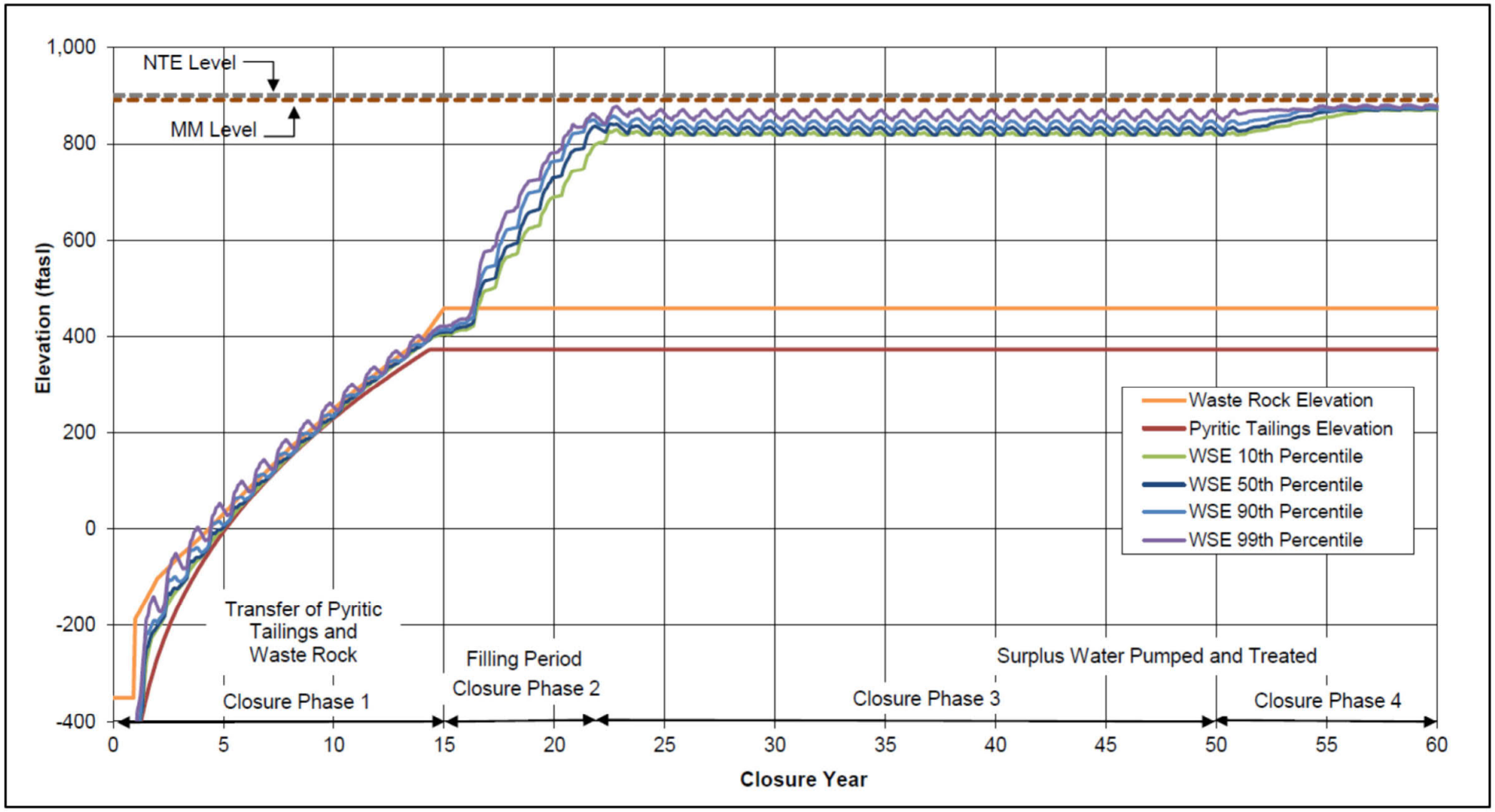
This section contains the results of water balance and water quality modeling for mine site facilities in closure, including the TSFs, main WMP, main SCP, WTPs, and open pit. Additional modeling of pit lake water quality in later closure phases related to lake water stratification is provided at the end of this section.

Water Balance Model

The closure and post-closure water balance model was developed similar to the operations model to estimate water flow volumes for the various facilities during the closure phases under varying historical climate conditions. The development and methodologies used in the closure phase models are similar to those described above for operations phase. Details regarding model inputs and assumptions are provided in Knight Piésold (2018d, 2019s).

Water balance model information in Section 4.16, Surface Water Hydrology, and Appendix K4.16 describes the sources of contact water entering the main WMP, the WTPs, and the open pit in the closure phases. The results of the closure and post-closure water balance model are summarized in Figure K4.18-6 through Figure K4.18-8. Figure K4.18-6 shows the estimated open pit water surface elevations during closure. The approximate elevations of the PAG waste rock and pyritic tailings are also shown for reference. Approximately 420 feet of water cover would be maintained over these materials to minimize the potential for pyrite oxidation and the development of acidic pit lake water. Studies have shown that water cover reduces pyrite oxidation up to 96 percent because water limits the transport of oxygen. Figure K4.18-6 indicates that it would take 21 to 23 years to fill the open pit to the maximum management (MM) level, depending on climatic conditions (Knight Piésold 2019s). The MM level is set at 890 feet above mean sea level, 10 feet below the not to exceed (NTE) level of 900 feet (Knight Piésold 2018n), so that the open pit can maintain sufficient freeboard to store the probable maximum flood without encroaching on the NTE level. The NTE level is set below the static groundwater level so that the open pit functions as a hydraulic sink, maintaining groundwater flow towards the pit. Surplus water from the open pit yields a flow rate of about 6 cfs, when averaged throughout the year and across climate scenarios (Knight Piésold 2018d, 2019s). This water would be pumped and treated to maintain the water surface elevation below the MM level throughout post-closure.

Main WMP pond volumes are expected to vary based on the amount of water captured at the mine site, which depends on climate variability. Figure K4.18-7 shows the expected range of pond volumes in early closure representing dry to wet conditions. The results depicted on this figure indicate that the main WMP has the capacity to manage surplus water from the mine site during closure phases 1 and 2, when the bulk and pyritic TSF are being reclaimed. The water in the main WMP is estimated to operate at or below the maximum operating pond capacity at all times during closure.



NOTES:

1. NTE LEVEL IS THE NOT TO EXCEED LEVEL.
2. MM LEVEL IS THE MAXIMUM MANAGEMENT LEVEL.

Source: Knight Piesold 2019s

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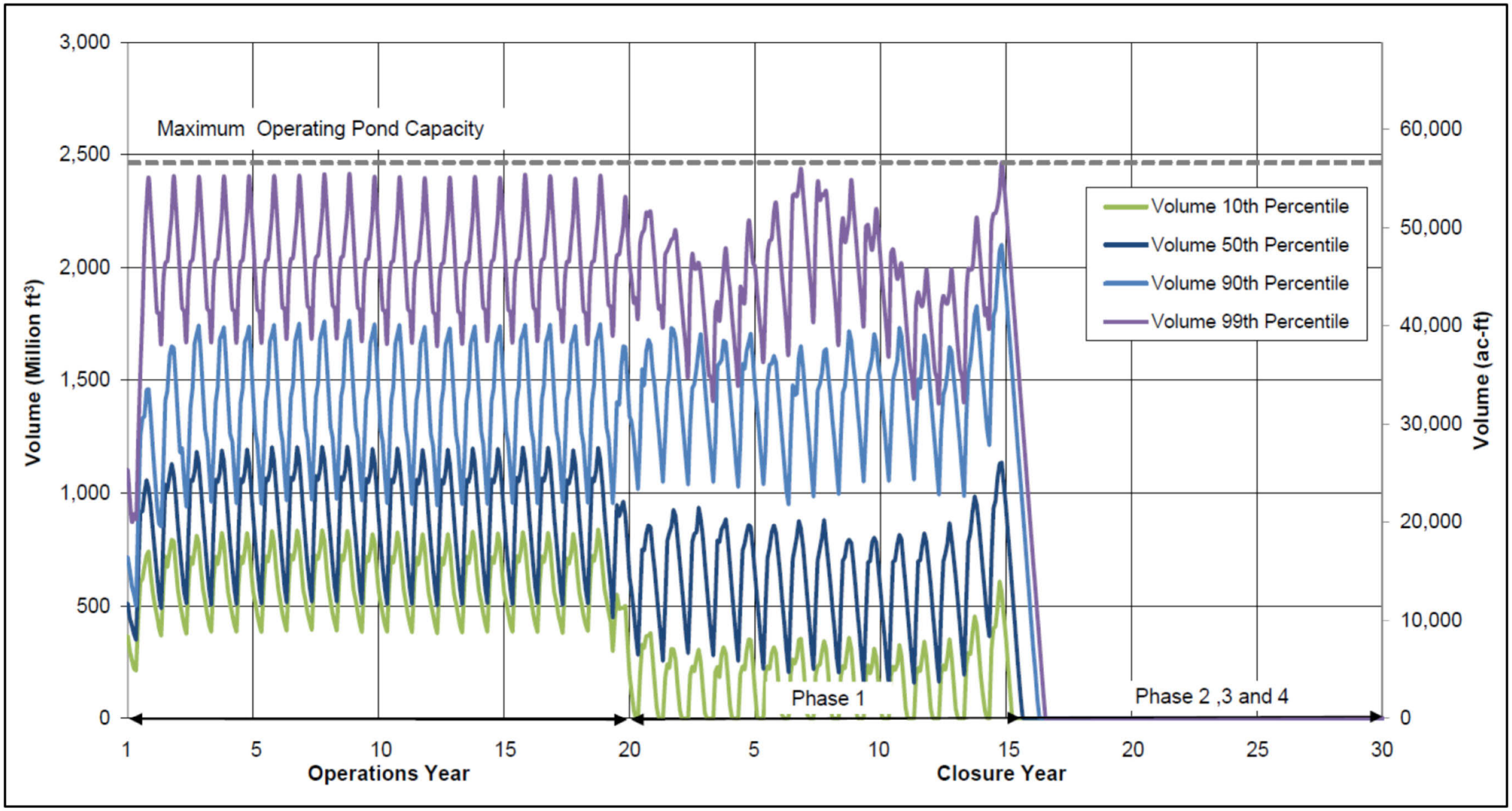
OPEN PIT SURFACE WATER ELEVATIONS



Source: Knight Piesold 2019s

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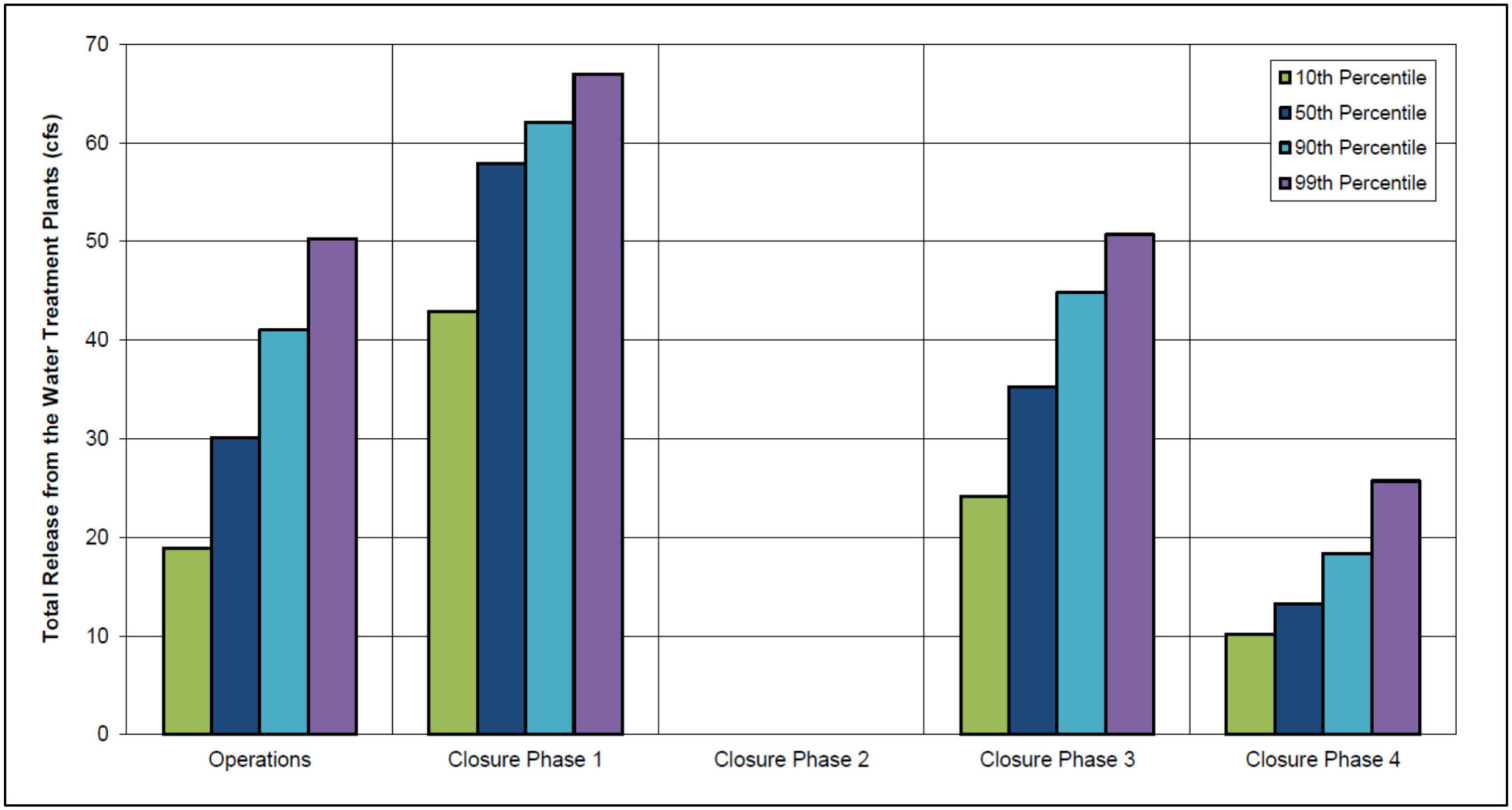
MAIN WMP VOLUMES IN EARLY CLOSURE

PEBBLE PROJECT EIS

FIGURE K4.18-7



NOTE: RELEASES INCLUDE THOSE FROM BOTH WTP#2 AND WTP#3 IN CLOSURE PHASE 3.

Source: Knight Piesold 2019s

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AVERAGE ANNUAL FLOW FROM WTPS IN OPERATIONS AND CLOSURE PHASES

Table K4.18-6 and Figure K4.18-8 show the estimated average annual flows and flow volumes discharged from the WTPs during closure. Data are presented on a monthly basis for various different modeled scenarios ranging from the 1st percentile (near minimum discharge volume anticipated) to the 99th percentile (near maximum discharge volume anticipated). Phase 2 shows no expected water discharge, because water treatment would not be required as the pyritic TSF and main WMP are empty, and the pit lake is filling to its MM level. Closure phase discharge locations for WTP #3 are in the SFK and UTC catchments. Figure K4.18-8 indicates that the total amount of water treatment required is greatest during the early closure phase when the mine site footprint is larger, and lowest during closure phase 4 once all the mine facilities are reclaimed and the only water being treated is surplus pumped from the open pit to maintain water levels. Total flow releases from the WTPs are estimated to vary from a high of 68 cfs during closure phase 1, to a low of 1 cfs during closure phase 4 (post-closure). The total flow released downstream of the mine site is a combination of freshwater from diversion channels, surface runoff from reclaimed facilities, and treated water from WTPs. The WTP flows are estimated to vary with historical climatic patterns.

Water Quality Model

A closure and post-closure water quality model was developed in GoldSim® by Knight Piésold (2018d, 2019s). It was coupled with the closure and post-closure water balance model to calculate constituent loads in the various mine facilities under completely mixed, steady-state conditions. Details regarding the model inputs and assumptions are provided in Knight Piésold (2018d, 2019s).

The maximum monthly predicted constituent concentrations in on-site ponds for the four closure phases are provided in Table K4.18-7 through Table K4.18-10, and Table K4.18-11 displays predicted water quality inflows to WTPs through all phases of closure. Bolded values in these tables indicate where predicted constituent concentrations exceed the discharge water quality criteria and would require treatment at the WTPs. Use of 95th percentile geochemical source terms in the water quality model represents an upper bound condition in which concentrations are greater than 95 percent of all expected inputs. Because of this, water quality predictions in Table K4.18-7 through Table K4.18-11 are considered to represent a reasonable, long-term conservative range of estimates for dry to wet flow conditions (10th to 90th percentile flows).

These water quality model results do not account for the short-term effects of the "first flush" attributable to leaching of oxidation products that accumulate during natural weathering and oxidation of mined rocks. The proposed waste management approach of submerging PAG rock would limit the effects of the first flush of oxidation products, because the mined materials would be exposed for 1.5 years or less, which does not allow sufficient time for significant oxidation products to develop. Although constituent concentrations in the first flush may be higher than those predicted over the long-term, the first flush effect is expected to have a transient, limited effect on long-term water quality at the site. Solubility limits placed on selected constituents further limit the effects of the first flush, as well as long-term constituent releases.

Table K4.18-10, the predicted water quality in the bulk TSF pond in closure phase 4 meets discharge water quality criteria for all parameters modeled. The pond water would continue to be monitored and surplus water from precipitation events would only be discharged from the bulk TSF to the downstream NFK catchment once it meets discharge water quality criteria. Bulk TSF seepage water reporting to the bulk TSF main SCP would continue to exceed water quality criteria in closure phase 4 for a number of constituents, and would continue to be treated in WTP #3 (Table K4.18-11).

Table K4.18-6: Total WTP Discharge Flows in Closure

Closure Phase 1

Month	Total Release from WTPs (cfs)				
	1st Percentile	10th Percentile	50th Percentile	90th Percentile	99th Percentile
January	7	41	50	58	67
February	6	17	50	53	67
March	6	9	50	51	65
April	5	7	49	52	66
May	36	55	62	65	68
June	52	62	66	68	68
July	36	55	66	67	67
August	46	57	66	67	67
September	55	58	66	67	67
October	23	53	64	67	67
November	19	50	55	66	67
December	7	50	51	64	67
Annual Average	25	43	58	62	67

Closure Phase 2

Month	Total Release from WTPs (cfs)				
	1st Percentile	10th Percentile	50th Percentile	90th Percentile	99th Percentile
January	0	0	0	0	0
February	0	0	0	0	0
March	0	0	0	0	0
April	0	0	0	0	0
May	0	0	0	0	0
June	0	0	0	0	0
July	0	0	0	0	0
August	0	0	0	0	0
September	0	0	0	0	0
October	0	0	0	0	0
November	0	0	0	0	0
December	0	0	0	0	0
Annual Average	0	0	0	0	0

Closure Phase 3

Month	Total Release from WTPs (cfs)				
	1st Percentile	10th Percentile	50th Percentile	90th Percentile	99th Percentile
January	4	4	31	44	52
February	3	4	31	35	46
March	4	4	11	31	52
April	2	2	11	34	43
May	14	37	43	44	52
June	35	44	44	45	52
July	12	39	44	50	52
August	24	41	44	52	52
September	35	43	44	52	52
October	6	36	44	52	52
November	4	28	41	51	52
December	4	5	31	46	52
Annual Average	12	24	35	45	51

Closure Phase 4

Month	Total Release from WTPs (cfs)				
	1st Percentile	10th Percentile	50th Percentile	90th Percentile	99th Percentile
January	2	4	5	19	24
February	3	3	5	10	19
March	2	2	5	5	24
April	1	2	5	11	19
May	9	16	18	19	24
June	11	19	18	22	24
July	0	15	18	24	34
August	10	18	18	24	34
September	13	19	18	24	30
October	1	16	19	23	29
November	3	5	18	21	25
December	2	5	7	19	24
Annual Average	5	10	13	18	26

Notes:
Total release from WTPs during closure phases is the sum of the flows available for release from WTP #2 and WTP #3
Percentiles represent predicted variations in closure water balance due to modeled climate variability
cfs = cubic feet per second
WTP = water treatment plant
Source: Knight Piésold 2019s

Table K4.18-7: Predicted Water Quality in Mine Site Ponds—Closure Phase 1

Parameters (mg/L)	Open Pit Water Management Pond			Bulk TSF			Main Embankment Seepage Collection Pond			Pyritic TSF			Main Water Management Pond			Open Pit[d]		
	Maximum Monthly			Maximum Monthly			Maximum Monthly			Maximum Monthly			Maximum Monthly			Maximum Monthly		
	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile
pH	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8
TDS	**1,901**	**2,401**	**2,638**	**1,336**	**1,917**	**2,034**	**4,139**	**4,141**	**4,143**	**3,151**	**3,334**	**3,385**	343	480	**3,445**	**2,907**	**3,003**	**3,116**
Alkalinity	105	131	150	205	285	312	757	757	758	177	189	203	54	80	628	161	173	187
Acidity	420	499	538	2.4	3.1	3.2	7.37	7.38	7.38	645	772	996	18.2	22.3	42.5	591	635	693
Chloride	86	107	129	13.06	18.61	19.41	9.61	9.61	9.62	143	153	160	4.25	5.44	11.83	141	151	158
Fluoride	0.333	0.407	0.437	0.193	0.262	0.287	0.882	0.882	0.882	0.467	0.479	0.489	0.077	0.107	0.734	0.478	0.487	0.500
Sulfate	**1,353**	**1,714**	**1,835**	**704**	**1,020**	**1,074**	**2,317**	**2,318**	**2,319**	**2,231**	**2,350**	**2,350**	200	**270**	**1,921**	**2,038**	**2,072**	**2,130**
Aluminum	0.00477	0.00717	0.01249	0.000600	0.000600	0.000600	0.000600	0.000600	0.000600	0.000600	0.000600	0.000600	0.001	0.001	0.001	0.000600	0.000600	0.000600
Antimony	**0.0101**	**0.0130**	**0.0149**	**0.0224**	**0.0313**	**0.0345**	**0.196**	**0.196**	**0.196**	**0.0174**	**0.0184**	**0.0199**	**0.0095**	**0.0160**	**0.1603**	**0.0162**	**0.0174**	**0.0187**
Arsenic	**0.0432**	**0.0543**	**0.0583**	**0.0349**	**0.0489**	**0.0539**	**0.254**	**0.254**	**0.254**	**0.0699**	**0.0785**	**0.0932**	**0.0148**	**0.0228**	**0.2083**	**0.0640**	**0.0667**	**0.0708**
Barium	0.049	0.061	0.068	0.059	0.083	0.089	0.148	0.148	0.148	0.078	0.082	0.085	0.0122	0.0179	0.1240	0.075	0.079	0.082
Beryllium	**0.0057**	**0.0072**	**0.0078**	**0.010**	**0.014**	**0.015**	**0.00529**	**0.00530**	**0.00531**	**0.0090**	**0.0093**	**0.0097**	0.00100	0.00135	**0.00459**	**0.0084**	**0.0088**	**0.0093**
Bismuth	0.00464	0.00608	0.00699	0.0115	0.0165	0.0178	0.0978	0.0978	0.0978	0.00839	0.00899	0.00980	0.00478	0.00804	0.08023	0.00748	0.00813	0.00892
Boron	0.203	0.259	0.292	0.474	0.686	0.722	0.526	0.527	0.527	0.359	0.380	0.408	0.0558	0.0784	0.4447	0.323	0.344	0.373
Cadmium	**0.0447**	**0.0544**	**0.0587**	**0.0047**	**0.0068**	**0.0072**	**0.0099**	**0.0099**	**0.0099**	**0.0709**	**0.0839**	**0.1075**	**0.00279**	**0.00349**	**0.00824**	**0.0644**	**0.0685**	**0.0738**
Calcium	155	196	224	198	283	301	758	758	758	260	277	290	50.0	76.3	628.3	244	259	275
Chromium	0.0085	0.0105	0.0113	0.00417	0.00595	0.00635	**0.0196**	**0.0196**	**0.0196**	0.0137	0.0156	**0.0193**	0.00161	0.00220	0.01618	0.0121	0.0127	0.0135
Cobalt	**0.151**	**0.174**	**0.189**	0.0171	0.0247	0.0259	0.0494	0.0494	0.0494	**0.218**	**0.256**	**0.317**	0.0098	0.0122	0.0408	**0.209**	**0.231**	**0.256**
Copper	**0.00694**	**0.00844**	**0.00883**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**
Iron	0.0433	0.0678	0.1220	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200
Lead	**0.0053**	**0.0067**	**0.0073**	**0.0101**	**0.0147**	**0.0155**	**0.0491**	**0.0491**	**0.0491**	**0.0082**	**0.0087**	**0.0092**	**0.00285**	**0.00449**	**0.04039**	**0.0077**	**0.0082**	**0.0087**
Magnesium	38.9	49.2	57.2	54	78	83	99	99	99	64	67	69	8.9	12.5	82.4	61.7	65.7	68.6
Manganese	**1.39**	**1.71**	**1.80**	**2.00**	**2.00**	**2.00**	**2.00**	**2.00**	**2.00**	**2.00**	**2.00**	**2.00**	**0.397**	**0.508**	**1.913**	**2.00**	**2.00**	**2.00**
Mercury	**0.000068**	**0.000085**	**0.000096**	**0.000108**	**0.000155**	**0.000164**	**0.000491**	**0.000491**	**0.000491**	**0.000110**	**0.000115**	**0.000120**	**0.0000295**	**0.0000460**	**0.0004040**	**0.000101**	**0.000108**	**0.000113**
Molybdenum	**0.369**	**0.474**	**0.578**	**1.10**	**1.58**	**1.73**	**11.7**	**11.7**	**11.7**	**0.661**	**0.725**	**0.798**	**0.540**	**0.925**	**9.603**	**0.582**	**0.642**	**0.720**
Nickel	**0.76**	**0.95**	**1.04**	**0.038**	**0.055**	**0.058**	**0.0503**	**0.0503**	**0.0504**	**1.26**	**1.49**	**1.94**	**0.0401**	**0.0457**	**0.0821**	**1.12**	**1.18**	**1.28**
Potassium	46.5	58.7	69.2	36.3	51.7	55.2	36.5	36.6	36.6	78.9	84.4	88.4	5.30	7.12	32.31	75.0	80.3	84.6
Selenium	**0.0223**	**0.0277**	**0.0287**	**0.0167**	**0.0241**	**0.0255**	**0.0542**	**0.0542**	**0.0543**	**0.0259**	**0.0267**	**0.0277**	0.00388	**0.00580**	**0.04486**	**0.0297**	**0.0367**	**0.0441**
Silver	0.00075	0.00093	0.00107	0.00097	**0.00139**	**0.00152**	**0.00977**	**0.00977**	**0.00978**	**0.00125**	**0.00134**	**0.00146**	0.000478	0.000800	**0.008007**	**0.00111**	**0.00119**	**0.00126**
Sodium	106	134	160	116	168	177	132	132	132	185	199	209	16.3	22.3	114.2	172	186	198

Table K4.18-7: Predicted Water Quality in Mine Site Ponds—Closure Phase 1

Parameters (mg/L)	Open Pit Water Management Pond			Bulk TSF			Main Embankment Seepage Collection Pond			Pyritic TSF			Main Water Management Pond			Open Pit[d]		
	Maximum Monthly			Maximum Monthly			Maximum Monthly			Maximum Monthly			Maximum Monthly			Maximum Monthly		
	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile
Thallium	0.000548	0.000640	0.000654	0.00039	0.00055	0.00059	0.000503	0.000503	0.000503	0.00069	0.00070	0.00072	0.000062	0.000083	0.000424	0.00074	0.00085	0.00097
Silicon	10.07	11.48	13.27	9.1	12.5	13.1	31.5	31.5	31.5	13.7	14.5	14.9	4.93	6.04	26.97	13.9	14.8	15.2
Tin	0.0126	0.0157	0.0179	0.0186	0.0268	0.0292	0.195	0.195	0.196	0.0207	0.0220	0.0234	0.0094	0.0158	0.1601	0.0186	0.0200	0.0215
Vanadium	0.00382	0.00463	0.00521	0.0065	0.0089	0.0099	0.0294	0.0294	0.0295	0.00586	0.00610	0.00627	0.00190	0.00290	0.02425	0.0054	0.0058	0.0061
Zinc	**6.6**	**8.2**	**8.9**	**0.66**	**0.96**	**1.01**	**1.88**	**1.88**	**1.88**	**10.8**	**12.8**	**16.6**	**0.441**	**0.556**	**1.551**	**9.7**	**10.2**	**11.0**
Nitrate_N	2.62	3.38	3.99	3.07	4.37	4.69	0.130	0.135	0.141	4.51	4.94	5.34	0.261	0.353	0.588	4.27	4.68	5.23
Nitrate (ion)	10.81	14.09	16.70	11.6	16.4	17.7	0.485	0.506	0.530	18.80	20.66	22.37	1.03	1.40	2.29	17.92	19.72	22.03
Nitrite	0.2174	0.2847	0.3360	0.231	0.326	0.352	0.00965	0.01008	0.01056	0.376	0.412	0.445	0.0204	0.0279	0.0456	0.361	0.395	0.440
Ammonia	0.461	0.586	0.703	0.337	0.481	0.514	0.0143	0.0148	0.0154	0.770	0.817	0.858	0.0313	0.0440	0.0716	0.757	0.821	0.866
Hardness as $CaCO_3$	548	691	796	717	1,029	1,092	2,298	2,298	2,299	913	967	1,011	161	242	1,908	864	918	970

Notes:
Tailings pond adjustment values were applied for Al, SO_4, Fe, Cu, and Mn in the TSFs, main SCP, main WMP, and open pit
Model input concentrations provided by SRK (2018a, 2019e)
Model assumes return of sludge and reject flows from WTP #2 and WTP #3 to the open pit. Reject flows and concentrations provided by HDR (2019g).
Percentile results are based on 76 realizations of climate model simulations from the water balance model
TDS values were calculated by summing alkalinity, Cl, F, SO_4, Ca, Mg, K, Na, and Si
Bold values indicate exceedances of the most stringent water quality criteria (Appendix K3.18, Table K3.18-1)
Hardness values were calculated based on the following: hardness ($CaCO_3$) = calcium concentration (mg/L)*2.497 + magnesium concentration (mg/L)*4.118
pH was not modeled
$CaCo_3$ = calcium carbonate
mg/L = milligrams/liter
TSF = tailings storage facility
WMP = water management pond
WTP = water treatment plant
Source: Knight Piésold 2019s

Table K4.18-8: Predicted Water Quality in Mine Site Ponds—Closure Phase 2

Parameters (mg/L)	Bulk TSF			Main Embankment Seepage Collection Pond			Open Pit		
	Maximum Monthly			Maximum Monthly			Maximum Monthly		
	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile
pH	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8
TDS	**903**	**1,551**	**1,808**	**4,139**	**4,141**	**4,143**	229	274	318
Alkalinity	135	224	260	757	757	758	44.0	51.8	59.2
Acidity	3.3	3.4	3.5	7.37	7.38	7.38	16.2	17.2	18.1
Chloride	8.90	15.08	17.47	9.61	9.61	9.62	1.5	1.7	1.8
Fluoride	0.114	0.173	0.197	0.882	0.882	0.882	0.081	0.089	0.098
Sulfate	**478**	**831**	**972**	**2,317**	**2,318**	**2,319**	122	148	173
Aluminum	0.000600	0.000600	0.000600	0.000600	0.000600	0.000600	0.000600	0.000600	0.000600
Antimony	**0.0141**	**0.0245**	**0.0289**	**0.196**	**0.196**	**0.196**	**0.0080**	**0.0098**	**0.0115**
Arsenic	**0.0182**	**0.0314**	**0.0370**	**0.254**	**0.254**	**0.254**	**0.0120**	**0.0144**	**0.0167**
Barium	0.0396	0.0662	0.0768	0.148	0.148	0.148	0.0123	0.0140	0.0156
Beryllium	**0.0067**	**0.0117**	**0.0135**	**0.00529**	**0.00530**	**0.00531**	0.00094	0.00104	0.00115
Bismuth	0.0078	0.0135	0.0159	0.0978	0.0978	0.0978	0.00407	0.00497	0.00582
Boron	0.320	0.560	0.652	0.526	0.527	0.527	0.0431	0.0494	0.0583
Cadmium	**0.0032**	**0.0056**	**0.0065**	**0.0099**	**0.0099**	**0.0099**	**0.00174**	**0.00189**	**0.00205**
Calcium	133	228	267	758	758	758	38	46	53
Chromium	0.00287	0.00482	0.00562	**0.0196**	**0.0196**	**0.0196**	0.00109	0.00129	0.00148
Cobalt	0.0117	0.0202	0.0235	0.0494	0.0494	0.0494	0.0139	0.0149	0.0158
Copper	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**
Iron	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200
Lead	**0.0070**	**0.0121**	**0.0141**	**0.0491**	**0.0491**	**0.0491**	**0.00263**	**0.00313**	**0.00362**
Magnesium	36	63	73	99	99	99	6.0	7.2	8.4
Manganese	**2.00**	**2.00**	**2.00**	**2.00**	**2.00**	**2.00**	**0.86**	**0.95**	**1.00**
Mercury	**0.000072**	**0.000125**	**0.000146**	**0.000491**	**0.000491**	**0.000491**	**0.0000226**	**0.0000276**	**0.0000323**
Molybdenum	**0.75**	**1.30**	**1.54**	**11.7**	**11.7**	**11.7**	**0.471**	**0.577**	**0.681**
Nickel	**0.026**	**0.045**	**0.052**	**0.0503**	**0.0503**	**0.0504**	**0.012**	**0.013**	**0.014**
Potassium	23.5	41.1	47.5	36.5	36.6	36.6	2.7	3.1	3.7
Selenium	**0.0114**	**0.0196**	**0.0229**	**0.0542**	**0.0542**	**0.0543**	**0.0085**	**0.0093**	**0.0100**
Silver	0.00066	**0.00115**	**0.00135**	**0.00977**	**0.00977**	**0.00978**	0.000401	0.000490	0.000576
Sodium	80	138	160	132	132	132	10.1	11.5	13.6
Thallium	0.000256	0.000444	0.000513	0.000503	0.000503	0.000503	0.000133	0.000144	0.000154
Silicon	8.3	11.3	12.5	31.5	31.5	31.5	4.65	4.83	4.99

Table K4.18-8: Predicted Water Quality in Mine Site Ponds—Closure Phase 2

Parameters (mg/L)	Bulk TSF			Main Embankment Seepage Collection Pond			Open Pit		
	Maximum Monthly			Maximum Monthly			Maximum Monthly		
	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile
Tin	0.0128	0.0221	0.0261	0.195	0.195	0.196	0.0079	0.0097	0.0114
Vanadium	0.00400	0.00671	0.00784	0.0294	0.0294	0.0295	0.00155	0.00183	0.00211
Zinc	**0.45**	**0.79**	**0.92**	**1.877**	**1.878**	**1.879**	**0.18**	**0.21**	**0.23**
Nitrate_N	2.07	3.61	4.23	0.129	0.135	0.141	0.144	0.167	0.189
Nitrate (ion)	7.8	13.6	15.9	0.483	0.506	0.530	0.511	0.592	0.665
Nitrite	0.155	0.270	0.317	0.0096	0.0101	0.0106	0.0102	0.0118	0.0133
Ammonia	0.227	0.397	0.464	0.0142	0.0148	0.0154	0.014	0.017	0.019
Hardness as $CaCO_3$	482	829	966	2,298	2,298	2,299	119	144	168

Notes:
Tailings pond adjustment values were applied for Al, SO_4, Fe, Cu, and Mn
Model input concentrations provided by SRK (2018a, 2019e)
Model assumes return of sludge and reject flows from WTP #2 and WTP #3 to the open pit. Reject flows and concentrations provided by HDR (2019g)
Percentile results are based on 76 realizations of climate model simulations
TDS values were calculated by summing alkalinity, Cl, F, SO_4, Ca, Mg, K, Na, and Si
Bold values indicate exceedances of the most stringent water quality criteria (Appendix K3.18, Table K3.18-1)
Hardness values were calculated based on the following: hardness ($CaCO_3$) = calcium concentration (mg/L)*2.497 + magnesium concentration (mg/L)*4.118
pH was not modeled
$CaCo_3$ = calcium carbonate
mg/L = milligrams per liter
TDS = total dissolved solids
TSF = tailings storage facility
WTP = water treatment plant
Source: Knight Piésold 2019s

Table K4.18-9: Predicted Water Quality in Mine Site Ponds—Closure Phase 3

Parameters (mg/L)	Bulk TSF			Main Embankment Seepage Collection Pond			Open Pit		
	Maximum Monthly			Maximum Monthly			Maximum Monthly		
	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile
pH	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8
TDS	89	192	309	**4,162**	**4,162**	**4,164**	230	249	276
Alkalinity	22	37	53	762	762	763	61	66	73
Acidity	2.39	2.46	2.53	7.42	7.42	7.42	14.4	14.9	15.3
Chloride	1.19	2.19	3.36	9.49	9.49	9.49	64.03	70.14	79.66
Fluoride	0.036	0.046	0.057	0.889	0.889	0.889	0.0733	0.0770	0.0810
Sulfate	35	91	154	**2,330**	**2,330**	**2,331**	57	62	67
Aluminum	0.000600	0.000600	0.000600	0.000600	0.000600	0.000600	0.000600	0.000600	0.000600
Antimony	0.00109	0.00277	0.00456	**0.197**	**0.197**	**0.197**	0.00134	0.00146	0.00165
Arsenic	0.00141	0.00357	0.00585	**0.256**	**0.256**	**0.257**	0.00304	0.00318	0.00348
Barium	0.0049	0.0093	0.0141	0.149	0.149	0.149	0.0074	0.0078	0.0082
Beryllium	0.00048	0.00127	0.00216	**0.00518**	**0.00518**	**0.00519**	0.00048	0.00051	0.00054
Bismuth	0.00067	0.00159	0.00258	0.0987	0.0987	0.0987	0.000711	0.000768	0.000868
Boron	0.0241	0.0620	0.1047	0.524	0.524	0.525	0.0165	0.0177	0.0189
Cadmium	**0.00024**	**0.00061**	**0.00104**	**0.0100**	**0.0100**	**0.0100**	**0.00114**	**0.00120**	**0.00124**
Calcium	12.8	28.0	45.2	762	763	763	19.8	21.4	23.3
Chromium	0.000400	0.000715	0.001063	**0.0198**	**0.0198**	**0.0198**	0.000403	0.000417	0.000443
Cobalt	0.00089	0.00226	0.00381	0.0496	0.0496	0.0497	0.0104	0.0108	0.0112
Copper	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**
Iron	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200
Lead	**0.00064**	**0.00145**	**0.00235**	**0.0495**	**0.0495**	**0.0495**	**0.00080**	**0.00084**	**0.00090**
Magnesium	3.2	7.4	12.2	99	99	99	2.41	2.57	2.79
Manganese	**0.28**	**0.74**	**1.27**	**2.00**	**2.00**	**2.00**	**0.616**	**0.652**	**0.675**
Mercury	0.0000060	**0.0000144**	**0.0000238**	**0.000495**	**0.000495**	**0.000495**	0.00000473	0.00000504	0.00000563
Molybdenum	**0.053**	**0.143**	**0.237**	**11.8**	**11.8**	**11.8**	**0.0661**	**0.0727**	**0.0845**
Nickel	0.0020	0.0051	0.0085	**0.0502**	**0.0502**	**0.0502**	0.0086	0.0090	0.0093
Potassium	1.84	4.61	7.76	36.3	36.3	36.4	6.76	7.40	8.35
Selenium	0.00092	0.00224	0.00372	**0.0545**	**0.0545**	**0.0546**	**0.00561**	**0.00587**	**0.00607**
Silver	0.000051	0.000130	0.000213	0.00986	0.00986	0.00986	0.0000626	0.0000682	0.0000782
Sodium	7.4	16.6	27.1	131	131	131	12.7	13.8	15.3
Thallium	0.000023	0.000053	0.000086	0.000502	0.000502	0.000502	0.000103	0.000108	0.000112
Silicon	5.45	5.93	6.41	31.7	31.7	31.7	6.36	6.57	6.88

Table K4.18-9: Predicted Water Quality in Mine Site Ponds—Closure Phase 3

Parameters (mg/L)	Bulk TSF			Main Embankment Seepage Collection Pond			Open Pit		
	Maximum Monthly			Maximum Monthly			Maximum Monthly		
	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile
Tin	0.00095	0.00248	0.00408	0.197	0.197	0.197	0.00115	0.00126	0.00146
Vanadium	0.00058	0.00102	0.00150	0.0297	0.0297	0.0297	0.000542	0.000561	0.000599
Zinc	**0.033**	**0.087**	**0.147**	**1.886**	**1.887**	**1.887**	**0.097**	**0.103**	**0.107**
Nitrate_N	0.222	0.471	0.736	0.0858	0.0861	0.0863	0.111	0.116	0.121
Nitrate (ion)	0.89	1.82	2.81	0.340	0.342	0.343	0.395	0.408	0.427
Nitrite	0.0177	0.0363	0.0560	0.00680	0.00684	0.00686	0.00784	0.00811	0.00848
Ammonia	0.0237	0.0509	0.0802	0.00864	0.00897	0.00933	0.0096	0.0100	0.0106
Hardness as $CaCO_3$	45	100	163	2,310	2,311	2,311	59	64	70

Notes:
Tailings pond adjustment values were applied for Al, SO_4, Fe, Cu, and Mn
Model input concentrations provided by SRK (2018a, 2019e)
Model assumes return of sludge and reject flows from WTP #2 and WTP #3 to the open pit. Reject flows and concentrations provided by HDR (2019g)
Percentile results are based on 76 realizations of climate model simulations
TDS values were calculated by summing alkalinity, Cl, F, SO_4, Ca, Mg, K, Na, and Si
Bold values indicate exceedances of the most stringent water quality criteria (Appendix K3.18, Table K3.18-1)
Hardness values were calculated based on the following: hardness ($CaCO_3$) = calcium concentration (mg/L)*2.497 + magnesium concentration (mg/L)*4.118
pH was not modeled.
$CaCo_3$ = calcium carbonate
mg/L = milligrams per liter
TDS = total dissolved solids
TSF = tailings storage facility
WTP = water treatment plant
Source: Knight Piésold 2019s

Table K4.18-10: Predicted Water Quality in Mine Site Ponds—Closure Phase 4

Parameters (mg/L)	Bulk TSF			Main Embankment Seepage Collection Pond			Open Pit		
	Maximum Monthly			Maximum Monthly			Maximum Monthly		
	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile
pH	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8
TDS	43.8	43.8	43.8	**1,989**	**2,045**	**2,049**	81.2	85.7	91.8
Alkalinity	22.3	22.3	22.3	370	381	381	20.5	21.4	23.0
Acidity	3.77	3.77	3.77	6.05	6.23	6.23	26.9	27.5	28.0
Chloride	0.949	0.949	0.949	5.43	5.45	5.49	10.88	11.91	14.25
Fluoride	0.0488	0.0488	0.0488	0.441	0.454	0.455	0.0679	0.0693	0.0708
Sulfate	1.89	1.89	1.89	**1,100**	**1,132**	**1,134**	32.5	34.2	35.4
Aluminum	0.0554	0.0554	0.0554	0.000600	0.000600	0.000600	0.000600	0.000600	0.000600
Antimony	0.000162	0.000162	0.000162	**0.092**	**0.094**	**0.094**	0.000402	0.000485	0.000577
Arsenic	0.000232	0.000232	0.000232	**0.119**	**0.123**	**0.123**	0.00327	0.00341	0.00351
Barium	0.00380	0.00380	0.00380	0.073	0.075	0.075	0.00773	0.00791	0.00806
Beryllium	0.0000168	0.0000168	0.0000168	0.00298	0.00300	0.00302	0.000719	0.000740	0.000756
Bismuth	0.000199	0.000199	0.000199	0.0459	0.0473	0.0473	0.000206	0.000247	0.000292
Boron	0.00241	0.00241	0.00241	0.264	0.266	0.267	0.0151	0.0156	0.0159
Cadmium	0.0000168	0.0000168	0.0000168	**0.00476**	**0.00490**	**0.00491**	**0.00214**	**0.00220**	**0.00224**
Calcium	5.89	5.89	5.89	363	373	374	7.82	8.25	8.60
Chromium	0.000340	0.000340	0.000340	0.0094	0.0097	0.0097	0.000361	0.000369	0.000375
Cobalt	0.0001163	0.0001163	0.0001163	0.0235	0.0242	0.0242	0.0203	0.0208	0.0212
Copper	0.000568	0.000568	0.000568	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**
Iron	0.229	0.229	0.229	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200
Lead	0.000249	0.000249	0.000249	**0.0232**	**0.0239**	**0.0239**	**0.000846**	**0.000876**	**0.000891**
Magnesium	1.120	1.120	1.120	47.8	49.2	49.3	1.10	1.15	1.17
Manganese	0.01372	0.01372	0.01372	**1.85**	**1.85**	**1.86**	**1.14**	**1.17**	**1.19**
Mercury	0.00000166	0.00000166	0.00000166	**0.000232**	**0.000239**	**0.000239**	0.00000232	0.00000254	0.00000275
Molybdenum	0.000241	0.000241	0.000241	**5.49**	**5.66**	**5.66**	**0.0155**	**0.0204**	**0.0260**
Nickel	0.000336	0.000336	0.000336	**0.0249**	**0.0254**	**0.0255**	**0.0160**	**0.0164**	**0.0167**
Potassium	0.314	0.314	0.314	18.5	18.6	18.7	1.234	1.347	1.573
Selenium	0.000214	0.000214	0.000214	**0.0260**	**0.0268**	**0.0268**	**0.0104**	**0.0107**	**0.0109**
Silver	0.00000702	0.00000702	0.00000702	**0.00458**	**0.00472**	**0.00472**	0.0000230	0.0000272	0.0000317
Sodium	3.10	3.10	3.10	67	67	68	3.28	3.48	3.84
Thallium	0.00000854	0.00000854	0.00000854	0.000250	0.000255	0.000255	0.000179	0.000184	0.000188

Table K4.18-10: Predicted Water Quality in Mine Site Ponds—Closure Phase 4

Parameters (mg/L)	Bulk TSF			Main Embankment Seepage Collection Pond			Open Pit		
	Maximum Monthly			Maximum Monthly			Maximum Monthly		
	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile
Silicon	8.29	8.29	8.29	17.8	18.4	18.4	3.89	3.92	4.02
Tin	0.0000915	0.0000915	0.0000915	0.092	0.094	0.094	0.000302	0.000384	0.000477
Vanadium	0.000510	0.000510	0.000510	0.0141	0.0145	0.0145	0.000421	0.000433	0.000442
Zinc	0.00255	0.00255	0.00255	**0.89**	**0.92**	**0.92**	**0.168**	**0.172**	**0.176**
Nitrate_N	0.1236	0.1236	0.1236	0.312	0.323	0.334	0.085	0.086	0.087
Nitrate (ion)	0.547	0.547	0.547	1.02	1.06	1.11	0.185	0.189	0.192
Nitrite	0.01094	0.01094	0.01094	0.0202	0.0211	0.0221	0.00368	0.00376	0.00384
Ammonia	0.01236	0.01236	0.01236	0.0293	0.0304	0.0316	0.00432	0.00443	0.00453
Hardness as $CaCO_3$	19.3	19.3	19.3	1,102	1,135	1,136	24.0	25.3	26.3

Notes:
Tailings pond adjustment values were applied for Al, SO_4, Fe, Cu, and Mn
Model input concentrations provided by SRK (2018a, 2019e)
Model assumes return of sludge and reject flows from WTP #2 and WTP #3 to the open pit. Reject flows and concentrations provided by HDR (2019g)
Percentile results are based on 76 realizations of climate model simulations
TDS values were calculated by summing alkalinity, Cl, F, SO_4, Ca, Mg, K, Na, and Si
Bold values indicate exceedances of the most stringent water quality criteria (Appendix K3.18, Table K3.18-1)
Hardness values were calculated based on the following: hardness ($CaCO_3$) = calcium concentration (mg/L)*2.497 + magnesium concentration (mg/L)*4.118
pH was not modeled
$CaCo_3$ = calcium carbonate
mg/L = milligrams/liter
TDS = total dissolved solids
TSF = tailings storage facility
WTP = water treatment plant
Source: Knight Piésold 2019s

Table K4.18-11: Predicted Water Quality of WTP Inflows in Closure Phases

Parameters (mg/L)	Closure Phase 1						Closure Phase 3						Closure Phase 4					
	WTP #3 Open Pit Inflows			WTP #2 Inflows			WTP #3 Open Pit Inflows			WTP #3 SCP Inflows			WTP #3 Open Pit Inflows			WTP #3 SCP Inflows		
	Maximum Monthly			Maximum Monthly			Maximum Monthly			Maximum Monthly			Maximum Monthly			Maximum Monthly		
	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile
pH	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8	7 to 8
TDS	**1,901**	**2,401**	**2,638**	343	480	**3,445**	230	249	276	**4,162**	**4,162**	**4,164**	81.2	85.7	91.8	**1,989**	**2,045**	**2,049**
Alkalinity	105	131	150	54	80	628	61	66	73	762	762	763	20.5	21.4	23.0	370	381	381
Acidity	420	499	538	18.2	22.3	42.5	14.4	14.9	15.3	7.42	7.42	7.42	26.9	27.5	28.0	6.05	6.23	6.23
Chloride	86	107	129	4.25	5.44	11.83	64.03	70.14	79.66	9.49	9.49	9.49	10.88	11.91	14.25	5.43	5.45	5.49
Fluoride	0.333	0.407	0.437	0.077	0.107	0.734	0.0733	0.0770	0.0810	0.889	0.889	0.889	0.0679	0.0693	0.0708	0.441	0.454	0.455
Sulfate	**1,353**	**1,714**	**1,835**	200	**270**	**1,921**	57	62	67	**2,330**	**2,330**	**2,331**	32.5	34.2	35.4	**1,100**	**1,132**	**1,134**
Aluminum	0.00477	0.00717	0.01249	0.000600	0.000600	0.000600	0.000600	0.000600	0.000600	0.000600	0.000600	0.000600	0.000600	0.000600	0.000600	0.000600	0.000600	0.000600
Antimony	**0.0101**	**0.0130**	**0.0149**	**0.0095**	**0.0160**	**0.1603**	0.00134	0.00146	0.00165	**0.197**	**0.197**	**0.197**	0.000402	0.000485	0.000577	**0.092**	**0.094**	**0.094**
Arsenic	**0.0432**	**0.0543**	**0.0583**	**0.0148**	**0.0228**	**0.2083**	0.00304	0.00318	0.00348	**0.256**	**0.256**	**0.257**	0.00327	0.00341	0.00351	**0.119**	**0.123**	**0.123**
Barium	0.049	0.061	0.068	0.0122	0.0179	0.1240	0.0074	0.0078	0.0082	0.149	0.149	0.149	0.00773	0.00791	0.00806	0.073	0.075	0.075
Beryllium	**0.0057**	**0.0072**	**0.0078**	0.00100	0.00135	**0.00459**	0.00048	0.00051	0.00054	**0.00518**	**0.00518**	**0.00519**	0.000719	0.000740	0.000756	0.00298	0.00300	0.00302
Bismuth	0.00464	0.00608	0.00699	0.00478	0.00804	0.08023	0.000711	0.000768	0.000868	0.0987	0.0987	0.0987	0.000206	0.000247	0.000292	0.0459	0.0473	0.0473
Boron	0.203	0.259	0.292	0.0558	0.0784	0.4447	0.0165	0.0177	0.0189	0.524	0.524	0.525	0.0151	0.0156	0.0159	0.264	0.266	0.267
Cadmium	**0.0447**	**0.0544**	**0.0587**	**0.00279**	**0.00349**	**0.00824**	**0.00114**	**0.00120**	**0.00124**	**0.0100**	**0.0100**	**0.0100**	**0.00214**	**0.00220**	**0.00224**	**0.00476**	**0.00490**	**0.00491**
Calcium	155	196	224	50.0	76.3	628.3	19.8	21.4	23.3	762	763	763	7.82	8.25	8.60	363	373	374
Chromium	0.0085	0.0105	0.0113	0.00161	0.00220	0.01618	0.000403	0.000417	0.000443	**0.0198**	**0.0198**	**0.0198**	0.000361	0.000369	0.000375	0.0094	0.0097	0.0097
Cobalt	**0.151**	**0.174**	**0.189**	0.0098	0.0122	0.0408	0.0104	0.0108	0.0112	0.0496	0.0496	0.0497	0.0203	0.0208	0.0212	0.0235	0.0242	0.0242
Copper	**0.00694**	**0.00844**	**0.00883**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**	**0.0100**
Iron	0.0433	0.0678	0.1220	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200	0.00200
Lead	**0.0053**	**0.0067**	**0.0073**	**0.00285**	**0.00449**	**0.04039**	**0.00080**	**0.00084**	**0.00090**	**0.0495**	**0.0495**	**0.0495**	**0.000846**	**0.000876**	**0.000891**	**0.0232**	**0.0239**	**0.0239**
Magnesium	38.9	49.2	57.2	8.9	12.5	82.4	2.41	2.57	2.79	99	99	99	1.10	1.15	1.17	47.8	49.2	49.3
Manganese	**1.39**	**1.71**	**1.80**	**0.397**	**0.508**	**1.913**	**0.616**	**0.652**	**0.675**	**2.00**	**2.00**	**2.00**	**1.14**	**1.17**	**1.19**	**1.85**	**1.85**	**1.86**
Mercury	**0.000068**	**0.000085**	**0.000096**	**0.0000295**	**0.0000460**	**0.0004040**	0.00000473	0.00000504	0.00000563	**0.000495**	**0.000495**	**0.000495**	0.00000232	0.00000254	0.00000275	**0.000232**	**0.000239**	**0.000239**
Molybdenum	**0.369**	**0.474**	**0.578**	**0.540**	**0.925**	**9.603**	**0.0661**	**0.0727**	**0.0845**	**11.8**	**11.8**	**11.8**	**0.0155**	**0.0204**	**0.0260**	**5.49**	**5.66**	**5.66**
Nickel	**0.76**	**0.95**	**1.04**	**0.040**	**0.046**	**0.082**	0.0086	0.0090	0.0093	**0.0502**	**0.0502**	**0.0502**	**0.0160**	**0.0164**	**0.0167**	**0.0249**	**0.0254**	**0.0255**
Potassium	46.5	58.7	69.2	5.30	7.12	32.31	6.76	7.40	8.35	36.3	36.3	36.4	1.234	1.347	1.573	18.5	18.6	18.7
Selenium	**0.0223**	**0.0277**	**0.0287**	0.00388	**0.00580**	**0.04486**	**0.00561**	**0.00587**	**0.00607**	**0.0545**	**0.0545**	**0.0546**	**0.0104**	**0.0107**	**0.0109**	**0.0260**	**0.0268**	**0.0268**
Silver	0.00075	0.00093	0.00107	0.000478	0.000800	**0.008007**	0.0000626	0.0000682	0.0000782	**0.00986**	**0.00986**	**0.00986**	0.0000230	0.0000272	0.0000317	**0.00458**	**0.00472**	**0.00472**
Sodium	106	134	160	16.3	22.3	114.2	12.7	13.8	15.3	131	131	131	3.28	3.48	3.84	67	67	68
Thallium	0.000548	0.000640	0.000654	0.000062	0.000083	0.000424	0.000103	0.000108	0.000112	0.000502	0.000502	0.000502	0.000179	0.000184	0.000188	0.000250	0.000255	0.000255

Table K4.18-11: Predicted Water Quality of WTP Inflows in Closure Phases

Parameters (mg/L)	Closure Phase 1						Closure Phase 3						Closure Phase 4					
	WTP #3 Open Pit Inflows			WTP #2 Inflows			WTP #3 Open Pit Inflows			WTP #3 SCP Inflows			WTP #3 Open Pit Inflows			WTP #3 SCP Inflows		
	Maximum Monthly			Maximum Monthly			Maximum Monthly			Maximum Monthly			Maximum Monthly			Maximum Monthly		
	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile
Silicon	10.07	11.48	13.27	4.93	6.04	26.97	6.36	6.57	6.88	31.7	31.7	31.7	3.89	3.92	4.02	17.8	18.4	18.4
Tin	0.0126	0.0157	0.0179	0.0094	0.0158	0.1601	0.00115	0.00126	0.00146	0.197	0.197	0.197	0.000302	0.000384	0.000477	0.092	0.094	0.094
Vanadium	0.00382	0.00463	0.00521	0.00190	0.00290	0.02425	0.000542	0.000561	0.000599	0.0297	0.0297	0.0297	0.000421	0.000433	0.000442	0.0141	0.0145	0.0145
Zinc	**6.6**	**8.2**	**8.9**	**0.441**	**0.556**	**1.551**	**0.097**	**0.103**	**0.107**	**1.89**	**1.89**	**1.89**	**0.168**	**0.172**	**0.176**	**0.89**	**0.92**	**0.92**
Nitrate_N	2.62	3.38	3.99	0.261	0.353	0.588	0.111	0.116	0.121	0.0858	0.0861	0.0863	0.0846	0.0857	0.0874	0.312	0.323	0.334
Nitrate (ion)	10.81	14.09	16.70	1.03	1.40	2.29	0.395	0.408	0.427	0.340	0.342	0.343	0.185	0.189	0.192	1.02	1.06	1.11
Nitrite	0.2174	0.2847	0.3360	0.0204	0.0279	0.0456	0.0078	0.0081	0.0085	0.00680	0.00684	0.00686	0.00368	0.00376	0.00384	0.0202	0.0211	0.0221
Ammonia	0.461	0.586	0.703	0.0313	0.0440	0.0716	0.0096	0.0100	0.0106	0.00864	0.00897	0.00933	0.00432	0.00443	0.00453	0.0293	0.0304	0.0316
Hardness as $CaCO_3$	548	691	796	161	242	1,908	59	64	70	2,310	2,311	2,311	24.0	25.3	26.3	1,102	1,135	1,136

Notes:
There is no water reporting to the WTP during phase 2, which is after the PAG waste rock/pyritic tailings transfer to the open pit is complete, but before pit lake is full
Background water quality was assumed during reclamation phase in the bulk TSF
Tailings pond adjustment values were applied for Al, SO_4, Fe, Cu, and Mn in the bulk TSF
Model assumes return of sludge and reject flows from WTP #2 and WTP #3 to the to the open pit
Percentile results are based on 76 Realizations of model simulations
pH was not modeled and pH values are based on the range of pH source terms provided by SRK 2018a
TDS values were calculated by summing alkalinity, Cl, F, SO_4, Ca, Mg, K, Na, and Si
Hardness Values were calculated based on the following: hardness ($CaCO_3$) = calcium Concentration (mg/L)*2.497 + magnesium concentration (mg/L)*4.118
Bold values indicate exceedances of the most stringent water quality criteria (Appendix K3.18, Table K3.18-1)
$CaCo_3$ = calcium carbonate
mg/L = milligrams/liter
SCP = seepage collection pond
TDS = total dissolved solids
TSF = tailings storage facility
WTP = water treatment plant
Source: Knight Piésold 2019s

Pit Lake Model

Once mining ceases, partial dewatering of the open pit would be continued to maintain pit wall stability to allow some PAG waste rock to be moved from the pyritic TSF to the open pit until the waste rock buttresses the lower walls of the pit. Transportation of PAG waste rock would be done via mine fleet haul trucks and spread using dozers to build a base for subsequent PAG waste rock and pyritic tailings deposition. An initial layer of PAG waste rock would be placed 1 year prior to deposition of pyritic tailings (Knight Piésold 2018d). The remaining PAG waste rock would be deposited in the open pit concurrently with the pyritic tailings as it is exposed during reclamation of the pyritic TSF (Knight Piésold 2018b, 2018d). The pyritic tailings would be re-slurried and pumped to the open pit for sub-aqueous disposal via floating dredge pumps. The water level in the open pit would be maintained to allow controlled placement and management of the PAG waste rock while keeping a water cover over the pyritic tailings. Backhauling of the pyritic tailings would end approximately 14 years into closure, and the PAG waste rock transfer would end about 15 years into closure. Dewatering of the open pit would cease at the end of closure phase 1 once the transfer of these materials is complete. Once dewatering ceases, groundwater in the surrounding bedrock, along with direct precipitation and surface water run-on, would flow into the pit, creating a pit lake. The open pit would be allowed to fill to the designated MM level of 890 feet above mean sea level so that the pit remains as a hydraulic sink and continues to capture nearby groundwater inflow and mitigates the potential for contaminant release along subsurface pathways. The MM level was also designed to allow sufficient storage for the probable maximum flood. General features of the backfilled pit lake are highlighted in Table K4.18-12.

Table K4.18-12: Backfilled Pit Lake General Features

Parameter	Value
Length	6,640 feet
Maximum width	5,550 feet
Lake depth to top of backfilled tailings	420 to 530 feet
Pit lake volume	188,000 acre-feet
Pit lake surface area	490 acres)
Time to fill	21 to 23 years

Source: Lorax Environmental 2018; Knight Piésold 2019s

Prior to closure year 15, the pit lake water quality is largely influenced by the pyritic tailings slurry water and PAG waste rock placed in the open pit (Knight Piésold 2018d, 2019s). After closure year 15, pit water quality is influenced by other water sources, including surplus water from the bulk TSF supernatant pond and main SCP, which would be pumped to the open pit through closure year 50 (Knight Piésold 2018d), as well as direct precipitation, surface water run-on, and groundwater inflow to the pit, which could leach metals from oxidized sulfide minerals exposed in the pit walls and metals in unmined mineralized rock adjacent to the pit. As a result, water quality in the pit lake would be expected to be initially acidic but become more alkaline with time, and have elevated concentrations of TDS, sulfate, and some metals (antimony, arsenic, cadmium, copper, lead, manganese, mercury, molybdenum, nickel, selenium, and zinc) that exceed water quality standards. The predicted water quality in a fully mixed pit lake is provided in Table K4.18-7 through Table K4.18-11 during the period of partial dewatering while backfilling, lake development and water level rise during closure phases 1 and 2, and pumping to WTP #3 in closure phases 3 and 4. These water quality predictions do not account for thermal and chemical stratification that may develop in the pit lake over time.

The final pit lake would be deep, having a water depth of at least 420 feet. As a consequence, the pit lake would likely develop thermal and chemical stratification over time. The salinity stratification may be sufficiently strong to inhibit mixing between the surface and deep waters, resulting in a meromictic lake. Pit lake stratification can be disturbed by factors such as groundwater inflow, sludge deposition, pit wall failure, and water transfers as a result of mine site management that may result in the mixing of the stratified waters, and potentially result in degraded near-surface water quality. Other factors can potentially increase or enhance meromixis, including salinity, salt exclusion from ice, and runoff.

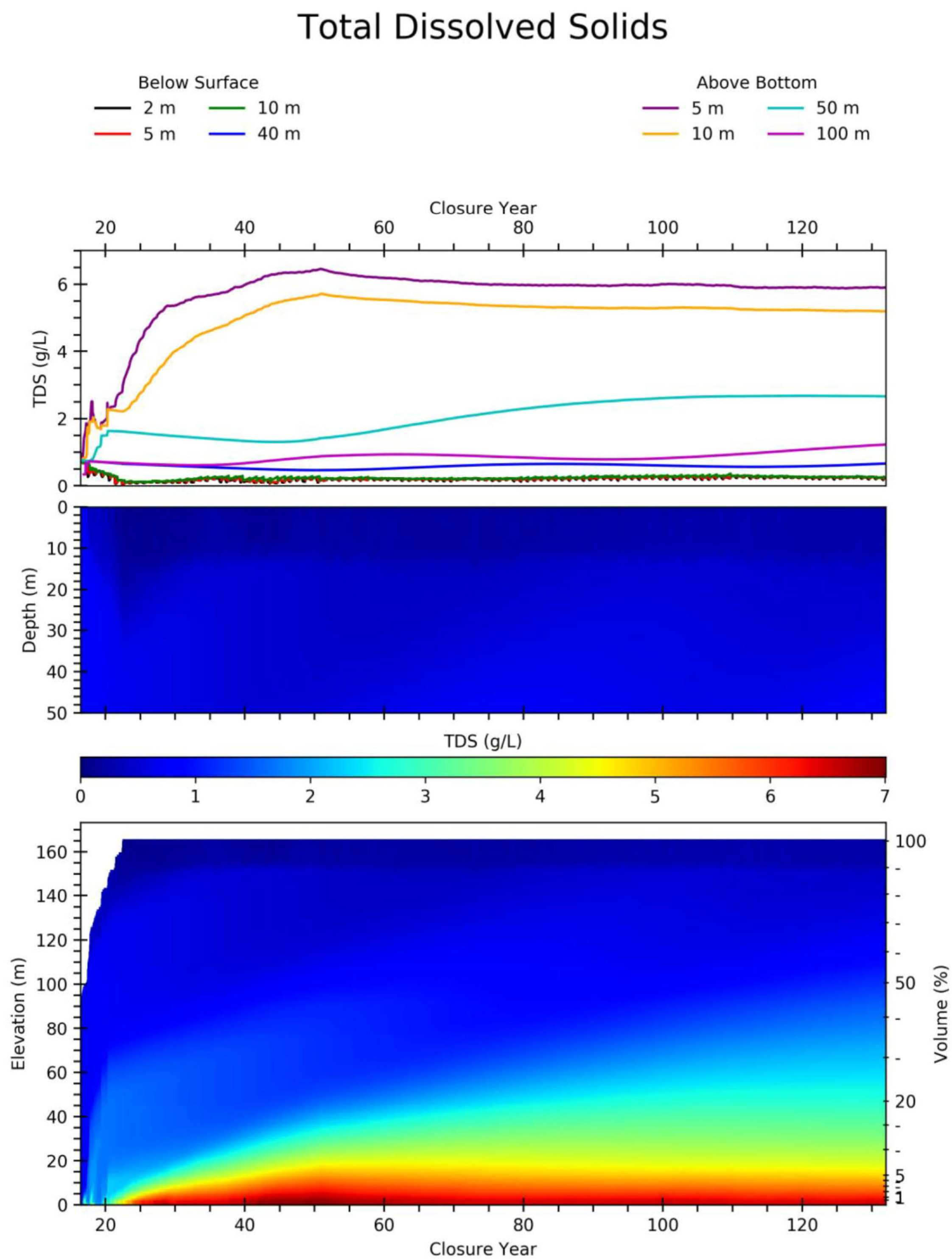
Given the potential for lake stratification, the evolution of pit lake water quality during closure was further evaluated by Lorax Environmental (2018) using a numerical one-dimensional hydrodynamic pit lake model called PitMod, developed by Dunbar (2013) and Martin et al. (2017). PitMod is capable of predicting the spatial and temporal distribution of temperature, density, dissolved oxygen, and water quality in pit lakes that may lead to thermal and chemical stratification. Lake processes simulated by PitMod include 1) heating and cooling of the lake surface; 2) wind-driven lake circulation; 3) convectional mixing in the lake; 4) ice formation and melting; 5) introduction and mixing of external water sources (e.g., direction precipitation to lake surface, pit wall runoff, mine site drainages, groundwater inflow, and surface water run-on); and 6) oxygen consumption. PHREEQC, an industry-standard equilibrium geochemical model developed by the US Geological Survey, was used to predict pH in the mixed surface layer of the pit lake.

PitMod was used to model pit lake water quality after the open pit is backfilled with PAG waste rock and pyritic tailings, and waters other than tailings slurry water influence pit lake development and quality. Pit lake waters are assumed to be fully mixed (i.e., not stratified) during the backfilling period through closure year 15. PitMod was used to predict pit lake water quality from closure years 16 to 131 (phases 2 to 4), a 115-year model period. With the exception of dissolved oxygen, water quality constituents are assumed to behave conservatively (i.e., are non-reactive). Biogeochemical processes (e.g., algal assimilation, mineral precipitation, adsorption, and surface complexation) that might lower metal concentrations in the pit lake water column were not simulated. Details regarding PitMod data sources, inputs, and assumptions are provided in Lorax Environmental (2018).

PitMod predicts that the pit lake would become thermally and chemically stratified after about closure years 25 to 30 (Lorax Environmental 2018). The input of higher-density WTP sludge and brine to the pit bottom promotes development of chemical stratification in the lower water column, as shown by TDS and sulfate concentrations in Figure K4.18-9 and Figure K4.18-10. By closure year 25, TDS and sulfate are expected to be below their respective water quality criteria of 500 mg/L and 250 mg/L in lake water above 30 feet. The salinity gradient (pycnocline) migrates upwards over time as the dense sludge and brine inflows progressively fill the pit from the bottom up. Salinity stratification is largely controlled by the concentrations of sulfate, calcium, magnesium, and chloride (Lorax Environmental 2018).

PitMod also predicts that the pit lake would become thermally stratified as shown in Figure K4.18-11. Pit lake surface water temperatures show strong seasonal variability ranging from 2 degrees Celsius (˚C) to 15˚C, resulting in a surface layer with seasonal mixing to depths of about 30 to 50 feet. At deeper depths, the pit lake water temperature remains near 4˚C, where water is at its maximum density, except at the pit bottom, where the input of WTP sludge and brine sustains temperatures of approximately 8˚C.

Dissolved oxygen also becomes stratified in the pit lake, with well-oxygenated, near-surface waters seasonally extending to depths of approximately 50 feet, and progressively decreasing dissolved oxygen concentrations below 50 feet as the initially oxygenated waters are isolated from atmospheric influences over time (Figure K4.18-12). However, the fully oxygenated bottom water inputs (e.g., WTP sludge and brine) sustain oxic conditions in the lowermost 130 feet of pit lake water column throughout the simulation period.



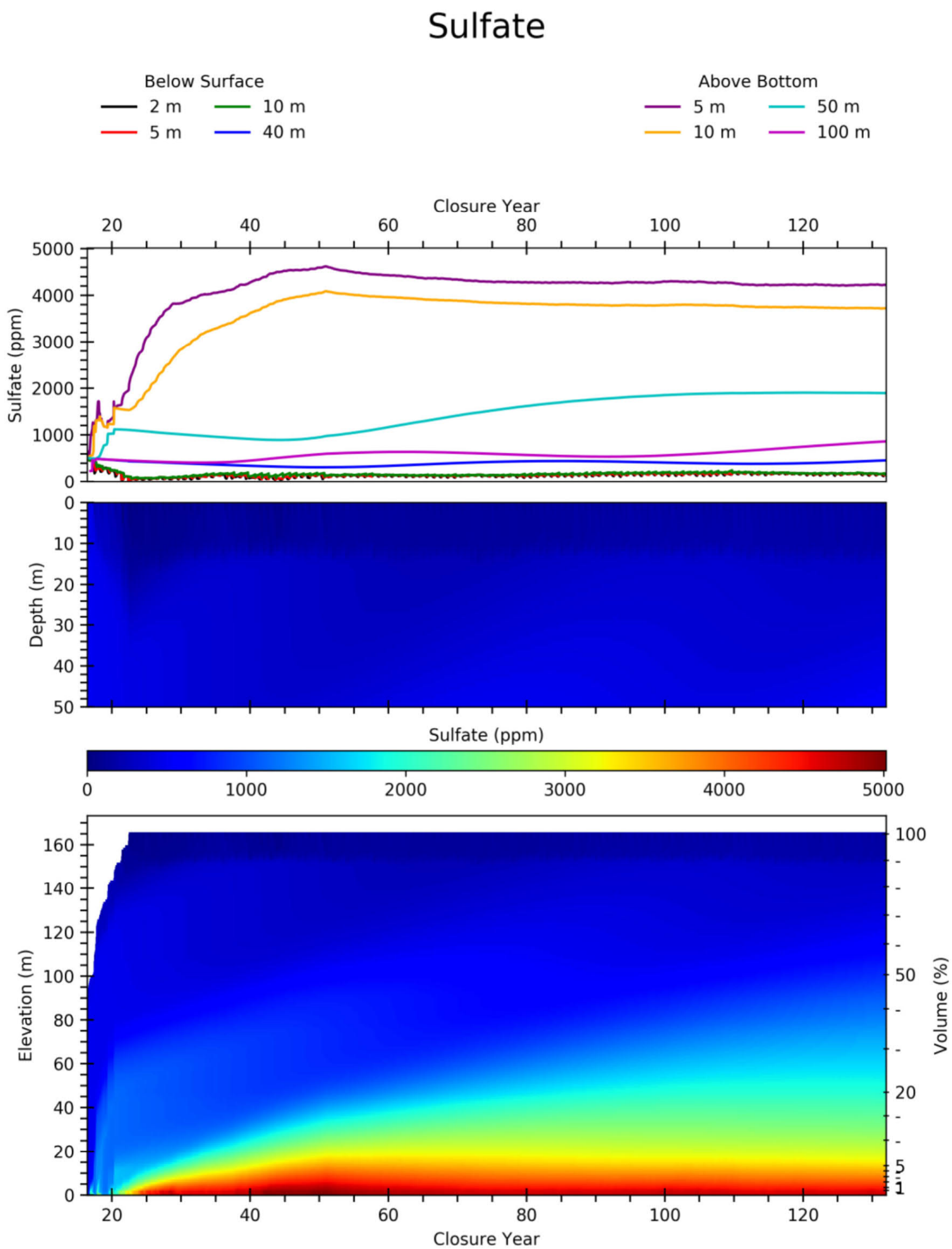
Sources: Lorax Environmental 2018

US Army Corps of Engineers®

MODELED TDS IN PIT LAKE

PEBBLE PROJECT EIS

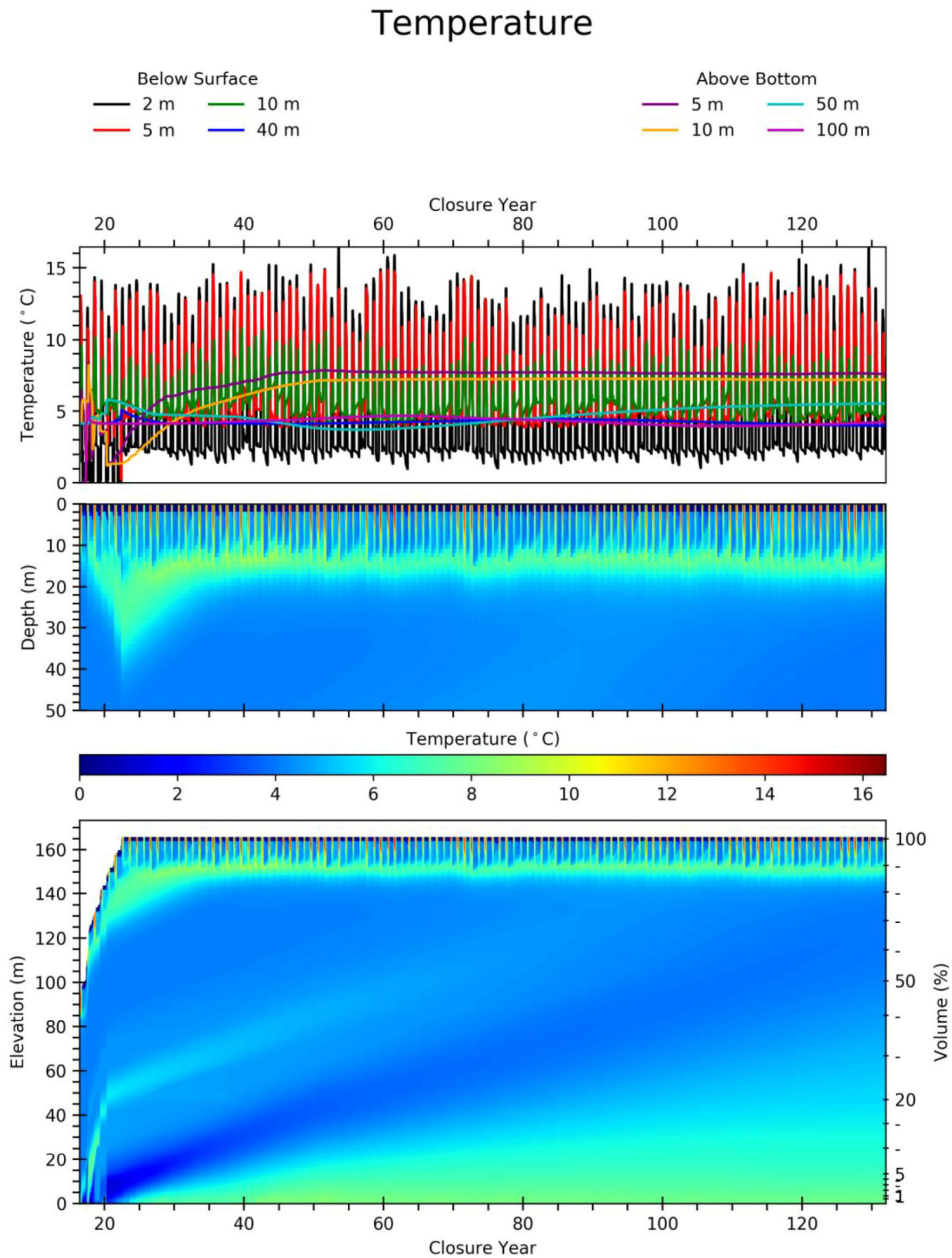
FIGURE K4.18-9



Sources: Lorax Environmental 2018

US Army Corps of Engineers

MODELED SULFATE CONCENTRATION IN PIT LAKE



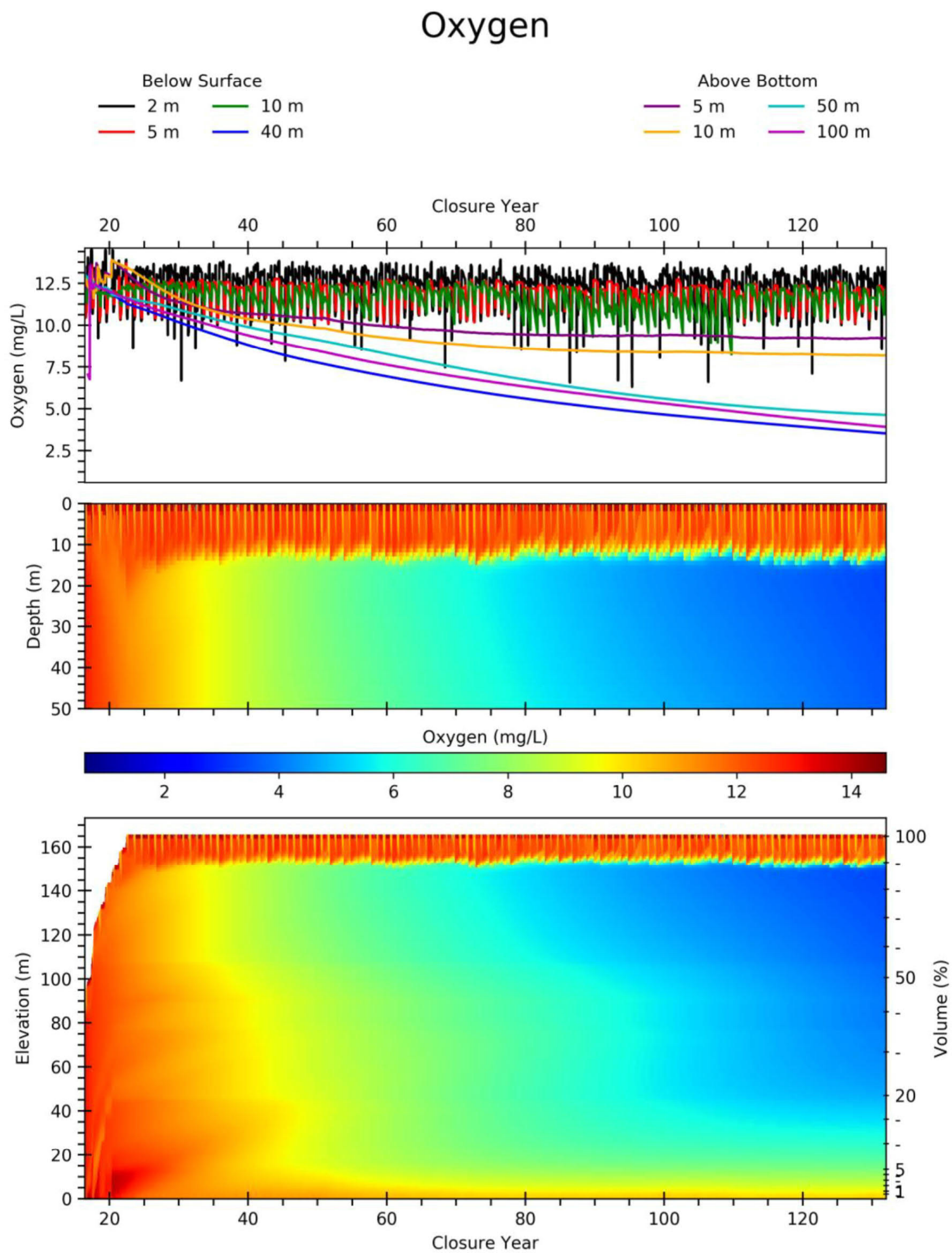
Sources: Lorax Environmental 2018

US Army Corps of Engineers

MODELED TEMPERATURE GRADIENT IN PIT LAKE

PEBBLE PROJECT EIS

FIGURE K4.18-11



Sources: Lorax Environmental 2018

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MODELED DISSOLVED OXYGEN CONCENTRATION IN PIT LAKE

Pit lake water quality predictions for metals are summarized in Table K4.18-7 through Table K4.18-11 for all closure phases without regard to stratification. PitMod predicts that hardness and trace metals (Al, As, Cd, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Sb, Se, and Zn) in the near-surface (upper 30 feet) pit lake water would exceed discharge limits in a stratified pit lake. Predictions for copper and zinc specifically are shown on Figure K4.18-13 and Figure K4.18-14 for closure phases beyond year 15 (phase 2 and beyond) based on a stratified pit lake. For copper (Cu), the highest concentrations are predicted in the pit lake surface layer (Figure K4.18-13), owing to the large influence of runoff from the oxidized pit walls. Copper concentrations predicted by PitMod in near-surface waters are in the range of 0.2 to 0.3 mg/L in closure phase 4, as compared to the lower mixed lake prediction of 0.01 mg/L in Table K4.18-10 and Table K4.18-11. In contrast to copper, initially higher concentrations of zinc are predicted in the deep pit water during the first few years (Figure K4.18-14) from short-term inputs of the bulk TSF supernatant and SCP waters, which are progressively diluted over time once these inputs cease. These examples highlight the importance of monitoring differences in pit lake water quality with depth as it stratifies, and taking an adaptive management approach to adjusting pit lake pumping depth to optimize WTP performance.

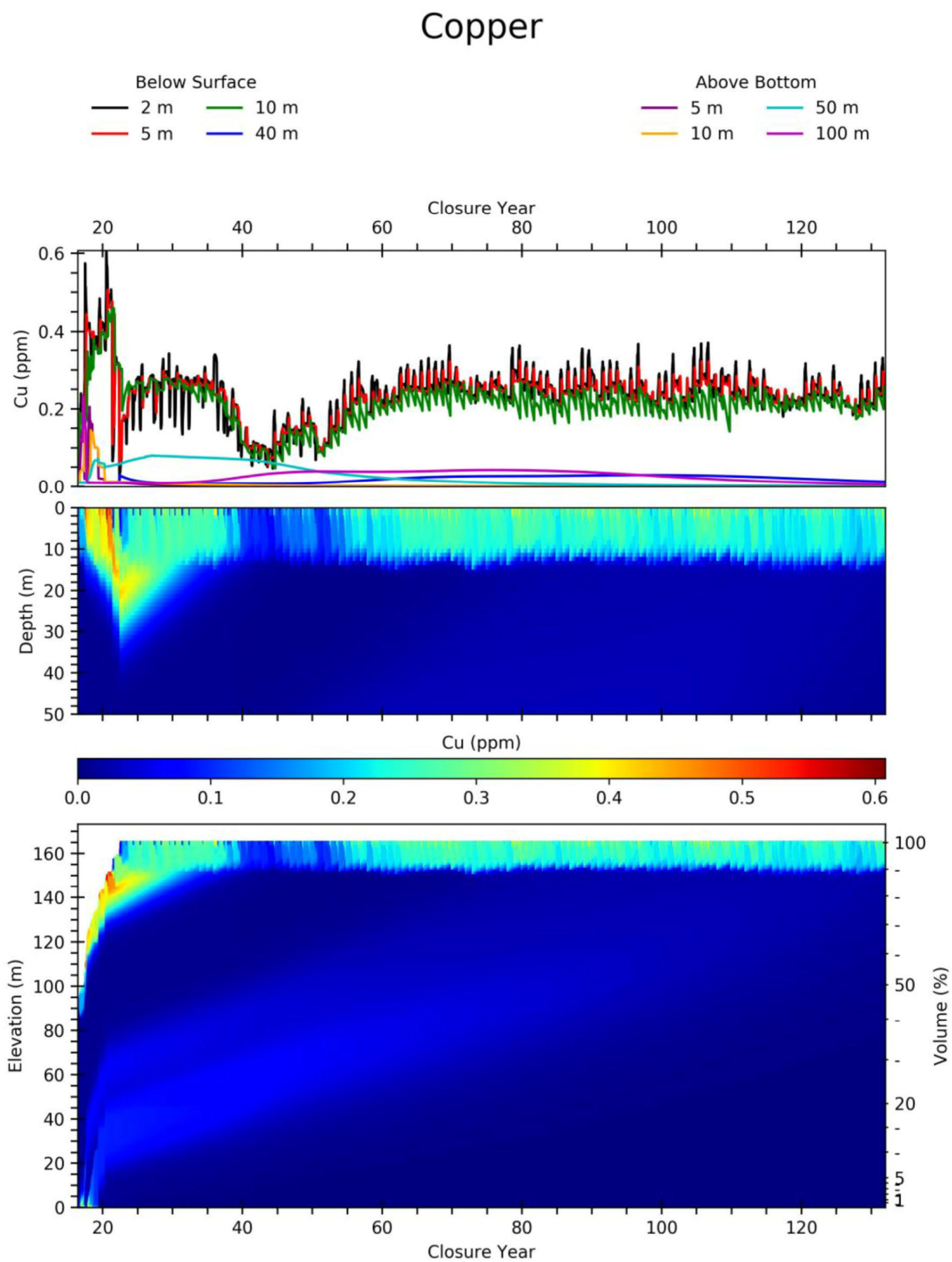
Although the mass balance model cannot predict pH (under "Predicted Water Quality," above), pH was modeled using PHREEQC in the pit lake model, which predicted that the pit lake surface water would have slightly basic pH (7.6 to 8.2), all within discharge limits. Values of pH are predicted to decline slightly from 8.2 at closure year 20 to 7.6 at closure year 45 (during closure phase 3 after the lake level reaches its final level), then rise again slightly to 8.0 at closure year 65 (closure phase 4) and 8.1 at closure year 105 (Lorax Environmental 2018). At these pH values, concentrations of some of the metals (Al, Cd, Cu, Fe, Hg, Mn, Ni, Pb, and Zn) may be reduced via precipitation and adsorption (which is not accounted for in PitMod); however, several metals form oxyanions (As, Mo, Sb, and Se) and are likely mobile at these pH values. Therefore, it would be important to continue maintaining the pit lake as a hydraulic sink long-term to control metal releases to the environment. Although the pit lake model was not updated using the revised source terms from SRK (2019e), water management plans and models would be updated during closure and post-closure until pit lake conditions reach steady state (see Chapter 5, Mitigation).

K4.18.2 Water Treatment

This section contains technical information on water treatment methodologies for WTPs that would treat contact water at the mine site during operations and closure, along with predictions of WTP effluent concentrations following treatment. The WTPs planned for operations and closure at the mine site include the following:

Operations—Two WTPs are planned during operations:

- **WTP #1** would treat water from the open pit WMP and discharge treated water to the environment.
- **WTP #2** would treat water from the main WMP and discharge most of it to the environment, with a limited amount reused as process water for the mill site and power plant. The main WMP would store surplus water from the bulk TSF, main SCP, and pyritic TSF (Knight Piésold 2018a, 2019s).



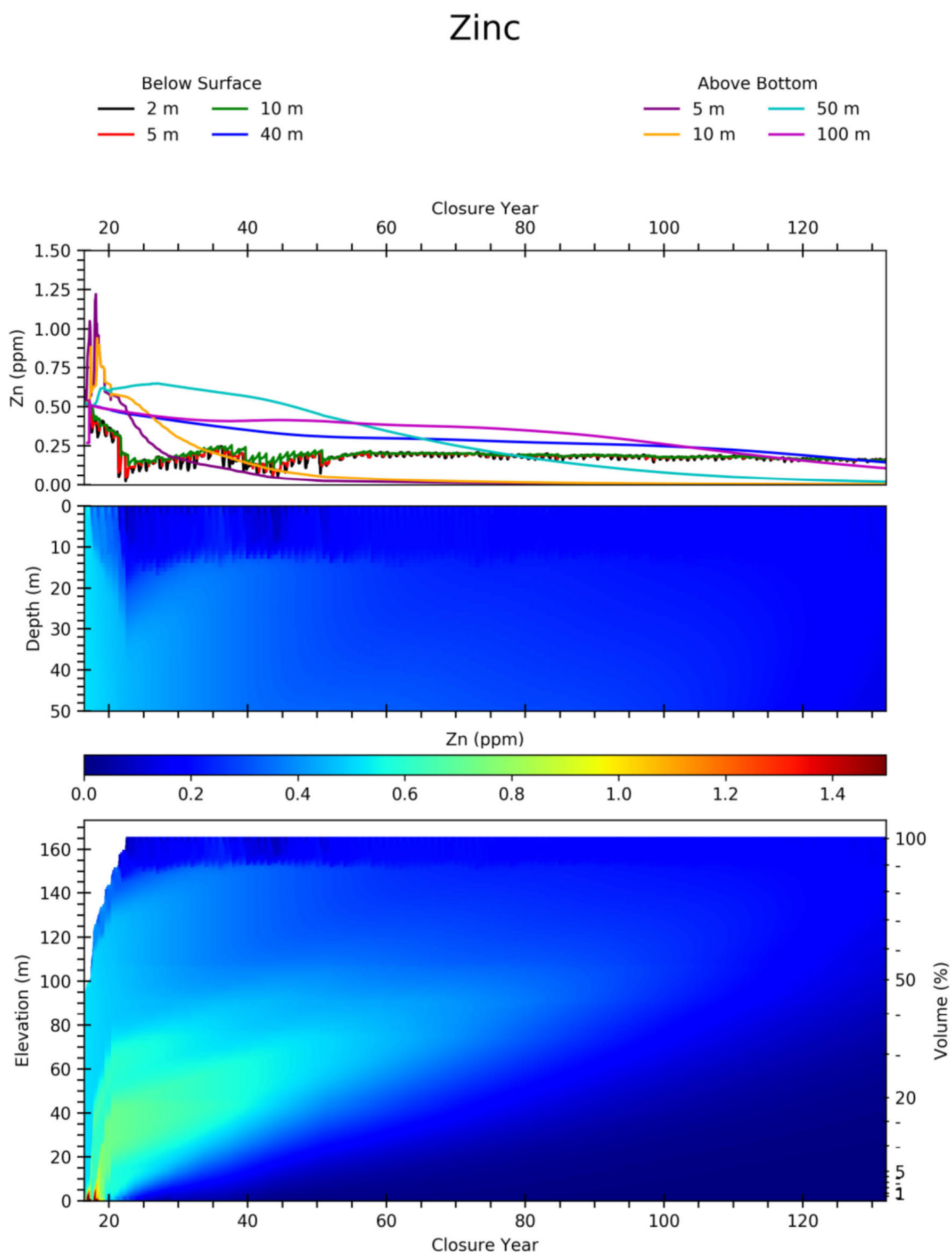
Sources: Lorax Environmental 2018

US Army Corps of Engineers

MODELED DISSOLVED COPPER CONCENTRATION IN PIT LAKE

PEBBLE PROJECT EIS

FIGURE K4.18-13



Sources: Lorax Environmental 2018

US Army Corps of Engineers

MODELED DISSOLVED ZINC CONCENTRATION IN PIT LAKE

Closure—Two WTPs are planned for the various closure phases:

- **WTP #2** would continue to treat water from the main WMP through phase 1 of closure (years 0 to 15), at which point it would be decommissioned.
- **WTP #3** would be newly constructed for the closure phases at the location of WTP #1. The treatment rate of WTP #3 would be increased relative to WTP #1 to meet anticipated treatment and discharge rates. It would treat surplus water from the open pit during the period that PAG waste rock and pyritic tailings are being transferred to the pit (closure phase 1), and surplus waters from the bulk TSF pond and main SCP are transferred to the open pit between years 23 and 50 (closure phases 3 and 4). WTP #3 would also operate as necessary during closure phase 4 (year 50 and beyond) to maintain the water level in the open pit below the NTE level, and to manage any additional surplus water from the bulk TSF main SCP (HDR 2019b, g, h).
- No water treatment would be necessary during closure phase 2 (years 16 to 23), because no discharge to the environment is planned as the open pit fills (Knight Piésold 2018d, 2019s).

Discharge locations for treated water during both operations and closure include the SFK, NFK, and UTC catchment (Figure 4.18-1).

WTP processes were developed based on inflows predicted by the water quality modeling in the previous sections. Variable water treatment rates would be required to manage surplus water from the mine site under differing climate conditions, with higher treatment rates during extended wet periods and lower treatment rates during extended dry periods. For example, the treatment rates for WTP #1 and WTP #2 in operations would be dictated by the volumes of water stored in the open pit WMP and the main WMP, respectively (Knight Piésold 2018a).

The WTPs would use an automated control system using supervisory control and data acquisition to monitor and adjust treatment operations to minimize the likelihood of upset conditions and inadvertent discharges above water quality criteria. This system would also provide information and alarms to the treatment plant operations staff. Specific details of the operational strategy and control system are not available at this time, and would typically be completed in a later phase of project engineering.

Specific details of the treatment processes that would be employed by each WTP are discussed in the following sections.

K4.18.2.1 Open Pit Water Treatment Plant (WTP #1)—Operations

The open pit WTP (WTP #1) would operate throughout mine production to treat water from the open pit WMP, which would receive water primarily from dewatering of the pit. WTP #1 would have two treatment trains of equal capacity to meet the influent flow of 14 cfs. A third treatment train would be installed to allow for maintenance rotation and enable ongoing water treatment during mechanical interruption of either train. The current design yields a total design capacity of 16 cfs (HDR 2019g). Water in the open pit WMP is expected to be significantly lower in TDS than in the main WMP (Knight Piésold 2018d).

Figure 2-11 provides a schematic of key water treatment processes to be employed in WTP #1 during mining operations. Treatment processes include influent heating, manganese oxidation, iron co-precipitation, high rate clarification, sulfide precipitation, metals polishing, media filtration, ultrafiltration (UF), reverse osmosis (RO), and effluent storage and equalization. Further description for specific key treatment steps for the water treatment process are described by HDR (2019g) in PLP 2019-RFI 021e.

Waste streams from WTP #1 are expected to be primarily metal hydroxides and metal sulfides (HDR 2019g). Waste streams would be managed through several management strategies as described in HDR 2019g:

- Precipitates removed by the ballasted high-rate flocculation/clarification systems, backwash from sand filters, and backwash from UF membranes would be sent to the sludge thickener.
- Used UF and RO membrane clean-in-place (CIP) chemicals would be neutralized at the respective equipment's CIP tankage prior to transfer to the sludge thickener.
- The thickened sludge stream from the sludge thickener would be split. Most of the thickened sludge would be recycled to the first step of the water treatment process (oxidation and co-precipitation tanks) to minimize WTP chemical usage. The remaining sludge would be disposed with the pyritic tailings in the pyritic TSF.
- Supernatant from the sludge thickener would be returned to the co-precipitation tank.
- Concentrated reject brine from the fourth stage of RO would be blended with pyritic tailings and pumped to the pyritic TSF (PLP 2020-RFI 166).

K4.18.2.2 Main Water Treatment Plant (WTP #2)—Operations and Closure Phase 1

The main WTP (WTP #2) would operate during operations and through phase 1 of closure, and would treat water from the main WMP, which would receive water from the bulk and pyritic TSFs, pyritic TSF north SCP, bulk TSF main SCP, power plant blowdown water, open pit WMP, direct precipitation, undisturbed surface runoff, and mill site runoff (HDR 2019g). A water balance model diagram in Appendix K4.16, Surface Water Hydrology, depicts where water would be collected, stored, moved, and treated around the mine site.

WTP #2 would have six treatment trains to meet the anticipated influent flow of 46 cfs. The current design has a total design capacity of 53 cfs (HDR 2019g). A seventh train would be installed during maintenance to enable ongoing water treatment during mechanical interruption of any one train. Figure 2-12 provides a schematic of key water treatment processes to be employed in WTP #2 during mining operations. Treatment processes would be similar to WTP #1, with additional stages of RO and a calcium sulfate (gypsum) precipitation and clarification process added before each RO stage to remove sulfate. Further description for specific key treatment steps for the water treatment process are described by HDR (2019g) in PLP 2019-RFI 021e.

Waste streams from WTP #2 are anticipated to be high in metal hydroxide and metal sulfide precipitates, calcium sulfate precipitate, and TDS (HDR 2019g). Waste streams would be managed through several management strategies:

- Precipitates wasted from the ballasted high-rate flocculation/clarification systems, backwash from sand filters, backwash from UF membranes, and precipitates wasted from the calcium sulfate precipitation process clarifiers would be sent to the sludge thickener.
- Used UF and RO membrane CIP chemicals would be neutralized at the respective equipment's CIP tankage prior to transfer to the sludge thickener.
- The thickened sludge from the sludge thickener would be blended with the pyritic tailings and pumped to the pyritic TSF.
- Supernatant from the sludge thickener would be reprocessed in oxidation tanks from water during the first step in the water treatment process.
- Fourth-stage RO membrane reject would be blended with the pyritic tailings and pumped to the pyritic TSF for storage.

WTP #2 would be repurposed for closure phase 1 at the end of operations, and would treat surplus water from the main WMP. Water from the main WMP would be composed of water from the bulk and pyritic TSFs, the bulk and pyritic TSF SCPs, direct precipitation, undisturbed surface runoff, and diversion channel leakage. Similar to during operations, WTP #2 would operate with six trains and at the same anticipated treatment rate and design capacity as during operations.

Figure 2-13 provides a schematic of key water treatment processes to be employed in WTP #2 during closure phase 1. Because the water quality model predicts that influent water to WTP #2 would contain greater concentrations in closure phase 1 than in operations, the same treatment processes would continue to be used in closure phase 1, with the exception that the first stage of RO would be replaced by a nanofiltration step (HDR 2019h; PLP 2019-RFI 021e addendum; PLP 2020-RFI 166). In addition, chemical feed rates and other operational adjustments would be made to allow for successful treatment of influent water (HDR 2019g). If necessary to meet both hydraulic capacity and discharge criteria, trains would be installed as needed (PLP 2019-RFI 106).

Waste streams from WTP #2 in closure phase 1 are anticipated to be high in metal hydroxide and metal sulfide precipitates, calcium sulfate precipitate, and TDS. Waste streams would be managed through several management strategies as described in HDR (2019g):

- Precipitates wasted from the ballasted high-rate flocculation/clarification systems, backwash from sand filters, backwash from UF membranes, and precipitates wasted from the calcium sulfate precipitation process clarifiers would be sent to the sludge thickener.
- Used UF and RO membrane CIP chemicals would be neutralized at the respective equipment's CIP tankage prior to transfer to the sludge thickener.
- The thickened sludge from the sludge thickener would be pumped to the open pit.
- Supernatant from the sludge thickener would be returned to the oxidation tank for reprocessing.
- Fourth-stage RO membrane reject, which is a stream of concentrated brine, would be pumped to the open pit. Although the brine stream itself would be relatively high in TDS, the volume would be relatively small compared to the total volume of the open pit, which would allow for a slow rise in the bulk concentration of salts. This buffering capacity would allow for continued compliant operations of the existing treatment works until later periods of the closure phase, at which point additional technologies could be more economically deployed to manage salt mass in the water circuit.

K4.18.2.3 Closure Water Treatment Plant (WTP #3)—Closure Phase 1

WTP #3 would be newly constructed during closure phase 1 to treat water from the open pit dewatering while the pit is partially backfilled with materials that were temporarily stored in the pyritic TSF during operations (HDR 2018a). WTP #3 would treat surplus water from the open pit while PAG waste rock and pyritic tailings are being transferred during closure phase 1 (closure years 0 through 15). Water from the open pit would be sourced from the reject sludge and brine from WTPs, direct precipitation, undisturbed surface runoff, groundwater, pit wall runoff, runoff from backhauled waste rock, and water entrained from transferring the pyritic tailings to the pit. WTP #3 would consist of three trains operating in parallel and be designed to maintain at the maximum required flow rate of 25 cfs, but would have a total design capacity of 29 cfs (HDR 2019g).

Figure 2-14 provides a schematic of key water treatment processes to be employed in WTP #3 during closure phase 1. WTP #3 would use the same steps described above for WTP #2 in closure phase 1, with the addition of a brine evaporation and crystallization system to remove salts (HDR 2019h). Waste streams from WTP #3 during closure phase 1 are anticipated to be high in metal hydroxide and metal sulfide precipitates, calcium sulfate precipitate, and TDS. Waste streams would be managed through several management strategies identical to those described above for WTP #2 in closure phase 1 (HDR 2019g). The additional salts generated from the brine evaporation step would be disposed of in an approved disposal facility (HDR 2019h; PLP 2019-RFI 021h). Because evaporation technology is an adaptive management technique based on conditions that develop during operations, further analysis would be required during the engineering phase prior to closure to determine if the final salt would pass regulator requirements for disposal in traditional landfill, or if it would require special dispensation as a hazardous waste. Engineering would also need to determine if the salt should be disposed of off site, or if it could be properly entombed in an on-site impoundment (see Appendix M1.0, Mitigation Assessment).

K4.18.2.4 Closure Water Treatment Plant (WTP #3)—Closure Phase 3 and Phase 4

WTP #3 would house two separate treatment processes in closure phases 3 and 4 for:

- Surplus water from the bulk TSF main SCP
- Water from the pit lake (Knight Piésold 2018d, 2019a, s; HDR 2019b, g)

Main SCP Stream—Figure 2-15 provides a schematic of key water treatment processes for the main SCP stream to be employed in WTP #3 during closure phases 3 and 4. The portion of WTP #3 that would treat the main SCP stream would be repurposed from the closure phase 1 WTP #3 open pit stream. Treatment for the main SCP stream would include processes similar to WTP #2 in operations, but with fewer RO and calcium sulfate stages. The main SCP treatment circuit would be designed with four trains operating in parallel, yielding a total design capacity of 29 cfs. The predicted maximum influent flow for the main SCP stream is 15 cfs.

Waste streams from WTP #3 in closure phases 3 and 4 for the main SCP stream are anticipated to be high in metal hydroxide and metal sulfide precipitates, calcium sulfate precipitate, and TDS (HDR 2019g). Waste streams would be managed through several management strategies as described in HDR (2019g):

- Precipitates wasted from the ballasted high-rate flocculation/clarification systems, backwash from sand filters, backwash from UF membranes, and precipitates wasted from the calcium sulfate precipitation process clarifiers would be sent to the sludge thickener.
- Used UF and RO membrane CIP chemicals would be neutralized at the respective equipment's CIP tankage prior to transfer to the sludge thickener.
- The thickened sludge from the sludge thickener would be pumped to the open pit.
- Supernatant from the sludge thickener would be returned to the oxidation tank for reprocessing.
- Third-stage RO membrane reject, which is a stream of concentrated brine, would be pumped to the open pit.

Open Pit Stream—Prior to closure phase 3, an additional water treatment circuit would be constructed in WTP #3 to treat a waste stream from the open pit. The portion of WTP #3 treating the open pit stream would include five treatment trains operating in parallel (a sixth train would be installed for maintenance rotation) with a total design capacity of 44 cfs (HDR 2019g). Maximum anticipated treatment flow is 38 cfs in closure phase 3, and 11 cfs in closure phase 4 (Knight Piésold 2019s).

Figure 2-16 provides a schematic of key water treatment processes for the open pit stream to be employed in WTP #3 during closure phases 3 and 4. Treatment would include processes similar to those of WTP #1 in operations, but without UF/RO.

Open pit waste streams from WTP #3 are anticipated to be high in metal hydroxide and metal sulfide precipitates. Waste streams would be managed through several management strategies as described in HDR (2019g):

- Precipitates removed by the ballasted high-rate flocculation/clarification systems, backwash from sand filters, and backwash from UF membranes would be sent to the sludge thickener.
- Used UF membrane CIP chemicals would be neutralized and then transferred to the sludge thickener.
- The thickened sludge would be pumped to the open pit for storage.
- Supernatant from the sludge thickener would be reprocessed in the oxidation tank.

K4.18.2.5 Review of WTP Methodologies

HDR (2019g, h) and PLP (2019-RFI 021h) provide a general description of the above treatment processes to be employed for each of the WTPs, as well as adaptive management strategies to address failure in meeting anticipated discharge quality; however, specific treatment processes and mass balance information are not provided. A high-level independent review of the WTP designs was conducted by AECOM (2018i) to assess the effectiveness of the planned water treatment approach in meeting water treatment goals. The results of that review, as well as a review of updated WTP information, are summarized in the discussion below.

The technical content of HDR (2019g, h) and PLP (2019-RFI 021h) was found to be generally in line with expected treatment strategies for the mining industry, including the use of chemical precipitative technologies combined with sedimentary and filtration techniques to remove constituents of concern from the waters. The documents do not include specifics as to the operating conditions, and do not show intra-plant treatment approaches, but rather focus on the overall mass balance for each treatment plant, and provide references for the basis of their analysis. Given that the information provided is at a conceptual stage of development, there is limited ability to identify significant technical failures of the treatment strategies. It should be disclosed that the approaches have not been demonstrated elsewhere at the scale of the Pebble mine, and the specific configurations of treatment processes have not been commercially demonstrated. The technical viability of this strategy would require further evaluation during the permitting phase with the State of Alaska to demonstrate that the configurations can achieve the suggested water quality. Specifically, the following key elements should be the subject of further scrutiny as part of that process. These are summarized as recommendations in Appendix M1.0, and have been largely adopted by the Applicant:

- The treatment process anticipates using a combination of precipitative techniques (pH control via lime addition, iron co-precipitation, sulfide reduction) to convert dissolved species to a state that would allow removal by sedimentation and filtration processes. Although the solution is fundamentally sound, the mechanism for removal of various constituents requires different operational conditions in terms of pH and ORP to produce the solids. The information provided in HDR (2019g, h) and PLP 2019-RFI 021h does not specifically define the operating conditions in the WTPs, which creates uncertainty as to the effectiveness of the overall solutions. Further information would be required during the permitting process to fully assess the treatment solution.

- Subsequent to conversion to a solid phase in WTP #2, the solution assumes that salt mass would be sequestered in the pyritic TSF, and would be effectively removed from the water circuit permanently. This condition relies on the assumption that the solids remain thermodynamically stable in the pyritic TSF; and further, that the conditions in the impoundments themselves do not change appreciably over time or be subject to significant changes in the mining operations. There are numerous possible permutations of salts that could occur; further mass balance analysis using equilibrium equations would indicate if and where the concentrations of salts species might reach their solubility limits in the pyritic TSF. Therefore, further evaluation of conditions in the pyritic TSF and the potential for remobilization of salt mass would be required during the permitting process to identify the validity of this assumption.
- The removal efficiencies for various constituents are quite high relative to performance observed in other operating mine treatment systems in the world. Although PLP has provided literature references as the basis for their assumption, the information appears to be optimistic. This is particularly true for selenium, which is to be removed to less than 2 parts per billion (ppb) using a sulfide-based chemical-reducing agent combined with iron-coprecipitation. The literature references provided for this technique in PLP 2019-RFI 021h are dated, and do not align with more recent references such as the North American Metals Council white paper on selenium removal technologies (CH2MHill 2010, 2013). Further evaluation would be required during the permitting process to fully assess the validity and reasonableness of the treatment solution of the removal efficiencies under the specific operational conditions to confirm potential effectiveness, and would also need to consider the impacts of operational conditions on the removal of other various constituents of concern.

If the treatment strategy proves to be ineffective, modification to the treatment system would be required, which may include the modification of the treatment plants with additional unit processes, such as further RO trains and/or salt removal techniques such as thermal evaporation. Further, the contention is that the water ponds would allow for sufficient storage for up to 3 years of impoundment to allow for implementation of these changes. The mitigations are reasonable technical strategies, but the ability to implement such significant changes to the treatment processes within a 3-year period requires further evaluation to determine if engineering and construction can be completed.

K4.18.2.6 Water Quality of WTP Discharge

Operations Phase. Predicted quality of discharge water from both WTPs in operations is provided in Table K4.18-13 for HDR (2019g). The starting source terms for this analysis are the 90th percentile (highest) concentrations provided in Table K4.15-4 and Table K4.18-5 from Knight Piésold (2019s).

Based on a comparison of the data to most stringent discharge limits shown in Appendix K3.18, Table K3.18-1, discharge water is currently expected to meet Alaska Department of Environmental Conservation (ADEC) criteria. However, as described above, there is some concern that during operations, waste products high in selenium and salt placed in the pyritic TSF may, over time, lead to increased TDS concentrations in the main WMP, and thereby affect the inflow conditions to WTP #2 (AECOM 2018i). Such a change in condition of the inflow to the WTPs may warrant additional design consideration, or development of adaptive management strategies to ensure that mine site WTPs are capable of and effective at meeting treatment goals over the duration of time that treatment would be required.

Table K4.18-13: Predicted Water Quality of WTP Discharge in Operations

Parameter	Open Pit WTP (WTP #1)					Main WTP (WTP #2)				
	Influent Water	Treated Water	Waste Streams to Pyritic TSF			Influent Water	Treated Water	Waste Streams to Pyritic TSF		
mg/L			Sludge Total	Soluble Sludge	Brine			Sludge Total	Soluble Sludge	Brine
Flow (cfs)	14	13.617	0.0459	0.0413	0.211	46	44.51	1.02	0.865	0.573
Flow (gpm)	6,283.62	6,111.72	20.60	18.54	94.61	20,646.18	19,976.47	456.76	388.25	257.34
pH (std units)	7 to 8	7.3	7.3	8	8.1	7 to 8	8	7.3	8	**10.2**
TDS	420.95	452.97	**611.20**	**611.20**	**11,199.19**	**3,077.15**	190.01	**6,617.727**	**6,617.73**	**43,194.06**
TSS	**20**	0.0367	**100,000**	0	0	**20**	0	**150000**		0
Alkalinity (as $CaCO_3$)	50.24	27.01	36.0	36.0	627.57	500.3	32.08	762.36	762.36	1309
Acidity (as $CaCO_3$)	72.81	—	—	—	—	19.53	—	—	—	—
Chloride[1]	3.271	157.83	210.03	210.03	**3,911**	6.258	32.37	**2,039.38**	**2,039.38**	**26,040.64**
Fluoride	0.268	0.199	0.266	0.266	**4.87**	0.370	0.118	**4.48**	**4.48**	**7.2**
Sulfate	170.7	125.51	170.53	170.53	**3,147**	**1,765**	71.65	**74,783.03**	**1,832.04**	**3,662**
Aluminum	**5.234**	0.0360	**1,535.04**	0.0526	**0.865**	0.0006	2.34E-05	0.0262	0.00018	0.00048
Antimony	**0.00783**	0.00102	**1.88**	0.00160	**0.0246**	**0.0685**	0.00359	**2.90**	**0.00776**	**0.0192**
Arsenic	**0.02707**	0.00091	**7.45**	0.00168	**0.0219**	**0.0928**	0.00124	**4.13**	0.00304	0.0064
Barium	0.0659	0.0478	0.0645	0.0645	1.2	0.104	0.00297	**4.68**	0.160	0.199
Beryllium	0.00209	6.2E-05	**0.593**	9.14E-05	0.00150	**0.0387**	0.000462	**1.73**	0.00095	0.0024
Bismuth	0.00705	0.00079	1.711	0.00106	0.0189	0.0360	0.00160	1.54	0.00365	0.008
Boron	0.0808	0.0669	0.0800	0.0801	**0.958**	**0.781**	0.573	**10.62**	0.575	0.031
Cadmium	**0.0141**	2.4E-05	**4.25**	**0.000559**	**0.000588**	**0.0188**	2.10E-06	**0.849**	**0.00017**	**0.000057**
Calcium	46.47	33.83	45.81	45.99	1093.35	428.3	13.55	20,440.63	564.24	1,421
Chromium, total	0.00144	2.1E-05	**0.428**	3.97E-05	0.000516	0.01021	1.31E-05	**0.461**	0.00013	0.00038
Cobalt	**0.0924**	2.8E-05	**27.24**	0.00865	0.000678	**0.0545**	2.36E-06	**2.46**	0.0023	1.26E-08
Copper	**1.47**	0.00023	**441.50**	**0.0561**	**0.00545**	**0.01**	1.53E-07	**0.403**	**0.0149**	2.66E-13
Iron	**9.35**	0.0184	**48,013.25**	0.00005	0.442	0.002	0.000538	**6,015.54**	0.00279	0.000095
Lead	**0.00411**	5.9E-07	**1.19**	8.17E-06	1.42E-05	**0.0397**	1.86E-07	**1.77**	2.9E-06	9.5E-07
Magnesium	7.95	6.12	8.11	8.18	147.16	128.3	3.74	5,939.46	91.36	79.88
Manganese	**3.74**	0.01792	**3,301.6**	0.0323	**0.431**	**1.854**	0.000753	**169.89**	0.0248	0.0437
Mercury[2]	**0.000220**	1.6E-08	**0.0635**	2.11E-06	3.92E-07	**0.000279**	7.001E-10	**0.0126**	5.6E-07	7.6E-17
Molybdenum	**0.289**	0.00137	**82.78**	0.002281	**0.0329**	**3.90**	0.00170	**176.01**	**0.0155**	**0.0466**
Nickel	**0.0584**	0.00327	**15.80**	0.00606	**0.0786**	**0.121**	0.000333	**5.44**	0.00766	**0.0171**
Potassium	53.13	40.15	50.50	54.27	985.18	55.08	11.12	375.12	375.12	3065.5
Selenium	**0.0342**	0.00174	**9.38**	**0.00880**	**0.0420**	**0.0413**	0.000537	**1.85**	0.00482	**0.00648**
Silver	0.000378	2.3E-07	**0.106**	7.63E-05	5.45E-06	0.00332	1.30E-07	**0.150**	2.2E-05	4.94E-10
Sodium	83.33	62.12	83.33	83.72	1524.65	176.1	29.24	1,019.52	1,019.52	7,192.60

Table K4.18-13: Predicted Water Quality of WTP Discharge in Operations

Parameter	Open Pit WTP (WTP #1)					Main WTP (WTP #2)				
	Influent Water	Treated Water	Waste Streams to Pyritic TSF			Influent Water	Treated Water	Waste Streams to Pyritic TSF		
mg/L			Sludge Total	Soluble Sludge	Brine			Sludge Total	Soluble Sludge	Brine
Thallium	0.000735	0.00015	0.155	0.00024	0.00369	0.000894	1.62E-05	0.0398	0.00024	0.00045
Silicon	5.866	4.29	5.80	2.3	105.7	17.81	1.47	606.26	2.3	119.6
Tin	0.00116	4E-06	0.386	6.95E-05	9.52E-05	0.0658	7.44E-07	3.667	2.4E-05	0.000009
Vanadium	0.00177	3.3E-05	**0.502**	6.12E-05	0.000795	0.0144	1.54E-05	**0.651**	0.00023	0.000665
Zinc	**0.8603**	0.00038	**257.59**	0.01341	0.00904	**2.74**	2.28E-05	**123.98**	0.0039	0.00076
Nitrate-N	8.083	5.14	6.79	0.108	**117.84**	5.975	5.97	7.68	0.108	**513.19**
Nitrite	0.7010	0.526	0.691	0.691	**12.06**	0.499	0.453	0.597	0.596	**1.96**
Ammonia	0.791	0.610	0.786	0.786	**12.75**	0.615	0.157	2.48	2.48	**291.62**
Hardness (as $CaCO_3$)	148.88	110.05	147.90	148.64	3,346.52	1,597.81	49.28	75,543.78	1,786.56	3,881.22

Notes:
[1] Chloride increases in the water balance due to contributions from both minerals processing activities and various treatment chemicals. The level of increase is not considered consequential with respect to treatment capacity or effluent criteria.
[2] The mercury concentration in treated water is estimated as a function of mass balance equations based on solubility curves and membrane performance specifications, which indicate results below the EPA Method 1631 mercury detection limit of 0.5 ng/L. Further evaluation would be required to validate these assumptions during the permitting process as described in Appendix M1.0, Mitigation Assessment.
Values are based on 90th percentile water quality data
Units are mg/L unless otherwise noted
Bold values indicate exceedances of the most stringent water quality criteria (Appendix K3.18, Table K3.18-1)
$CaCO_3$ = calcium carbonate
gpm = gallons/minute
cfs = cubic feet/second
mg/L = milligrams/liter
TDS = total dissolved solids
TSS = total suspended solids
WTP = water treatment plant
— = no data
Source: HDR 2019g

Closure Phases—Table K4.18-14 includes anticipated water quality for influent and effluent for closure phase 1 from WTP #2 and WTP #3, based on both 50th and 90th percentile water quality data (Table K4.18-7 and Table K4.18-11). The 50th percentile data are included, because they may be more representative of influent water into the plant over this closure period. Influent to the WTPs during closure phase 1 would primarily be water from the pyritic TSF as the tailings are moved into the open pit. Because water in the pyritic TSF would have accrued over the 20-year life of the mine, peaks and valleys in the water quality concentrations would be attenuated and the 50th percentile would be expected (i.e., the 90th percentile water quality data would not be expected to be produced every day of every year for the 20-year life of the mine). For consistency with other mine phases and for a more conservative analysis, however, results from the mass balance model using 90th percentile water quality data for closure phase 1 are also included. Effluent water quality using both data sets is predicted to meet the most stringent water quality criteria.

No water treatment is anticipated during closure phase 2 as the pit lake fills. WTP #2 would be decommissioned and WTP #3 would be on standby status.

The predicted water quality of effluent from the WTP #3 main SCP stream in closure phase 3 is provided in Table K4.18-15, based on 90th percentile inflow data in Table K4.18-9 and Table K4.18-11. Likewise, the predicted water quality of effluent from the WTP #3 open pit stream is provided in Table K4.18-16; these values are based off the 90th percentile water quality data for year 105 of closure phase 4 (Table K4.18-10 and Table K4.18-11). Effluent from both WTP #3 streams meet the most stringent criteria (HDR 2019g).

K4.18.2.7 Water Treatment at Marine Port

The WTP at the marine port site would be newly constructed prior to the beginning of mining operations. The port site WTP would be smaller in scale then mine site WTPs, because the large scale treatment of mine runoff water would not be required. The port WTP would use treatment processes as described in HDR (2019g), and would include the following processes:

- Sedimentation for solid constituents would be removed via sedimentation.
- Potassium permanganate followed by a co-precipitation with ferric iron salt and lime would be used for the treatment of dissolved metals.
- Flocculators/clarifiers would be used to remove precipitated solids.
- As necessary, clarified water would be re-treated with sodium hydrogen sulfide to precipitate metal sulfides followed by a ferrous iron salt to further co-precipitate remaining metals under reducing conditions.
- Treated water would be filtered prior to discharge into marine waters.

Additionally, water treatment at the port site would include the treatment of petroleum, oils, and lubricants (POL) (PLP 2018-RFI 087). Stormwater runoff at the port may be impacted by fuels, lubricants, and other hydrocarbons leaked at the port site. POLs at the port site would be collected and managed as part of the Storm Water Pollutant Prevention Plan.

K4.18.3 Dust Deposition Methodologies

This section describes the methodology used to calculate potential increases in sediment and surface water from both direct deposition to waterbodies and runoff from dust in soil. The methodology for calculating incremental increases in the top inch of soil from dust deposition is provided in Appendix K4.14, Soils.

Table K4.18-14: Predicted Water Quality of WTP Discharge in Closure Phase 1

Parameter	50th Percentile Water Quality Data										90th Percentile Water Quality Data									
	Main WTP (WTP #2)					WTP #3					Main WTP (WTP #2)					WTP #3				
			Waste Streams to Pyritic TSF					Waste Streams to Pyritic TSF					Waste Streams to Pyritic TSF					Waste Streams to Pyritic TSF		
mg/L	Influent Water	Treated Water	Sludge Total	Soluble Sludge	Brine	Influent Water	Treated Water	Sludge Total	Soluble Sludge	Brine	Influent Water	Treated Water	Sludge Total	Soluble Sludge	Brine	Influent Water	Treated Water	Sludge Total	Soluble Sludge	Brine (Salt to Solid Waste Disposal)
Flow (cfs)	46	45.6	0.22	0.19	0.19	5,835	5,733	130	111	—	46	43.4	1.05	0.90	0.27	25	24.49	0.618	0.53	
Flow (gpm)	20,646	20,447	100	85	84	—	—	—	—	—	20,646	19,493	473	402.1	120.6	11,221	10,990	278	236	~80-90% solids, ~15 lb/gal density 3.66 gpm as solid (55.0 lb/min)
pH (std units)	7 to 8	8	7.3	7.3	**10.7**	7 to 8	7.3	7.3	7.3	—	7 to 8	8	7.3	7.3	**10.7**	7 to 8	7.3	7.3	7.3	
TDS	479	39	**1,625**	**1,625**	**17,973**	**2,402**	392	**3,665**	**3,665**	—	**3,445**	104.3	**4,649**	**4,649**	**26,494**	**2,638**	225.91	**5307**	**5307**	
TSS	**20**	0	**150,000**	0	—	**20**	—	**149,427**	—	—	**20**	0	**150,000**	-	0	**20**	—	**149,427**	—	
Alkalinity (as $CaCO_3$)	79	18	269	269	1309	131	17	601	247	—	628	18.6	1,347	1,347	1,309	150	53.8	601	1023	
Acidity (as $CaCO_3$)	20.4	—	—	—	—	499	—	—	—	—	42.5	—	—	—	—	538	-	—	—	
Chloride	7.72	4	104	104	**4,395**	107	159	**350**	**350**	**411,111**	11.8	8.76	74.7	74.7	**2711**	129	46.9	**601**	**601**	**266,725**
Fluoride	0.106	0.014	**10.7**	0.3	**10**	0.41	0.18	**6.3**	0.2	**197**	0.73	0.22	**17.7**	0.3	**15.9**	0.44	0.208	**6.46**	0.0101	**161**
Sulfate	**266**	9	**69,798**	**862**	**4,743**	**1,714**	69	**94,346**	**1,800**	**89,752**	**1,921**	27.8	**94,092**	**2,149**	**3,440**	**1,835**	63.7	**90,674**	**1,800**	**79,485**
Aluminum	0.0006	1.40E-04	0.076	0.001	0.014	0.0072	4.20E-04	**0.27**	0.0035	**1.19**	0.0006	2.17E-04	0.0096	0.0038	0.033	0.012	5.07E-04	**0.44**	0.00603	**1.24**
Antimony	**0.016**	0.001	**2.52**	**0.02**	**0.34**	**0.013**	0.001	**0.50**	0.003	**1.32**	**0.160**	0.0031	**6.69**	**0.029**	**0.22**	**0.015**	0.00115	**0.53**	**0.0061**	**1.21**
Arsenic	**0.022**	0	**4.42**	0.003	**0.03**	**0.05**	0.001	**2.36**	0.003	**1.68**	**0.208**	0.0049	**8.66**	**0.033**	**0.45**	**0.058**	0.00116	**2.28**	0.0062	**1.23**
Barium	0.019	0.004	1.28	0.1	1.57	0.061	0.005	1.3	0.16	**115**	0.12	0.016	0.15	0.69	**15.0**	0.068	0.00404	1.56	0.15	**77.8**
Beryllium	0.0013	0	**0.26**	0.0002	0.0021	**0.007**	0.0001	**0.31**	0.0004	**0.20**	**0.0046**	9.54E-05	**0.19**	0.00066	**0.0087**	**0.0078**	0.00014	**0.31**	0.00067	**0.141**
Bismuth	0.0080	0.001	1.51	0.003	0.01	0.006	0.0004	0.24	0.002	0.22	0.080	0.0043	3.23	0.027	0.008	0.0070	0.00045	0.26	0.0027	0.193
Boron	0.077	0.06	0.66	0.07	**2.57**	0.26	0.22	**1.7**	0.26	**10.19**	0.45	0.34	**2.51**	0.45	**11.98**	0.29	0.248	**1.67**	0.283	**8.63**
Cadmium	**0.0033**	2.00E-06	**0.67**	0	**1.00E-04**	**0.054**	3.00E-06	**2.43**	**0.0002**	**1.60E-03**	**0.0082**	2.76E-06	**0.36**	**0.00015**	5.70E-05	**0.059**	3.58E-06	**2.37**	**0.00029**	**1.37E-03**
Calcium	76	0.43	33021	270	1798	196	92.7	38524	550	38736	628	5.14	27234	660	1,418	224	13.4	39,172	550	34,259
Chromium, total	0.0022	1.00E-05	**0.45**	0.0003	0.0034	0.011	3.00E-05	**0.46**	0.0003	**0.2067**	0.016	4.86E-05	**0.69**	0.0015	0.0315	0.011	2.61E-05	**0.45**	0.00056	**0.16**
Cobalt	0.011	1.00E-06	**2.33**	0	4.00E-08	**0.17**	1.60E-05	**7.75**	0.002	**5.41E-02**	0.041	5.86E-06	**1.78**	0.00075	1.49E-03	**0.19**	2.08E-05	**7.61**	0.0034	4.50E-02
Copper	**0.01**	1.30E-06	**2.07**	0.0001	3.00E-04	**0.01**	2.00E-07	**0.38**	0.00006	1.68E-03	**0.01**	5.31E-07	**0.44**	7.86E-05	2.39E-04	**0.0088**	1.84E-07	**0.36**	0.000129	1.20E-03
Iron	0.002	0.0049	**8832**	0.005	0.0008	0.068	0.0026	**7059**	0.035	**35.42**	0.002	0.0032	**5,434**	0.077	**1.53**	0.122	0.0024	**6,126**	0.071	**23.3**
Lead	**0.0044**	3.00E-07	**0.92**	1.00E-05	1.66E-04	**0.007**	1.00E-07	**0.3**	3.00E-06	**9.66E-04**	**0.0404**	8.08E-07	**1.76**	3.93E-05	5.13E-04	**0.0073**	1.37E-07	**0.29**	5.71E-06	7.78E-04
Magnesium	12	0.1	1185	116	1662	49	1.14	2075	60	5441	82.41	6.08	3,206	247	177	57.21	5.69	2033	83.5	3,842
Manganese	**0.51**	0.0009	**105**	0.03	**0.25**	**1.71**	0.0012	**127**	0.03	**9.43**	**1.91**	0.0021	**139**	**0.063**	1.14	1.80	0.00077	120.70	0.031	5.44
Mercury	**4.57E-05**	4.50E-09	**0.008**	0.00E+00	0.00E+00	0.000085	1.00E-09	**0.004**	0.00E+00	1.00E-05	**0.00040**	1.22E-08	**0.018**	9.50E-07	5.47E-06	**9.58E-05**	1.12E-09	**0.0039**	8.03E-07	8.47E-06
Molybdenum	**0.92**	0.001	**190**	**0.03**	**0.51**	**0.47**	0.0004	**21**	0	**3.13**	**9.60**	0.0074	**416**	**0.28**	**5.78**	**0.58**	0.00043	**23.3**	**0.0102**	**2.72**
Nickel	**0.042**	0.0009	**8.22**	**0.018**	**0.23**	**0.95**	0.00749	**40.3**	**0.11**	**102**	**0.082**	0.0011	**3.30**	**0.029**	**0.56**	**1.04**	0.0020	**41.7**	**0.025**	**4.48**
Potassium	7.6	2.6	475.2	66	690	58.7	18.6	166	166	80,549	32.3	10.3	178.47	153.9	3694	69.15	19.43	281.79	281.79	129574.7
Selenium	**0.0058**	0.0001	**1.10**	0.004	**0.032**	**0.028**	0.0006	**1.14**	**0.006**	**2.67**	**0.045**	0.0042	**0.68**	**0.064**	**4.53**	**0.029**	0.00072	**1.08**	**0.011**	**2.30**
Silver	0.00080	2.00E-07	**0.17**	1.00E-05	0.00E+00	0.0009	7.00E-08	**0.04**	1.00E-05	1.04E-03	**0.0080**	1.30E-06	**0.35**	4.46E-05	6.27E-04	0.0011	1.26E-07	**0.043**	3.19E-05	1.25E-03

Table K4.18-14: Predicted Water Quality of WTP Discharge in Closure Phase 1

Parameter	50th Percentile Water Quality Data										90th Percentile Water Quality Data									
	Main WTP (WTP #2)					WTP #3					Main WTP (WTP #2)					WTP #3				
			Waste Streams to Pyritic TSF					Waste Streams to Pyritic TSF					Waste Streams to Pyritic TSF					Waste Streams to Pyritic TSF		
mg/L	Influent Water	Treated Water	Sludge Total	Soluble Sludge	Brine	Influent Water	Treated Water	Sludge Total	Soluble Sludge	Brine	Influent Water	Treated Water	Sludge Total	Soluble Sludge	Brine	Influent Water	Treated Water	Sludge Total	Soluble Sludge	Brine (Salt to Solid Waste Disposal)
Sodium	24	11	181	181	3063	134	37	588	588	315,076	114.2	31.73	648.87	648.87	13,997	160	40.3	1,153	1,153	343,643
Thallium	0.000082	0.00001	**0.013**	0.0002	0.0014	0.0006	3.00E-05	**0.022**	0.0004	**0.15**	0.00042	3.28E-05	**0.014**	0.00017	**0.0085**	0.00065	3.02E-05	**0.022**	0.00055	**0.12**
Silicon	6.1	0.4	557	2.3	740	11.5	1.79	378	2.3	5405	27.0	2.02	1,021	2.3	187	13.3	1.69	412	2.3	4,333
Tin	0.016	5.00E-06	3.26	0	0.00077	0.02	1.60E-06	0.7	3.00E-05	0.0081	0.16	1.72E-05	6.98	0.0019	0.0045	0.018	1.66E-06	0.72	5.03E-05	0.0065
Vanadium	0.0029	2.00E-05	**0.58**	0.0004	0.0051	0.0046	1.00E-05	**0.2**	0.0002	**0.12**	0.024	1.19E-04	**1.03**	0.0028	0.053	0.0052	1.21E-05	**0.21**	0.00033	0.088
Zinc	**0.53**	1.60E-04	**108.8**	0.0019	0.0076	**8.23**	1.30E-04	**367**	0.0043	**1.56**	**1.55**	1.21E-04	**67.7**	0.0072	**0.059**	**8.94**	1.44E-04	**361**	0.00904	**1.20**
Nitrate-N	0.41	0.12	**15.74**	0.11	**55**	3.38	2.65	**15.34**	**15.34**	**36**	0.59	0.53	1.10	0.11	7.04	3.99	3.77	**14.7**	**14.7**	**64.3**
Nitrite	0.033	0.01	**1.08**	**1.08**	**4.1**	0.29	0.26	**1.45**	**1.45**	**3.51**	0.046	0.036	0.099	0.099	**1.29**	0.34	0.32	**1.32**	**1.32**	**4.44**
Ammonia	0.054	0.007	2.18	2.18	**8.7**	0.59	0.32	2.11	2.11	**6.8**	0.071	0.026	0.34	0.34	**6.75**	0.703	0.66	3.33	3.33	**14.8**
Hardness (as $CaCO_3$)	240	1.3	87,429	1,154	11,335	691	236	104,847	1,009	—	1,908	37.85	81,279	2,6645	4,271	796	56.8	106,293	1,431	—

Notes:
Values are based on 50th and 90th percentile water quality data
Units are mg/L unless otherwise noted
Bold values indicate exceedances of the most stringent water quality criteria (Appendix K3.18, Table K3.18-1)
$CaCO_3$ = calcium carbonate
gpm = gallons/minute
cfs = cubic feet/second
mg/L = milligrams/liter
TDS = total dissolved solids
TSS = total suspended solids
WTP = water treatment plant
— = no data
Source: HDR 2019h, PLP 2019-RFI 021e addendum, PLP 2020-RFI 021i, PLP 2020-RFI 021k

Table K4.18-15: Predicted Water Quality of WTP #3 Main SCP Stream in Closure Phase 3

Parameter	Influent Water	Treated Water	Waste Streams to Pyritic TSF		
mg/L			Sludge Total	Soluble Sludge	Brine
Flow (cfs)	15	14.0	0.42	0.36	0.65
Flow (gpm)	6732	6266	190	162	292
pH (std units)	7 to 8	7.8	7.3	8.0	**10.1**
TDS	**4186**	158	**5129**	**5129**	**44380**
TSS	20	0	**150000**	—	0
Alkalinity (as $CaCO_3$)	766	63	1243	1113	13449
Acidity (as $CaCO_3$)	7.6	—	—	—	—
Chloride	9.25	79	**896**	**814**	**20387**
Fluoride	0.889	0.04	**18.1**	0.4	**7.1**
Sulfate	**2346**	13	**72088**	**2245**	**7338**
Aluminum	0.0006	0.00003	0.018	0.0001	0.0010
Antimony	**0.197**	**0.008**	**6.639**	0.005	**0.028**
Arsenic	**0.257**	0.003	**8.94**	0.003	**0.013**
Barium	0.1494	0.004	**4.6**	0.13	0.40
Beryllium	**0.00594**	0.0001	**0.20**	0.0002	0.002
Bismuth	0.0987	0.004	3.35	0.002	0.011
Boron	0.527	0.11	**14.5**	0.54	0.24
Cadmium	**0.01028**	0.000002	**0.36**	**0.0001**	**0.0001**
Calcium	764	43	33924	797	2847
Chromium, total	0.01982	0.00002	**0.70**	0.0001	0.0008
Cobalt	**0.0503**	0.000002	**1.77**	0.002	0.00000
Copper	**0.0100**	0.0000001	**0.35**	0.0001	0.000000
Iron	0.0020	0.0005	**5399**	0.002	0.0002
Lead	**0.0499**	0.0000002	**1.77**	0.000002	0.000002
Magnesium	100	0.33	3291	86	160
Manganese	**2.00**	0.001	**150**	0.02	**0.09**

Table K4.18-15: Predicted Water Quality of WTP #3 Main SCP Stream in Closure Phase 3

Parameter	Influent Water	Treated Water	Waste Streams to Pyritic TSF		
mg/L			Sludge Total	Soluble Sludge	Brine
Mercury	**0.000496**	0.000000001	**0.018**	0.00000	0.00000
Molybdenum	**11.84**	0.004	**419**	0.01	**0.06**
Nickel	**0.05212**	0.00028	**1.75**	0.006	**0.034**
Potassium	36.7	2.5	92	95	1936
Selenium	**0.0549**	0.0008	**1.88**	0.004	**0.013**
Silver	**0.00987**	0.0000004	**0.35**	0.00002	0.00000
Sodium	132	7.5	223	227	2879
Thallium	0.000513	0.00003	**0.0133**	0.0003	**0.0022**
Silicon	31.7	0.49	177	2.30	620
Tin	0.197	0.000002	6.98	0.00002	0.00002
Vanadium	0.0297	0.00003	**1.05**	0.0002	0.0013
Zinc	**1.93**	0.00002	**68**	0.0028	0.0015
Nitrate-N	0.0862	0.02	0.13	0.11	1.60
Nitrite	0.00686	0.001	0.01	0.01	0.13
Ammonia	0.00887	0.004	0.01	0.014	0.12
Hardness (as $CaCO_3$)	2321	110	98356	2345	7776

Notes:
Values are based on 90th percentile water quality data
Units are mg/L (milligrams/liter) unless otherwise noted
Bold values indicate exceedances of the most stringent water quality criteria (Table K3.18-1)
$CaCO_3$ = calcium carbonate
cfs = cubic feet/second
gpm = gallons/minute
mg/L = milligrams/liter
TDS = total dissolved solids
TSS = total suspended solids
SCP = seepage collection pond
WTP = water treatment plant
— = no data
Source: HDR 2019g

Table K4.18-16: Predicted Water Quality of WTP #3 Open Pit Stream in Closure Phase 4

Parameter	Influent Water[1]	Treated Water	Waste Streams to Open Pit	
mg/L			Sludge Total	Soluble Sludge
Flow (cfs)	11	11.01	0.01	0.01
Flow (gpm)	4937	4942	4.7	4.0
pH (std units)	8.1	7.3	7.3	8.0
TDS	259	336	344	344
TSS	**20**	0.05	100000	—
Alkalinity (as $CaCO_3$)	40	36	37	37
Acidity (as $CaCO_3$)	0.90	—	—	—
Chloride	2.00	58	58	58
Fluoride	0.12	0.12	0.12	0.12
Sulfate[2]	173	173	173	173
Aluminum	**1.00**	0.048	**989**	0.055
Antimony	**0.0110**	0.0019	**9.39**	0.0022
Arsenic	**0.016**	0.0007	**15.9**	0.0009
Barium	0.015	0.015	0.017	0.017
Beryllium	**0.0010**	0.00004	**1.00**	0.00005
Bismuth	0.007	0.0011	6.16	0.0012
Boron	0.034	0.034	0.038	0.034
Cadmium	**0.0017**	0.00003	**1.74**	0.00005
Calcium	59	59	59	59
Chromium, total	0.0020	0.00004	**2.04**	0.00005
Cobalt	0.014	0.000008	**14.6**	0.00041
Copper	**0.27**	0.0001	**281**	**0.0033**
Iron	**1.70**	0.02	**41131**	0.0001
Lead	**0.0038**	0.0000015	**3.91**	0.0000
Magnesium	7.7	7.7	7.7	7.7
Manganese	**0.89**	0.006	**1563**	0.007

Table K4.18-16: Predicted Water Quality of WTP #3 Open Pit Stream in Closure Phase 4

Parameter	Influent Water[1]	Treated Water	Waste Streams to Open Pit	
mg/L			Sludge Total	Soluble Sludge
Mercury	**0.00004**	0.00000001	**0.04**	0.0000
Molybdenum	**0.70**	0.005	**724**	0.005
Nickel	0.012	0.0009	**11.5**	0.0011
Potassium[2]	2.8	12.8	3.2	3.2
Selenium	**0.0096**	0.0029	**6.93**	0.004
Silver	0.00066	0.0000006	**0.69**	0.0000
Sodium	10.0	10.2	10.2	10.2
Thallium	0.00013	0.00004	0.10	0.0000
Silicon	2.30	2.30	2.30	2.30
Tin	0.013	0.00001	13.5	0.0002
Vanadium	0.002	0.00005	**2.03**	0.0001
Zinc	**0.18**	0.00045	**187**	0.0013
Nitrate-N	0.02	0.02	0.02	0.11
Nitrite	0.001	0.001	0.001	0.001
Ammonia	0.002	0.002	0.002	0.002
Hardness (as $CaCO_3$)	178	179	179	179

Notes:
[1] Values are based on 90th percentile water quality data for closure year 105.
[2] During this phase of the project, treatment shifts to maintaining both a water and salt balance, whereas previous phases allowed for accumulation of salt mass while discharging excess water. As a result, the sulfate discharge rate would increase in closure phase 4, and potassium accumulation from operations through closure phase 3 would result in an increased discharge rate in closure phase 4.
Units are mg/L (milligrams/liter) unless otherwise noted.
Bold values indicate exceedances of the most stringent water quality criteria (Appendix K3.18, Table K3.18-1).
$CaCO_3$ = calcium carbonate
cfs = cubic feet/second
gpm = gallons/minute
mg/L = milligrams/liter
TDS = total dissolved solids
TSS = total suspended solids
WTP = water treatment plant
— = no data
Source: HDR 2019g

K4.18.3.1 Sediment/Substrate Quality

Baseline sediment quality data are presented in Appendix K3.18, Water and Sediment Quality. Dust deposition impacts to sediment/substrate quality at the mine site were calculated following the same approach as for soils, outlined in Section 4.14, Soils. Baseline dry weight sediment quality data for the mine site (Appendix K3.18) were used for this analysis, and the same default parameters for sediment bulk density and mixing zone. Like the soils analysis, the maximum dust concentrations predicted at the mine site safety boundary (see Figure 4.14-1) were used in this analysis (PLP 2018-RFI 009). Table K4.18-17 provides the results of dust deposition impacts to sediment quality, including the percent increase in metals concentration and total estimated concentration of metals in sediment after the 20-year life of mining operations.

Air deposition represents the primary source of site-related contamination to waterbodies, with metals partitioning to both sediment and surface water. The equation used below for estimating sediment increases from dust conservatively assumes that all of the metals from air deposition partition to sediment, and that none partition into waters. Existing vegetation outside of the disturbed mine site area, as well as diversion channels that prevent off-site transport of disturbed soils, are expected to minimize contribution to sediment from an overland runoff pathway. Therefore, added metals contributions from this pathway are expected to be minor, and are not accounted for in the sediment model.

K4.18.3.2 Surface Water Quality

Sediment/Surface Water Partitioning Approach—Two different approaches were used to estimate the increase in metals concentrations in surface waterbodies due to fugitive dust. The first of these is a sediment/surface water partitioning approach, which uses the results from the sediment model in Table K4.18-17 as an input parameter based on the maximum dust deposition at the mine site safety boundary. This approach assumes that the ratio of metals concentrations between sediments and surface water in baseline pre-mining conditions would remain consistent after particulate deposition, and that all physical and chemical processes controlling the partitioning of constituents between sediments and surface water are the same in post-deposition as in baseline conditions. By using a ratio approach for surface water concentration estimation, chemical and physical processes such as erosion are indirectly taken into consideration. However, complexities of the physical system introduce uncertainties in estimations of surface water concentrations, and the assumptions described above under “Sediment/Substrate Quality” regarding the runoff pathway apply to this model as well.

Table K4.18-18 provides the results of the estimated increase in metals concentrations in surface water from dust deposition at the mine site, assuming that fugitive dust partitions between sediment and surface water. The 20-year total and dissolved concentrations due to dust deposition were calculated as follows:

$$Total\ SW_{20yr} = \frac{SD_{20yr}}{R_{total}};\ Dissolved\ SW_{20yr} = \frac{SD_{20yr}}{R_{dissolved}}$$

Equation K4.18-1

where SW_{20yr} is the surface water concentration (total and dissolved, respectively) after 20 years of operations, SD_{20yr} is the sediment concentration after 20 years of operations, and R is a site-specific relationship representing the ratio of sediment to surface water.

Table K4.18-17: Predicted Change in Sediment Quality from Dust Deposition

Analyte	Baseline Concentration[a]	Deposition from Dust			Sediment % Increase	Soil/Sediment Criteria[d]		
	Mean[b] (mg/kg)	Yearly Deposition Rate ($g/m^2 \cdot year$)[a]	Incremental Increase over 20 Years[c] (mg/kg)	Baseline + 20 Years Dust Deposition (mg/kg)		ADEC Soil Human Health (mg/kg)	TEL (mg/kg)	PEL (mg/kg)
Antimony	0.23	0.0000113	0.0075	0.24	3.17%	33	—	—
Arsenic	**14.2**[e]	0.0000884	0.059	**14.3**	0.41%	7.2 (inorganic)	5.9	17
Beryllium	0.35	0.0000032	0.0021	0.35	0.61%	170	—	—
Cadmium	0.26	0.0000026	0.0017	0.26	0.66%	76 (diet)	0.596	3.53
Chromium	15.4	0.00011	0.073	15.5	0.47%	1.0×10^5 (CrIII)	37.3	90
Cobalt[f]	7.86	0.0000293	0.02	7.88	0.25%	—	—	—
Copper	27.3	0.00254	1.693	28.99	5.84%	3300	35.7	197
Lead	6.9	0.0000307	0.02	6.92	0.30%	400	35	91.3
Manganese[f]	623	0.00104	0.69	624	0.11%	—	—	—
Mercury	0.04	1.92E-07	0.00013	0.04	0.32%	3.1 (elemental)	0.174	0.486
Nickel	8.95	0.0000264	0.018	8.97	0.20%	1,700 (soluble salts)	18	36
Selenium	1.15	0.0000113	0.008	1.16	0.65%	410	—	—

Notes:
[a] Source: SLR 2011a; PLP 2018-RFI 009
[b] All sediment data are presented on a dry-weight basis
[c] Because sediment data are presented in dry weight, the same soil equation and default parameters were used for sediment (i.e., bulk density and mixing zone) (EPA 2005)
[d] Source: Buchman 2008; ADEC 2017
[e] Bold values indicate exceedances of the most stringent water quality criteria (Appendix K3.18, Table K3.18-1)
[f] No available reference value per ADEC 18 Alaska Administrative Code (AAC) 75. Additional human health evaluation of all hazardous air pollutant (HAP) metals is provided in Section 4.10, Health and Safety, based on published US Environmental Protection Agency (EPA) Regional Screening Levels (RSLs). Additional human health evaluation of all HAP metals based on published EPA RSLs is provided in Section 4.10 (Health & Safety), and includes metals for which no ADEC reference value is shown in Table 4.14-1
— = no data
ADEC = Alaska Department of Environmental Conservation
CrIII = chromium III
$g/m^2 \cdot year$ = grams per square meter per year
mg/kg = milligrams per kilogram
PEL = probable effects level
TEL = threshold effects level

Table K4.18-18: Predicted Change in Surface Water Quality from Dust Deposition

Location	Analyte	Baseline Concentration			20-Year Sediment Concentration[c] (mg/kg)	20-Year Surface Water Concentration[d]			ADEC Most Stringent Water Quality (mg/L)
		Sediment Mean[a] (mg/kg)	Surface Water-Total Mean[b] (mg/L)	Surface Water-Dissolved Mean[b] (mg/L)		Total (mg/L)	Dissolved (mg/L)	% Increase (Total)	
NFK	Antimony	0.23	—	—	0.24	—	—	—	0.006
	Arsenic	**14.2[f]**	0.00034	0.00031	**14.3**	0.00034	0.00031	0.41%	0.01
	Beryllium	0.35	—	—	0.35	—	—	—	0.004
	Cadmium	0.26	0.00002	0.00002	0.26	0.00002	0.00002	0.66%	0.00008
	Chromium	15.4	0.00029	0.00028	15.5	0.00029	0.00028	0.47%	0.1 (total)
	Cobalt	7.86	—	—	7.88	—	—	—	0.05
	Copper	27.3	0.00042	0.00041	28.99	0.00045	0.000435	5.84%	0.00219
	Lead	6.9	0.00012	0.00007	6.92	0.00012	0.00007	0.30%	0.00039
	Manganese	623	0.013	0.0082	624	0.013	0.0082	0.11%	0.05
	Mercury	0.04	—	—	0.04	—	—	—	0.000012
	Nickel	8.95	0.00025	0.00033	8.97	0.00025	0.00033	0.20%	0.01287
	Selenium	1.15	0.00027	0.00028	1.16	0.00027	0.00028	0.65%	0.005
SFK	Antimony	0.23	—	—	0.24	—	—	—	0.006
	Arsenic	**14.2**	0.00033	0.00031	**14.3**	0.00033	0.00031	0.41%	0.01
	Beryllium	0.35	—	—	0.35	—	—	—	0.004
	Cadmium	0.26	0.000019	0.000019	0.26	0.000019	0.000019	0.66%	0.00008
	Chromium	15.4	0.00027	0.00025	15.5	0.00027	0.00025	0.47%	0.1 (total)
	Cobalt	7.86	—	—	7.88	—	—	—	0.05
	Copper	27.3	0.0014	0.0011	28.99	0.00151	0.001158	5.84%	0.00219
	Lead	6.9	0.00011	0.000072	6.92	0.00011	0.000072	0.30%	0.00039
	Manganese	623	0.024	0.019	624	0.024	0.0189	0.11%	0.05
	Mercury	0.04	—	—	0.04	—	—	—	0.000012
	Nickel	8.95	0.00033	0.00042	8.97	0.00033	0.00042	0.20%	0.01287
	Selenium	1.15	0.00029	0.00029	1.16	0.00029	0.0003	0.65%	0.005
UTC	Antimony	0.23	—	—	0.24	—	—	—	0.006
	Arsenic	**14.2**	0.00095	0.00082	**14.3**	0.00096	0.00082	0.41%	0.01
	Beryllium	0.35	—	—	0.35	—	—	—	0.004
	Cadmium	0.26	0.000017	0.000017	0.26	0.000017	0.000017	0.66%	0.00008
	Chromium	15.4	0.00036	0.00031	15.5	0.00036	0.00031	0.47%	0.1 (total)
	Cobalt	7.86	—	—	7.88	—	—	—	0.05
	Copper	27.3	0.00061	0.00047	28.99	0.00065	0.000503	5.84%	0.00219
	Lead	6.9	0.000089	0.000057	6.92	0.00009	0.000058	0.30%	0.00039
	Manganese	623	0.026	0.02	624	0.026	0.0199	0.11%	0.05
	Mercury	0.04	—	—	0.04	—	—	—	0.000012
	Nickel	8.95	0.00061	0.00068	8.97	0.00061	0.00068	0.20%	0.01287
	Selenium	1.15	0.0003	0.0003	1.16	0.0003	0.0003	0.65%	0.005

Table K4.18-18: Predicted Change in Surface Water Quality from Dust Deposition

Location	Analyte	Baseline Concentration			20-Year Sediment Concentration[c] (mg/kg)	20-Year Surface Water Concentrationd			ADEC Most Stringent Water Quality (mg/L)
		Sediment Mean[a] (mg/kg)	Surface Water-Total Mean[b] (mg/L)	Surface Water-Dissolved Mean[b] (mg/L)		Total (mg/L)	Dissolved (mg/L)	% Increase (Total)	
Frying Pan Lake	Antimony	0.23	—	—	0.24	—	—	—	0.006
	Arsenic	**14.2**	0.00048	0.00036	**14.3**	0.00048	0.00036	0.41%	0.01
	Beryllium	0.35	—	—	0.35	—	—	—	0.004
	Cadmium	0.26	0.000018	0.000018	0.26	0.000018	0.000018	0.66%	0.00008
	Chromium	15.4	—	—	15.5	—	—	—	0.1 (total)
	Cobalt	7.86	—	—	7.88	—	—	—	0.05
	Copper	27.3	0.0013	0.00083	28.99	0.00135	0.000883	5.84%	0.00219
	Lead	6.9	0.00011	0.00016	6.92	0.00011	0.000165	0.30%	0.00039
	Manganese	623	0.035	0.017	624	0.036	0.0171	0.11%	0.05
	Mercury	0.04	—	—	0.04	—	—	—	0.000012
	Nickel	8.95	0.00022	0.00036	8.97	0.00022	0.00037	0.20%	0.01287
	Selenium	1.15	—	—	1.16	—	—	—	0.005

Notes:
[a] Sediment data (in dry weight) obtained from Appendix K3.18, Table K3.18-19
[b] Surface water data from Appendix K3.18, Tables K3.18-7 through K3.18-10
[c] 20-year sediment concentration = baseline + incremental increase over 20 years (Table K4.18-17)
[d] 20-year surface water concentration = 20-year sediment concentration/site-specific baseline sediment-baseline surface water relationship factor
[e] Surface water quality criteria from Appendix K3.18, Table K3.18-1; most stringent criteria (e.g., of human health, aquatic life, drinking water) for total metals, unless specified as dissolved
[f] Bold values indicate exceedances of the most stringent water quality criteria (Appendix K3.18, Table K3.18-1)
[g] Water concentrations presented represent total water concentrations
ADEC = Alaska Department of Environmental Conservation
mg/kg = milligrams per kilogram
NFK = North Fork Koktuli
SFK = South Fork Koktuli
UTC = Upper Talarik Creek
— = no data

R is defined as follows:

$$R_{total} = \frac{SD_{BL}}{SW_{BL(total)}};\ R_{dissolved} = \frac{SD_{BL}}{SW_{BL(dissolved)}}$$

Equation K4.18-2

where SD_{BL} is the baseline sediment concentration and SW_{BL} is the baseline surface water concentration. This approach allows the estimation of impacts to surface water quality for the length of mining operations. This methodology was applied to mine site–related surface water sources, including the NFK, SFK, UTC, and Frying Pan Lake. Mean values of sediment and surface water metals concentrations were used for this analysis. This approach was developed as a semi-quantitative approach to be analogous to the EPA surface water pathway approach using chemical-specific soil-water partition coefficients (K_d) (Allison and Allison 2005).

Frying Pan Lake Mixing Model Approach—Additional surface water modeling was performed to provide an alternative analysis of impacts of fugitive particulate deposition to surface waterbodies in conjunction with the release of treated effluent water. This approach, further described in AECOM (2019h), examines Frying Pan Lake as a differential mixing problem, and uses the lake as a proxy for analyzing impacts to other mine site waterbodies. Additionally, this analysis includes estimates for scenarios in which discharge from WTP #1 is as predicted, as well as if treated water from WTP #1 is discharged at the most stringent water quality criteria limit (Table K3.18-1). The model conservatively assumes that 100 percent of fugitive dust deposited into the lake body remains fully entrained in the surface water, and contributes to total water concentrations.

This model assumes that a constant volume of Frying Pan Lake is maintained with an average discharge rate of 30 cfs to the SFK (see Section 3.16, Surface Water Hydrology); and that the lake maintains volume through a constant recharge rate of 23.4 cfs with surface water influenced by runoff, and 6.6 cfs for the annual average estimated rate of discharge from WTP #1 (Knight Piésold 2018i: Table 1). These flow rates are similar to those in other waterbodies affected by dust deposition; for example, flow rates in the NFK and UTC are on the order of 10 to 50 cfs in their upper reaches (see Section 3.16 and Appendix K3.16, Surface Water Hydrology).

The model assumes even mass loading of fugitive dust metals across the surface area of the lake, and that the lake mixes thoroughly. Concentrations of constituents in recharge water were derived from Equation K4.18-1 and Equation K4.18-2 described above. Following this approach for the metals concentrations in recharge water provides an estimation of fugitive dust–related metals transport from chemical and physical processes (such as erosional effects) independent of watershed size. A solution to the Frying Pan Lake mixing model is described by Equation K4.18-3.

$$M(t) = \frac{(B_{re}Q_{in} + WQ_{dis} + DA)V}{Q_{out}} + \left(BV - \frac{(B_{re}Q_{in} + WQ_{dis} + DA)V}{Q_{out}}\right)e^{-(\frac{Q_{out}}{V}t)}$$

Equation K4.18-3

Where M(t) is mass of constituents in the lake (mg), V is the volume of the lake (L), Q_{out} is the rate of discharge from Frying Pan Lake (L/year), B is the baseline concentration of constituents (mg/L), B_{re} is the concentration of constituents in recharge water (mg/L), W is the concentration of the most stringent water quality criteria (a maximum concentration discharge allowed from WTPs, mg/L), Q_{dis} is the rate of discharge from WTP #1 into Frying Pan Lake (L/year), Q_{in} is the baseline recharge rate of the lake (L/year), D is the rate of dust deposition (mg/m^{2}-year), A is the surface area of Frying Pan Lake (m^2), and t is time (years).

For integers t>0, the exponential term on the right side of the equation becomes very small due to Q_{out} being much greater than V, making the second term on the right side of the equation negligible (Equation K4.18-4).

$$As\ e^{-(\frac{F_{out}}{V}t)} is\ very\ large \rightarrow \left(BV - \frac{(B_{re}Q_{in} + WQ_{dis} + DA)V}{Q_{out}}\right)e^{-(\frac{Q_{out}}{V}t)} \approx 0$$

Equation K4.18-4

Effectively, for t>0, the mass of constituents in the lake is represented by the time independent (i.e., steady-state) Equation K4.18-5.

$$M = \frac{(B_{re}Q_{in} + WQ_{dis} + DA)V}{Q_{out}}$$

Equation K4.18-5

The percent increase of constituent concentrations in Frying Pan Lake was applied to other mine site waterbodies as an estimate of maximum potential increase of surface water concentrations due to fugitive dust deposition. Model results are provided in Table K4.18-19. Percent change in total water quality is presented using mean total water concentrations; percent increases were also calculated for the maximum detected total water concentrations, and resulted in no additional exceedances in water quality criteria.

Rates of dust deposition were varied to examine how much dust would need to be deposited to result in exceedances of the most stringent water quality criteria. Assuming 100 percent of dust remains entrained in the water column and WTP #1 effluent is discharged at the water quality criteria, the model indicates that direct dust deposition is roughly an order of magnitude too low to result in an exceedance in water quality standards.

The relative contributions of mass from each source of inflowing metals to the lake (recharge water, WTP discharge, and dust deposition) were also evaluated in AECOM (2019h). In both scenarios of effluent concentrations (predicted and maximum allowed), dust deposited directly onto the lake has little influence on concentrations in lake water. With the exception of copper, deposition makes up less than 1 percent of the total metals mass in the lake. The model estimates copper in direct dust deposition contributes about 4 to 5 percent of the total lake water concentrations. The results suggest that changes in surface water concentrations are controlled more by concentrations in effluent and recharge waters than by direct deposition.

The model attempts to use several conservative assumptions to estimate changes in mine site surface water concentrations, but also has some uncertainties. It conservatively assumes that 100 percent of direct dust deposition to the lake contributes to lake water concentrations and is not sequestered in lake sediment. Concentrations in the dust were derived from the point of highest concentration on the ambient air boundary (see Figure 4.14-1) and applied to Frying Pan Lake, regardless of its location compared to predicted dust deposition. Dust concentrations from the air dispersion model (PLP 2018-RFI 009), which were based on the maximum modeled year of fugitive dust emissions, were applied to all 20 years of operations. WTP effluent concentrations in the model were based on both predicted values and maximum allowed water quality criteria. Recharge water concentrations were estimated using the environmental ratio approach described in the previous section, which assumes that 100 percent of fugitive dust mixes into sediment, then partitions into surface water. This approach for estimating runoff is independent of watershed surface area. Model limitations and uncertainty lie within the complexities of the physical system. For example, fugitive dust deposited onto soils or snow may be more mobile and susceptible to transport erosion and snowmelt runoff. Additionally, although Frying Pan Lake is a surface waterbody located at the mine site boundary and feeds the SFK river, it is a lake, and is hydrologically different from streams.

Table K4.18-19: Predicted Change in Surface Water Quality from Dust Deposition—Mixing Model

Location	Analyte	Baseline Concentration	Effluent Discharge Concentrations		20-Year Surface Water Concentration[c]			
					Predicted Effluent Concentrations[d]		Treated Water Concentrations at WQC Limit[e]	
		Surface Water-Total Mean[a] (mg/L)	Predicted effluent concentrations in operations WTP #1 (mg/L)	ADEC Most Stringent Water Quality[b] (mg/L)	Predicted Concentration	Predicted % Increase	Mean Total (mg/L)	% Increase Mean (Total)
NFK	Antimony	—	0.003	0.006	—	—	—	—
	Arsenic	0.00034	0.004	0.01	0.000460	35.2%	0.00183	436.9%
	Beryllium	—	0.0002	0.004	—	—	—	—
	Cadmium	0.00002	0.000005	0.00008	1.62E-05	-18.9%	3.53E-05	76.4%
	Chromium	0.00029	0.0001	0.1 (total)	0.000232	-20.0%	0.0217	7386.1%
	Cobalt	—	0.008	0.05	—	—	—	—
	Copper	0.00042	0.000001	0.00219	0.000356	-15.3%	0.000512	21.8%
	Lead	0.00012	0.000001	0.00039	9.45E-05	-21.2%	0.000188	56.7%
	Manganese	0.013	0.003	0.05	0.0102	-21.4%	0.0142	9.54%
	Mercury	—	0.000001	0.000012	—	—	—	—
	Nickel	0.00025	0.00005	0.01287	0.000279	11.7%	0.00341	1265.3%
	Selenium	0.00027	0.004	0.005	0.000324	20.1%	0.00126	367.0%
SFK	Antimony	—	0.003	0.006	—	—	—	—
	Arsenic	0.00033	0.004	0.01	0.000446	35.2%	0.00177	436.9%
	Beryllium	—	0.0002	0.004	—	—	—	—
	Cadmium	0.000019	0.000005	0.00008	1.54E-05	-18.9%	3.35E-05	76.4%
	Chromium	0.00027	0.0001	0.1 (total)	0.000216	-20.0%	0.0202	7386.1%
	Cobalt	—	0.008	0.05	—	—	—	—
	Copper	0.0014	0.000001	0.00219	0.00119	-15.3%	0.00171	21.8%
	Lead	0.00011	0.000001	0.00039	8.66E-05	-21.2%	0.000172	56.7%
	Manganese	0.024	0.003	0.05	0.0189	-21.4%	0.0263	9.54%

Table K4.18-19: Predicted Change in Surface Water Quality from Dust Deposition—Mixing Model

Location	Analyte	Baseline Concentration	Effluent Discharge Concentrations		20-Year Surface Water Concentration[c]			
					Predicted Effluent Concentrations[d]		Treated Water Concentrations at WQC Limit[e]	
		Surface Water-Total Mean[a] (mg/L)	Predicted effluent concentrations in operations WTP #1 (mg/L)	ADEC Most Stringent Water Quality[b] (mg/L)	Predicted Concentration	Predicted % Increase	Mean Total (mg/L)	% Increase Mean (Total)
	Mercury	—	0.000001	0.000012	—	—	—	—
	Nickel	0.00033	0.00005	0.0129	0.000369	11.7%	0.00451	1265.3%
	Selenium	0.00029	0.004	0.005	0.000348	20.1%	0.00135	367.0%
UTC	Antimony	—	0.003	0.006	—	—	—	—
UTC	Arsenic	0.00095	0.004	0.01	0.00128	35.2%	0.0051	436.9%
UTC	Beryllium	—	0.0002	0.004	—	—	—	—
UTC	Cadmium	0.000017	0.000005	0.00008	1.38E-05	-18.9%	3E-05	76.4%
UTC	Chromium	0.00036	0.0001	0.1 (total)	0.000288	-20.0%	0.02695	7386.1%
UTC	Cobalt	—	0.008	0.05	—	—	—	—
UTC	Copper	0.00061	0.000001	0.00219	0.000517	-15.3%	0.000743	21.8%
UTC	Lead	0.000089	0.000001	0.00039	7.011E-05	-21.2%	0.000139	56.7%
UTC	Manganese	0.026	0.003	0.05	0.0204	-21.4%	0.02848	9.54%
UTC	Mercury	—	0.000001	0.000012	—	—	—	—
UTC	Nickel	0.00061	0.00005	0.0129	0.000681	11.7%	0.00833	1265.3%
UTC	Selenium	0.0003	0.004	0.005	0.000360	20.1%	0.00140	367.0%
Frying Pan Lake	Antimony	—	0.003	0.006	—	—	—	—
Frying Pan Lake	Arsenic	0.00048	0.004	0.01	0.000649	35.2%	0.00258	436.9%
Frying Pan Lake	Beryllium	—	0.0002	0.004	—	—	—	—
Frying Pan Lake	Cadmium	0.000018	0.000005	0.00008	1.46E-05	-18.9%	3.17E-05	76.4%
Frying Pan Lake	Chromium[f]	0.000297	0.0001	0.1 (total)	0.000238	-20.0%	0.0222	7386.1%

Table K4.18-19: Predicted Change in Surface Water Quality from Dust Deposition—Mixing Model

Location	Analyte	Baseline Concentration	Effluent Discharge Concentrations		20-Year Surface Water Concentration[c]			
					Predicted Effluent Concentrations[d]		Treated Water Concentrations at WQC Limit[e]	
		Surface Water-Total Mean[a] (mg/L)	Predicted effluent concentrations in operations WTP #1 (mg/L)	ADEC Most Stringent Water Quality[b] (mg/L)	Predicted Concentration	Predicted % Increase	Mean Total (mg/L)	% Increase Mean (Total)
	Cobalt	—	0.008	0.05	—	—	—	—
	Copper	0.0013	0.000001	0.00219	0.00110	-15.3%	0.00158	21.8%
	Lead	0.00011	0.000001	0.00039	8.66E-05	-21.2%	0.000172	56.7%
	Manganese	0.035	0.003	0.05	0.0275	-21.4%	0.0383	9.54%
	Mercury	—	0.000001	0.000012	—	—	—	—
	Nickel	0.00022	0.00005	0.0129	0.000246	11.7%	0.003004	1265.3%
	Selenium[f]	0.000283	0.004	0.005	0.000340	20.1%	0.00032	367.0%

Notes:
[a] Surface water data from Appendix K3.18, Table K3.18-6 through Table K3.18-9
[b] Surface water quality criteria from Appendix K3.18, Table K3.18-1; most stringent criteria (e.g., of human health, aquatic life, drinking water) for total metals, unless specified as dissolved
[c] 20 year total surface water concentrations calculated using Equation K4.18-5
[d] Subsequent data were calculated using mean surface water total concentrations and predicted concentrations from WTP #1 discharge in operations, Table K4.18-13
[e] Subsequent data were calculated using mean surface water total concentrations and assuming water concentrations from WTP #1 are equal to the most stringent water quality criteria, Table K3.18-1
[f] Selenium and Chromium concentrations from monitoring site SK100F, directly downstream of Frying Pan Lake, was used in the absence of data collected in Frying Pan Lake
[g] Water concentrations presented represent total water concentrations
ADEC = Alaska Department of Environmental Conservation
mg/L = milligrams per liter
NFK = North Fork Koktuli
SFK = South Fork Koktuli
UTC = Upper Talarik Creek
WQC = water quality criteria
— = no data

The intent of using conservative model assumptions where possible is to compensate for potential uncertainties and resultant underestimations in other aspects of the physical system. Modeling physical systems accurately is challenging because there are near-infinite variables to account for. Model accuracy is dependent on the balance between model assumptions and uncertainty. There is some uncertainty regarding the interplay and balance between conservative assumptions and model uncertainties in this analysis.

K4.18.3.3 Groundwater Quality

Table K4.18-20 displays baseline and predicted soil concentrations of hazardous air pollutant (HAPs) metals due to dust compared to ADEC migration to groundwater levels. The ADEC levels represent soil concentrations at which there is potential risk for substances to leach to groundwater and potentially result in a completed human health exposure pathway (ADEC 2017b). This approach was used to examine potential impacts to groundwater from dust deposition. Only one of the constituents, arsenic, is predicted to exceed the groundwater action level, due primarily to high baseline concentrations, which commonly occur in many areas of Alaska.

Table K4.18-20: Predicted Change in Groundwater Quality from Dust Deposition

Analyte	Baseline[a]	Soil Concentration Post-Dust Deposition			Comparative Action Levels[d]
	Soil Concentration Mean (mg/kg)	Incremental Increase over 20 Years (mg/kg)[b,c]	Baseline + 20 Years Dust Deposition	% Increase after 20 years	Migration to Groundwater (mg/kg)
Antimony	0.24	0.00753	0.248	3.04	4.6
Arsenic	**10.2**[e]	0.0589	**10.26**	0.57	0.2
Beryllium	0.41	0.00213	0.412	0.52	260
Cadmium	0.24	0.00173	0.242	0.72	9.1
Chromium	17.7	0.0733	17.8	0.41	1.0 × 10^5 (Cr^3)
Cobalt	6.55	0.0195	6.57	0.30	N/A
Copper[f]	27.4	1.69	29.09	6.18	370
Lead	8.74	0.0205	8.76	0.23	N/A
Manganese	388	0.693	389	0.18	N/A
Mercury	0.12	0.000128	0.120	0.11	0.36
Nickel	9.16	0.0176	9.18	0.19	340
Selenium	2.76	0.00753	2.77	0.27	6.9

Notes:
[a] Source: SLR et al. 2011b
[b] Based on PLP 2018-RFI 009 total HAPs concentration in dust and EPA 2005
[c] Calculation assumes time period of deposition be the operational life of the mine (20 years), a soil mixing zone depth of 2 centimeters, and soil bulk density of 1.5 g/cm^3 (EPA 2005)
[d] ADEC 2017b
[e] Bold values indicate exceedances of the most stringent water quality criteria (Appendix K3.18, Table K3.18-1)
[f] Based on PLP 2019-RFI 009b total copper concentration in dust and EPA 2005
mg/kg = milligrams per kilogram

K4.18.4 Environmental Mass Loading

Changes in the environmental load of metals, ions, and other water quality constituents as a result of discharge from WTPs and anticipated streamflow reduction were examined. This analysis was performed for the mining operations phase, and examined the resultant changes in mass load in each watershed (NFK, SFK, UTC), as well as for the environment as a whole (i.e., the sum of all three watersheds). The baseline environmental mass was calculated as the product of the pre-mine average annual streamflow (see Appendix K3.16, Surface Water Hydrology) and the average water quality concentrations of each receiving stream (Table K3.18-7, Table K3.18-8, and Table K3.18-9). Baseline environmental mass load was calculated as

$$M_{BL} = Q_{NFK}C_{SFK} + Q_{SFK}C_{SFK} + Q_{UTC}C_{UTC}$$

Equation K4.18-6

Where

- M_{BL} is the total baseline environmental mass flowing through the system on an annual basis.
- Q_{XX} is the average annual streamflow for the NFK, SFK, and UTC.
- C_{XX} is the average water quality concentration of the NFK, SFK, and UTC.

The annual environmental mass load in the mining operational phase incorporated average anticipated streamflow reduction in each main-stem stream of the mine site area (Knight Piésold 2019r), as well as the average annual environmental discharge from WTPs into the environment that are based on predicted 90th percentile water quality inflows (Table K4.18-13). The annual mass passing through the environment (via the stream system) was approximated by summing the product of the annual average reduced streamflow multiplied by average baseline water quality concentrations, summed with the product of the total annual volume discharge from WTPs and the anticipated water quality concentrations of the effluent discharged. Because WTPs are anticipated to yield effluent of different chemistry, it is necessary to partition how much water is discharged from each WTP. For this analysis, flow was partitioned between the two based off the average anticipated flow of treated water through the plants (Table K4.18-13). This approach results in 75 percent of treated water being discharged from WTP #2, and 25 percent from WTP #1. Following these assumptions, the operational mass was calculated via the following:

$$M_{Op} = Q_{Nre}C_{NFK} + Q_{Sre}C_{SFK} + Q_{Ure}C_{UTC} + \underbrace{Q_{WTP1}C_{WTP1}}_{25\%\ Effluent} + \underbrace{Q_{WTP2}C_{WTP2}}_{75\%\ Effluent}$$

Equation K4.18-7

Where

- M_{Op} is the environmental mass flowing through the system on an annual basis during operations.
- Q_{Xre} is the average annual reduced streamflow for the NFK, SFK, and UTC.
- C_{XX} is the average water quality concentration of the NFK, SFK, and UTC.
- $Q_{WTP\#}$ is the average annual discharge from WTPs (#1 and #2) into the environment.
- $C_{WTP\#}$ is the anticipated water quality (90th percentile) concentrations for effluent water.

Further, the annual environmental mass in the stream system before and after operations was compared by taking the difference to assess the anticipated change in total environmental mass load.

$$\Delta M = M_{Op} - M_{BL}$$

Equation K4.18-8

An estimation of mass loading into individual watersheds was analyzed by adding the discharged mass load from the two WTPs together, then dividing the total among the three streams in proportions consistent with the average rate of WTP discharge into each stream. This approach recognizes that PLP's plan for the distribution of discharges from individual WTPs would be flexible to optimize aquatic habitat (Knight Piésold 2019r). Table K4.18-21 presents anticipated change in mass load of individual constituents flowing through the environment for the NFK, SFK, UTC, and combined environment.

Uncertainty is inherent in all physical models, and results from the complexities of physical systems and model assumptions. The mass loading analysis presented is an attempt to use the best assumptions available to provide a high-level assessment of potential environmental changes that may result from mining operations. The resulting environmental mass loads are subject to variations in annual precipitation, flow, mine site water management, and water quality from WTPs.

K4.18.5 Effluent Downstream Mixing

The magnitude of alterations to water chemistry as a result of mass loading via the mixing of discharged treated effluent with baseline recharge water would be higher near the discharge points and would taper downstream from discharge points as baseline flows increase. The average mass loading values in Table K4.18-21 are based on average stream flows for all reaches in each of the main-stem streams. These values would be higher close to the discharge points and lower than the averages at the downstream reaches. Effectively, the magnitude of water chemistry alterations associated with mass loading would be decreased downstream of the mine site as effluent is diluted into the environment.

Dilution of loaded water quality parameters is anticipated to be proportionate to the ratio of discharge volume to streamflow volume. Knight Piésold (2019r) provides estimates of the average annual WTP discharge volume into each main-stem stream, as well as the average anticipated reduced streamflow at gage stations and stream reaches downstream of the mine site. Stream gage locations, reaches, and WTP discharge points are depicted in Figure 3.16-4 and in Figure K4.16-6 through Figure K4.16-8. The factor by which effluent is diluted with baseline quality water can be calculated by dividing the final volume of water by the initial volume of treated effluent (Equation K4.18-9).

$$Dilution\ Factor = \frac{Effluent\ Volume + Reduced\ Streamflow\ Volume}{Effluent\ Volume}$$

Equation K4.18-9

In this analysis, dilution refers to a reduction in the magnitude of alterations from the discharge point to the downstream reaches. As a result, the dilution factor can be conceptualized as being inversely proportional to changes to baseline water concentrations as a result of effluent discharge. That is, the greater the dilution factor, the closer water quality is to baseline levels (not zero). For some metals and other water constituent concentrations, the mass loading analysis predicts a negative change in environmental mass load; for these constituents, as the dilution factor increases, stream concentrations would increase compared to effluent.

Table K4.18-21: Annual Environmental Mass Loading—Mining Operations

Field and Physical Parameters (mg/L, except where noted)	Environmental Mass Loading							
	NFK		SFK		UTC		Total Environmental Load	
	Incremental Change in Mass (kg/year)	Percent Change	Incremental Change in Mass (kg/year)	Percent Change	Incremental Change in Mass (kg/year)	Percent Change	Incremental Change in Mass (kg/year)	Percent Change
TDS	4,350,000	92.2%	547,000	23.4%	231,961	2.9%	5,120,000	33.8%
TSS	-38,200	-25.0%	-5,924	-5.9%	-2,550	-0.5%	-46,700	-6.3%
Major Ions (mg/L)								
Calcium	237,000	36.0%	28,200	7.7%	12,800	0.9%	278,000	11.6%
Magnesium	51,100	30.1%	6,690	8.1%	2,970	0.9%	60,700	10.6%
Sodium	732,000	238%	92,200	67.0%	37,900	8.9%	862,000	99.1%
Potassium	384,000	756%	48,000	228%	19,300	27.9%	452,000	320%
Alkalinity	-25,100	-0.91%	19,200	1.80%	7,820	0.2%	1,940	0.02%
Sulfate	1,770,000	622%	200,000	42.1%	86,200	9.0%	2,050,000	119%
Chloride	1,360,000	1,620%	168,000	412%	67,700	62.8%	1,590,000	685%
Fluoride	1,720	33.9%	214	8.1%	113	1.7%	2,040	14.2%
Nutrients, (mg/L)								
Total Ammonia	4,210	65.2%	538	17.2%	256	4.0%	5,010	31.3%
Nitrate-Nitrite	118,000	479%	14,900	150%	6,010	18.4%	139,000	207%
Total Metals (mg/L)								
Aluminum	-893	-20.6%	-111	-4.9%	-48.2	-0.4%	-1,050	-6.0%
Arsenic	14	32.1%	1.93	9.9%	0.48	0.3%	16.4	7.8%
Barium	197	45.5%	23.6	9.8%	10.9	1.3%	232	16.6%
Cadmium	-0.47	-18.6%	-0.05	-4.1%	-0.005	-0.2%	-0.52	-8.3%

Table K4.18-21: Annual Environmental Mass Loading—Mining Operations

Field and Physical Parameters (mg/L, except where noted)	Environmental Mass Loading							
	NFK		SFK		UTC		Total Environmental Load	
	Incremental Change in Mass (kg/year)	Percent Change	Incremental Change in Mass (kg/year)	Percent Change	Incremental Change in Mass (kg/year)	Percent Change	Incremental Change in Mass (kg/year)	Percent Change
Chromium	-8.9	-24.2%	-0.92	-5.7%	-0.27	-0.5%	-10.1	-9.4%
Copper	-12.2	-22.8%	-4.84	-5.8%	-0.42	-0.5%	-17.5	-7.6%
Iron	-7,020	-24.7%	-990	-5.9%	-184	-0.5%	-8,200	-10.0%
Lead	-3.90	-25.0%	-0.38	-5.9%	-0.07	-0.5%	-4.40	-12.2%
Manganese	-308	-18.5%	-69.9	-5.0%	-14.9	-0.4%	-392	-5.6%
Molybdenum	29.2	127%	2.54	8.4%	1.54	4.0%	33.3	36.3%
Nickel	15	46.3%	1.69	8.5%	0.66	0.7%	17.3	11.9%
Selenium	9.55	28.0%	1.23	7.2%	0.66	1.5%	11.4	11.8%
Silver	-0.20	-24.7%	-0.02	-5.8%	-0.006	-0.5%	-0.2	-9.8%
Zinc	-73.1	-24.2%	-9.31	-5.7%	-1.88	-0.5%	-84.3	-9.9%

Notes:

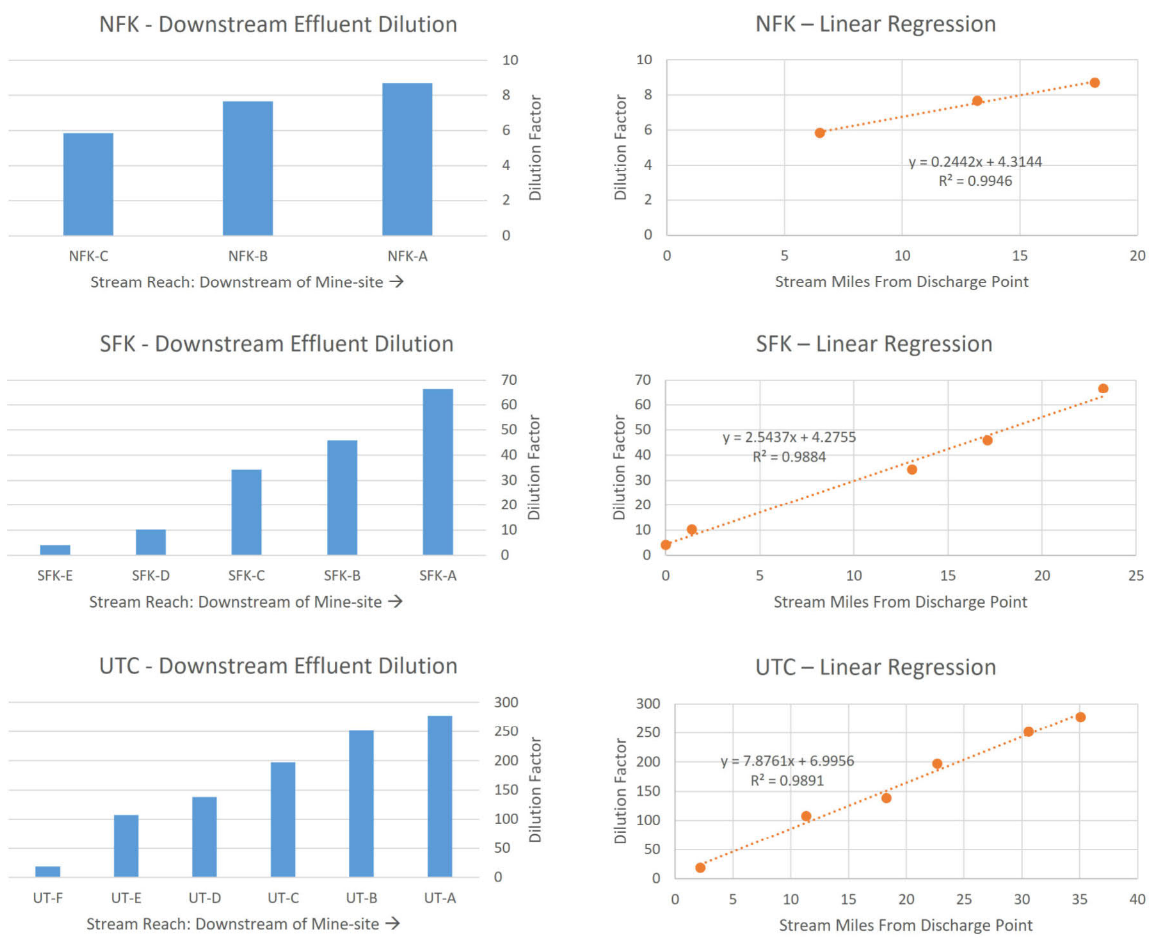
Mass balance calculations were performed for the operations phase.

Water quality values used for effluent are based on 90th percentile predicted water quality data.
Stream flows used in the calculations are based on the average of the predicted average annual reduced flows for reaches A through F in each stream.
kg/year = kilogram per year
mg/L = milligrams per liter
NFK = North Fork Koktuli
SFK = South Fork Koktuli
TDS = total dissolved solids
TSS = total suspended solids
UTC = Upper Talarik Creek

Source: Knight Piésold 2019r, HDR 2019g

An examination of the dilution factor as it relates to the distance downstream of the effluent discharge points can provide insights to how quickly changes in water chemistry are tapered. A simple linear regression analysis was applied to examine the average rate at which effluent is diluted downstream from discharge points. Figure K4.18-15 depicts the results of the effluent dilution calculations and linear regression analysis for effluent discharged into the NFK, SFK, and UTC. The results indicate that close to the WTP discharge points, effluent would be diluted approximately six times in the NFK, three times in the SFK, and 20 times in the UTC. At the farthest stream reaches in the analysis area, effluent is anticipated to be diluted roughly 9 times by the time it reaches NFK-A, and 65 times in the SFK as effluent reaches SFK-A, both of which are near the Koktuli River confluence; and would be roughly 275 times diluted in the UTC as it reaches UT-A near Iliamna Lake. Further dilution would occur as UTC enters Iliamna Lake, or NFK and SFK converge and flow down the Koktuli, Mulchatna, and Nushagak rivers towards Bristol Bay. For example, based on an average annual stream flow of about 20,000 cfs in the lower Nushagak River near Ekwok (USGS 2020f) compared to stream flows of about 200 cfs in reach A of the NFK and SFK, effluent entering these streams would be further diluted past their confluence by about 100 times.

This analysis is a high-level approach to estimate potential effluent dilution downstream of the WTP discharge points, and is subject to limitations and uncertainties as a result of assumptions and complexities of the hydrologic system. The analysis assumes that all effluent mixes into the streams and is flushed fully downstream on an average annual basis. The results are not intended to imply that the average mass loading values in Table K4.18-21 would be diluted by these factors; rather they indicate that mass load changes could be higher than the average close to the effluent discharge points and lower than the average in downstream reaches. The analysis does not account for seasonal variations, or for the potential for transport and storage of water or mass released from WTPs into and out of connected wetland environments, which may slow or increase the rate of effluent dilution. This analysis also does not account for stream+effluent water that would be lost to groundwater; however, the average annual stream flows used in the analysis are supported in part by groundwater baseline flow, and it is assumed that stream+effluent water entering the subsurface would mix with groundwater, migrate to gaining stream reaches, and continue to flow downstream.



Sources: Knight Piesold 2019r

US Army Corps of Engineers

Notes:
1. Dilution factor based on the ratio [effluent volume + reduced streamflow volume] / effluent volume.
2. Volumes based on predicted average annual effluent discharge and reduced streamflow for each stream reach at end-of-mining in Knight Piesold (2019r).

DOWNSTREAM EFFLUENT DILUTION