# K4.17 GROUNDWATER HYDROLOGY

Information on the development and calibration of the groundwater model at the mine site is provided in Section 3.17, Groundwater Hydrology, and Appendix K3.17. Use of the model to predict impacts to groundwater from mine site activities is described in Section 4.17, Groundwater Hydrology. This appendix contains additional technical information regarding the following impact analyses using the groundwater model:

- Input parameters and scenarios used in the model
- Open pit groundwater zones of influence
- Uncertainty analysis
- Groundwater flow and seepage beneath the bulk tailings storage facility (TSF) and main water management pond (WMP)
- Planning for potential upset conditions

#### K4.17.1 Model Development, Calibration, Input Scenarios, and Uncertainty

The groundwater model has been developed over a number of years, currently contains 12 layers, and is presented in a comprehensive report by BGC (2019a). The model was subsequently updated in a series of memoranda by BGC (2019b, d, j) to simulate active dewatering in the open pit, improve representations of the WMPs and pyritic TSF, more accurately represent conceptual drainage and seepage control measures at the bulk TSF, and reflect minor updates in the general arrangement of mine site facilities.

The groundwater model analysis considered a range of scenarios that evaluated variability in hydrogeologic properties and model boundary conditions. Model parameters representing hydraulic conductivity, streambed hydraulic conductivity, sediment thickness, fault hydraulic conductivity, bulk TSF properties, and recharge were varied by amounts representative of possible field condition variability. For example, hydraulic conductivity values measured in the weathered bedrock zone vary in the general vicinity by about five orders of magnitude (Table K3.17-2), and the weathered and fractured bedrock zone is known to be a pervasive aquifer in the area (Figure 3.17-3).

A summary of sensitivity analyses initially conducted on the model by BGC (2019a) is presented in Table K4.17-1. A review of these revealed that one of the largest sources of model uncertainty is the hydraulic conductivity of bedrock, both weathered and competent bedrock. The wide range of field-measured values of hydraulic conductivity supports this finding. Therefore, the uncertainty of the groundwater model results was re-evaluated by running numerous model simulations with both high K (K × 10 = scenario S7) and low K (K × 0.1 = scenario S8) values of hydraulic conductivity for all bedrock units. The high K scenario further contained in-pit and perimeter wells for the end of mining (to maximize predicted groundwater production), and the low K scenario included no wells at the end of mining (to minimize predicted groundwater production).

Revised groundwater flow estimates for the base case and high and low K scenarios are provided in Table K4.17-2. These conditions produced relatively high and low quantities of groundwater flow to the pit/dewatering wells, and are considered to reasonably bracket probable actual conditions at the site. Additional sensitivity analyses conducted on the TSFs and main WMP are discussed later in this appendix. In addition to affecting groundwater inflow to the pit, variations in the parameters also result in different zones of influence. The results of the high K and low K scenario simulations are propagated through other related impact predictions of this EIS: water treatment plant (WTP) sizing (Section 4.18, Water and Sediment Quality), wetland impacts (Section 4.22, Wetlands and Other Waters/Aquatic Sites), and changes to streamflow values (Section 4.16, Surface Water Hydrology).

Scenario	Description	Open Pit Groundwater	Bulk TSF Seepage	Basef	low Red (%)	uction	Effect on Predictive	
		Extraction (US gpm)	(US gpm)	NFK	SFK	UTC	Results	
S0	Base Case	980	630	14	7	0.7	-	
S1	Unconsolidated sediments K × 10	1,300	1,700	20	14	3.5	Significant	
S2	Unconsolidated sediments K × 0.1	740	500	12	5	0.0	Significant	
S3	Weathered bedrock K × 10	1,300	1,000	15	7	1.5	Significant	
S4	Weathered bedrock K × 0.1	820	590	13	7	0.5	Significant	
S5	Competent bedrock K × 10	2,900	1,200	13	7	4.3	Significant	
S6	Competent bedrock K × 0.1	700	610	14	7	0.4	Significant	
S7	Bedrock K × 10	3,000	1,700	14	7	4.8	Significant	
S8	Bedrock K × 0.1	600	570	13	7	0.4	Significant	
S9	Recharge × 1.5	1,100	750	14	7	0.8	Significant	
S10	Recharge × 0.5	680	540	13	7	0.6	Significant	
S11	Streambed K × 10	980	630	13	7	0.7	Insignificant	
S12	Streambed K × 0.1	980	630	15	7	0.7	Insignificant	
S13	Unconsolidated sediments thickness × 1.25	980	630	13	7	0.7	Insignificant	
S14	Unconsolidated sediments thickness × 0.75	980	630	14	7	0.7	Insignificant	
S15	High K faults	2,600	630	14	7	5.8	Significant	
S16	Low K faults	960	630	14	7	0.7	Insignificant	
S17	Bulk TSF tailings K increased by a factor of 10	980	1,800	14	7	0.7	Significant	
S18	Bulk TSF tailings K decreased by factor of 100	980	320	14	7	0.7	Significant	
S19	Bulk TSF pond increase to 2,270 acres (920 ha) water level at 1,700 feet	980	780	14	7	0.7	Significant	
S20	Bulk TSF tailings saturated with water level ranging from 1,690 feet to 1,720 feet	980	5,300	14	7	0.7	Significant	

#### Table K4.17-1: Initial Sensitivity Simulations Results for End of Mining Conditions

Notes:

All simulation results for the scenario without pumping wells. NFK, SFK, and UTC baseflow reduction reported above gaging stations NK100A1, SK100B1, and UT100D, respectively gpm = gallons per minute

ha = hectares

NFK = North Fork Koktuli

SFK = South Fork Koktuli

TSF = tailings storage facility

US = United States

UTC = Upper Talarik Creek

Source: BGC 2019a, Table 9-4

# Table K4.17-2: Range of Revised Sensitivity Results for High and Low K Scenarios Used in Subsequent Modeling, End of Mining

Scenario	Description	Open Pit Groundwater Extraction (US gpm)	Bulk TSF Seepage with Drainage Updates <sup>1</sup> (US gpm)
S0	Base Case	1,500 <sup>2</sup>	770
S7	Bedrock K × 10	4,300 <sup>2</sup>	770
S8	Bedrock K × 0.1	600 <sup>3</sup>	640

Notes:

<sup>1</sup>Conceptual drainage improvements, including foundation preparation, underdrains, embankment toe ditches, chimney and blanket drains at main embankment, seepage control at south embankment, and tailings segregation zones (BGC 2019j)

<sup>2</sup>Base case and S7 (high K) scenarios based on pit groundwater extraction with dewatering wells to provide conservative (high) range of pumping and drawdown effects (BGC 2019j)

<sup>3</sup>S8 scenario (low K) based on pit groundwater extraction without wells to provide low range of pumping and drawdown effects (BGC 2019a)

gpm = gallons per minute TSF = tailings storage facility US = United States Sources: BGC 2019a, j, m, o

# K4.17.2 Pit Zone of Influence

#### K4.17.2.1 Operations

Under base-case conditions (i.e., the calibrated model with in-pit and dewatering wells), most of the zone of influence from dewatering the pit is in the SFK watershed, with areas extending into upper tributary watersheds of the UTC watershed. The pit zone of influence also merges with zones of influence surrounding the pyritic TSF and open pit WMP (Figure 4.17-2). Modeled drawdown/mounding results for low K and high K bedrock scenarios at the end of operations are shown on Figure K4.17-1 and Figure K4.17-2, respectively.

The reduction in groundwater discharge to nearby headwaters catchments under two sensitivity analysis scenarios (the high K and low K scenarios) was also modeled (BGC 2019o). These analyses were conducted by evaluating predicted changes in base flow at stream segments (the downstream end of which are termed radial nodes) at all streams surrounding the mine pit that would be affected. Under the high K scenario (the broadest area of those simulated, Figure K4.17-2), the largest changes are found to occur in drainages removed during mining, while other drainages show reductions ranging from 0 to 0.6 cubic foot per second (cfs) compared to baseline conditions. Table K4.17-3 and Table K4.17-4 show modeled changes in streamflow for the base case (S0) and high K scenario (S7), respectively. Modeled streamflow reductions for the low K scenario (S8) for the non-mined-out segments were less than for the base-case scenario.

# K4.17.2.2 Closure and Post-Closure

The predicted rate of lake-level rise in the pit lake at closure in relation to pit backfill is shown on Figure K4.18-6. Once the lake level reaches an elevation of 890 feet above mean sea level (amsl) (known as the Maximum Managed, or MM elevation), pumping of water from the lake would commence to maintain the lake as a groundwater discharge-type lake and create hydraulic containment. The conceptual basis for groundwater discharge lakes was developed by Winter (1976) and discussed further by Webster et al. (2012). A modeled groundwater flow system configuration is shown in Figure 4.17-6 and Figure 4.17-8. These figures show that the hydraulic heads in the groundwater system surrounding and beneath the pit lake would be higher than the MM pit lake elevation of 890 feet amsl. Simulations were performed for both high K and low K lake sediment (tailings and waste rock backfill) scenarios (BGC 2019n). Groundwater levels would

be monitored during closure and post-closure to determine whether the MM elevation needs to be adjusted to prevent groundwater outflow from the pit (Knight Piésold 2018n). The groundwater inflow rate to the pit would gradually decrease during the first 20 years of closure as the pit lake level rises. The long-term steady-state average annual groundwater inflow to the pit during post-closure is estimated to be about 800 gallons per minute (about 1.8 cfs) (BGC 2019a).

		Baseline	Baseflow Red	duction (cfs)			
Watershed	Radial Node	Baseflow (cfs)	End-of- Mining	Post- Closure	Comment		
	SFK1	1.1	1.1	1.1	Mined out during open pit development		
	SFK2	0.9	0.9	0.9	Mined out during open pit development		
South Fork	SFK3	0.8	0.8	0.04	Removed during mine development, re-established at closure		
Koktuli River	SFK4	0.6	0.2	0.04	-		
	SFK5	0.3	0.0	0.0	-		
	SFK6	0.5	0.01	0.0	-		
	SFK7	0.6	0.0	0.0	-		
	SFK8	3.1	0.0	0.01	-		
	SFK9	2.8	0.0	0.0	-		
North Fork Koktuli	NFK1	1.8	1.8	0.6	Removed during mine development, re-established at closure		
River	NFK2	0.05	0.05	0.0	Removed during development, re-established at closure		
	UTC1	0.0	0.0	0.0	-		
	UTC2	0.7	0.3	0.1	-		
	UTC3	0.03	0.0	0.0	-		
	UTC4	0.1	0.0	0.0	-		
Upper Talarik	UTC5	0.1	0.0	0.0	-		
Creek	UTC6	0.4	0.01	0.0	-		
	UTC7	0.2	0.0	0.0	-		
	UTC8	0.6	0.0	0.0	-		
	UTC9	0.3	0.0	0.0	-		
	UTC10	2.3	0.0	0.0	-		

Table K4.17-3: Summary of Radial Node Baseflow Reduction Analysis: Scenario S0

Notes:

Predicted baseflow reduction less than 0.01 cubic foot per second (cfs) reported as 0.0 cfs

cfs = cubic foot per second

Source: BGC 2019o, Table 2

		Deseline	Baseflow Re	duction (cfs)		
Watershed	Radial Node	Baseflow (cfs)	End-of- Mining	Post- Closure	Comment	
	SFK1	1.2	1.2	1.2	Mined out during open pit development	
	SFK2	0.9	0.9	0.9	Mined out during open pit development	
South Fork	SFK3	0.8	0.8 0.3		Removed during mine development, reestablished at closure	
Koktuli River	SFK4	0.7	0.4	0.2	-	
	SFK5	0.6	0.05	0.0	-	
	SFK6	0.5	0.05	0.0	-	
	SFK7	0.8	0.04	0.0	-	
	SFK8	4.1	0.4	0.1	-	
	SFK9	2.9	0.0	0.0	-	
North Fork	NFK1	1.8	1.8	0.8	Removed during mine development, re-established at closure	
River	NFK2	0.07	0.07	0.05	Removed during mine development, re-established at closure	
	UTC1	0.0	0.0	0.0	-	
	UTC2	0.9	0.6	0.3	-	
	UTC3	0.08	0.02	0.0	-	
	UTC4	0.2	0.05	0.01	-	
Upper Telerik	UTC5	0.2	0.04	0.01	-	
Creek	UTC6	0.6	0.09	0.02	-	
	UTC7	0.2	0.01	0.0	-	
	UTC8	0.6	0.01	0.0	-	
	UTC9	0.3	0.0	0.0	-	
	UTC10	2.6	0.0	0.0	-	

#### Table K4.17-4: Summary of Radial Node Baseflow Reduction Analysis: Scenario S7 (high K)

Notes:

Predicted baseflow reduction less than 0.01 cubic foot per second (cfs) reported as 0.0 cfs cfs = cubic foot per second

Source: BGC 2019o, Table 3





Similar to operations, the post-closure model results for the low K and high K scenarios show smaller and larger, respectively, zones of influence around the lake compared to the base-case model (Figure K4.17-3 and Figure K4.17-4). The zone of influence surrounding the pit lake is projected to extend more than 1.5 miles northwest of the pit lake under the high K scenario. Other projected changes to the water table associated with the rock quarries and the bulk TSF are also shown. For these simulations, the main WMP and the pyritic TSF and their respective underdrain systems were assumed to have been removed.

To test the modeled pit capture zone against field data, a comparison was conducted of the projected hydraulic head at the bottom of the pit lake (which would be equal to the elevation of the lake surface, assuming static, fresh, and isothermal water in the lake) and hydraulic head data collected at deep monitoring well WB-1, approximately 3,000 feet east of the pit. The land surface elevation at the well site is approximately 935 feet amsl. Water levels measured at multiple depths up to 4,000 feet deep between 2006 and 2012 were almost all less than 25 feet below land surface (Schlumberger 2015a: Appendix 8.1K), meaning that the hydraulic head (at most depths, see below) was at an elevation of more than 910 feet amsl, compared to the not-to-exceed lake elevation (head) of 900 feet. This means that the deeper groundwater levels had a higher head than the lake would have, and that deep groundwater below the pit bottom would flow upwards toward the bottom of the lake. The exception to these measurements is that three water-level measuring locations between depths of 3,800 and 4,000 feet exhibited heads between 25 and 35.7 feet below ground surface between 2009 and 2012. Largely because well WB-1 was drilled 3.000 feet from the pit location, these deeper values do not change the conclusion that the notto-exceed lake elevation of 900 feet amsl would achieve hydraulic containment of the pit lake capture zone, and groundwater beneath the lake would flow towards the lake.

The hydraulic head data described above can also be used to evaluate uncertainty of the groundwater model. Figure 4.17-6 illustrates that the modeled hydraulic head at an elevation of approximately -3,000 feet amsl near the WB-1 well location during post-closure is expected to be more than 100 feet higher than measured heads at that location. As a result of the uncertainty related to the differences between modeled and measured values of hydraulic head, additional monitoring regarding the actual groundwater conditions (values of hydraulic head) at depth below the pit or near the pit lake are included in Table 5-2 and Appendix M1.0, Mitigation Assessment, to confirm or revise model findings and water pumping plans as needed; and to confirm that hydraulic containment would be maintained.

An important aspect of planning for long-term pumping of water from the pit lake to maintain hydraulic containment is to plan for possible upset conditions that could interfere with planned pumping. The model was used to evaluate various sensitivity analysis scenarios under which the pit lake may be more likely to lose hydraulic containment should the lake level rise (BGC 2019i). The most sensitive scenario was S15, in which faults were simulated as high hydraulic conductivity zones. This simulation (Figure K4.17-5) showed that even under these conditions, the lake would not lose hydraulic containment until the lake level rose to approximately 950 feet amsl, approximately 50 feet above the not-to-exceed level of 900 feet amsl.







Section 4.17, Groundwater Hydrology, explains that it would take approximately 1 year for the pit lake to rise 50 feet in the event of complete failure of pumping of water from the pit lake for any reason, and assuming a similar rate of lake-level rise as projected under late-closure conditions. Failure of simple mechanical systems such as pumps, valves, and pipes could likely be repaired within that timeframe.

Other conditions that could prevent planned operation of the water treatment plant (WTP) facilities without major modification include:

- Underestimation of net precipitation as a result of climate irregularities, multiple backto-back flood events, or climate change
- Increased groundwater inflow to the pit lake through fractures or faults compared to currently predicted amounts
- Increases in levels of salinity or other parameters in the water of the pit lake that require different water treatment methodologies than planned or implemented

These conditions would typically be foreseeable, and develop with long lead times; therefore, any necessary upgrades to the water treatment facilities would likely have sufficient lead time to be addressed. Monitoring of pit lake levels and water quality conducted in post-closure (PLP 2019-RFI 135) would enable predictions of these conditions and adjustments to post-closure WTP operations if necessary. Recommendations are also included in Appendix M1.0, Mitigation Assessment, for update of the groundwater model every 5 years in closure to refine predictions of lake level rise as a result of climate change or increased fracture flows.

Some low-probability events are possible during post-closure. It is important to consider these because according to probability theory, events considered low probability in any given year become more likely under long-term timeframes. Such events could include:

- Failure of a portion of the pit wall could result in destratification and mixing of the pit lake water, and a need to treat water with higher concentrations of dissolved constituents than planned.
- Occurrence of a major earthquake that could alter groundwater flow patterns and change the conditions under which hydraulic containment would be maintained. One potential response to such a condition would be to pump and treat more water from the lake, resulting in lower lake levels to re-establish hydraulic containment.
- Sudden failure of one or more major components of the water treatment plant, possibly related to the remote location, extreme weather, deterioration, malfunction, human error, or unforeseen conditions.

Fully addressing these conditions within a 1-year timeframe could be challenging, because of the expected need to design, obtain regulatory approval, and procure and construct the needed infrastructure, possibly under difficult seasonal conditions. Therefore, recommendations are included in Appendix M1.0, Mitigation Assessment, for consideration of the above types of failure scenarios during planning, design, and approval of WTP processes.

#### K4.17.3Seepage from Tailings Storage Facilities and Main Water Management Pond

**Bulk TSF**—Groundwater model sensitivity analyses were performed under a variety of conditions to evaluate potential escapement of groundwater from the bulk TSF (BGC 2019a, d).

Scenarios modeled were:

- S1: Unconsolidated sediments K increased by factor of 10
- S2: Unconsolidated sediments K decreased by factor of 10
- S7: Bedrock K increased by factor of 10
- S8: Bedrock K decreased by factor of 10
- S15: Faults simulated as high K features
- S16: Faults simulated as low K features
- S17: Bulk TSF tailings K increased by a factor of 10
- S18: Bulk TSF tailings K decreased by a factor of 10
- S20: Bulk TSF tailings saturated with water level ranging from 1,700 feet to 1,720 feet
- S25: Bulk TSF tailings groundwater recharge rate increased to 15 inches per year (in/yr)
- S26: Bulk TSF coarse tailings saturated
- S27: Coarse tailings lateral extent increased to 3,600 feet
- S28: Coarse tailings lateral extent decreased to 1,000 feet
- S29: Coarse tailings extent increased to 3,600 feet with Bulk TSF coarse tailings saturated
- S30: Coarse tailings extent decreased to 1,000 feet with Bulk TSF coarse tailings saturated

Particle tracking simulations were conducted for each end-of-mining sensitivity simulation. Particle tracking results showed that under all scenarios except one (Scenario S7), essentially all particles released report to a seepage collection pond (SCP). Scenario S7 exhibited flow bypassing the SCPs (Figure K4.17-6) as a result of groundwater flow bypassing perimeter ditches and underdrains through deeper bedrock flow paths. Scenario S7 was performed using a high hydraulic conductivity (K) scenario for bedrock, and the resulting simulation showed that baseline groundwater levels were poorly represented; the quality of the calibration had deteriorated; and that flow of particles past both SCPs is considered improbable (BGC 2019d). Localized areas of elevated bedrock K are likely, and further site characterization, hydraulic testing, and model simulations to support future stages of design in the vicinity of the bulk TSF have been added as suggested mitigation to Appendix M1.0, Mitigation Assessment.

The potential influence of a mapped fault (see Figure 3.17-1) along the western margin of the bulk TSF was investigated (BGC 2019I). As summarized by BGC (2019I):

Available hydrogeologic data (e.g., hydraulic conductivity and groundwater levels) suggest that the fault does not have a controlling effect on groundwater flow. Results of baseline simulations further indicate that bedrock hydraulic properties in the vicinity of the fault may be similar to the surrounding bedrock. Nevertheless, results of predictive simulations for end-of-mining and post-closure conditions indicate that a fault along the western margin of the Bulk TSF could influence seepage pathways from the facility if the K of the faulted bedrock is sufficiently high.

The location of the fault and a particle tracking analysis are shown in Figure K4.17-7. Other simulations with less-permeable fault assumptions resulted in no loss of containment of groundwater flow. For the simulation shown in Figure K4.17-7, the simulated bulk TSF fault is predicted to result in a depression in groundwater levels that is not evident from available groundwater level observations. Also, the magnitudes of computed residuals (i.e., difference between observed and simulated values) are greater than for the base case, indicating this

scenario results in a poorer representation of the hydrogeologic system. For example, the largest residuals are predicted for the scenario shown in Figure K4.17-7, where groundwater levels are underpredicted by up to 400 feet, suggesting that the simulation may be a poor representation of groundwater flow in the area of the fault.

Further hydrogeologic data collection at future stages of project design to characterize the hydraulic properties of the bedrock in the vicinity of this interpreted fault to allow for design of appropriate mitigation (e.g., grouting, partial liner placed over the fault trace, seepage collection wells) is recommended. This mitigation measure is included in Appendix M1.0, Mitigation Assessment, and has been adopted by PLP as shown in Table 5-2.

**Main WMP**—The groundwater model results for the main WMP indicate that groundwater levels would be lowered by several tens of feet in the area surrounding the facility due to the liner blocking natural recharge from reaching groundwater, and the effects of the underdrain and water collection and pumping system on shallow groundwater levels (BGC 2019c). Like the pyritic TSF, removing the main WMP after closure would allow natural recharge to be re-established and groundwater elevations to recover during post-closure.

The model was also used to predict the fate of liner leakage. Total leakage through the liners beneath the main WMP and the pyritic TSF was assumed to be 16 gallons per minute (gpm), and leakage through the liner beneath the open pit WMP was assumed to be 1.6 gpm because it is smaller (BGC 2019a), Contact water that leaks to shallow groundwater would be captured by the underdrain, sump, pumping, and treatment system, creating an area of hydraulic containment surrounding the main WMP.

Implementation of the monitoring plan (PLP 2019g) and associated groundwater monitoring would be used to confirm hydraulic containment of contact water from the main WMP (see Chapter 5, Mitigation). Prior to decommissioning of the main WMP seepage collection system, the quality of water collected by the system would be determined to meet appropriate water quality criteria, and the monitoring/pumpback wells would continue to operate as long as required to intercept potential leakage (Knight Piésold 2018b, n).





# 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 inhouse and GoldSim Technology Group GoldSim<sup>®</sup> 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.

Operations												
Month		Total R	elease from WTP	s (cfs)								
WOILII	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							
Мау	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							

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

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<sup>®</sup> 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.

		Back	ground		Overburden	Other	Rock			Open Pit				
Demonsterre	Direct	Non-Contact Surface Water	Non-Contact Surface Water	Groundwater	<u>Ctookriiloo</u>	Quarried Rock Fill (Dams)	Quarried Rock Fill (Dams)	Wall	Wall Runoff	Wall Runoff	In-Pit Stockpile	In-Pit Stockpile		
Parameters	<b>Precipitation</b> <sup>b</sup>	NFK (NK119A)	SFK SK100F	Pit Area	Stockpiles	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 <sup>c</sup>	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	<0.000009	0.0000011	0.0000011	_	0.000035	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	<0.00006	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	0.000078	0.000073	0.000078	0.000078	_	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		

Table K4.18-2: Predicted Water Quality from Mine Site Geochemical Sources<sup>a</sup>—Part 1

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

 Adjustments made for specific location and orographic effects. Tailings Pond Adjustment values were applied for Al, SO<sub>4</sub>, Fe, Cu and Mn in the Bulk TSF and Pyritic TSF
 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.</li> 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

			Tai	lings			Pyritic TSF V Oper	Naste Rock— ations	Pyritic TSF Waste Rock—D	e-Commissioning	Open Pit–	-Closure
Parameters	Bulk TSF Water <sup>b</sup>	Fresh Ore Leaching + Reagent	Pyritic Tailings	Ore	Tailings Pond Adjustment <sup>d</sup>	Pyritic Tailings Sand Wedge	PAG WR	Leached WR	Exposed Waste Rock	Exposed Waste Rock	Backfilled Waste Rock	Backfilled Waste Rock
	Supernatant <sup>b</sup>	_	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/m²/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 <sup>c</sup>	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 <sup>e</sup>	0.1	0.000036	<0.000009	—	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

#### Table K4.18-2: Predicted Water Quality from Mine Site Geochemical Sources<sup>a</sup>—Part 2

Notes:

<sup>a</sup> Values in table represent 95th percentile geochemical source terms

<sup>b</sup> Rows indicate source and sub-source

<sup>6</sup> Bold values indicate scalaes 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 <sup>d</sup> Adjustments made for specific location and orographic effects. Tailings Pond Adjustment values were applied for AI, SO<sub>4</sub>, Fe, Cu and Mn in the Bulk TSF and Pyritic TSF <sup>e</sup> 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 <sup>f</sup> Metals values presented represent dissolved water concentrations.

Nitrate-N = Nitrate as nitrogen; the concentration of nitrogen in solution due to nitrates. kg = kilogram

kg = kilogram mg/L = milligrams/liter mg/m<sup>2</sup> = milligrams/square meters mg/t = milligrams/tonne PAG = potentially acid-generating TSF = tailings storage facility WP = waste rock

WR = waste rock

— = no data

Source: SRK 2018a, 2019e

Table K4.18-3: 50th	Percentile Modeled Mass	Loads—Final Year of Operations
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Barrandard	WTP #1 Inflows	WTP #2 Inflows	Open Pit Water Management Pond	Bulk TSF <sup>a</sup>	Main Embankment Seepage Collection Pond	Pyritic TSF <sup>a,b</sup>	Main Water Management Pond
Parameter	Maximum Monthly Load <sup>d</sup> (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)
TDS⁰	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 <sup>c</sup>	WTP #1 Inflows	WTP #2 Inflows	Open Pit Water Management Pond	Bulk TSF <sup>a</sup>	Main Embankment Seepage Collection Pond	Pyritic TSF <sup>a,b</sup>	Main Water Management Pond
	Maximum Monthly Load <sup>d</sup> (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<sub>4</sub>, 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<sub>4</sub>, Ca, Mg, K, Na, and Si

kg = kilogram

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











## 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.

	Open Pit Water Management Pond			Bulk TSF		Main Embankme	Main Embankment Seepage Collection Pond			Pyritic TSF		Main Water Management Pond			
Parameters	Ma	aximum Mont	hly	Maximum Monthly		Ма	ximum Monthly		Ma	aximum Monthly		Ma	ximum Monthly		
(iiig/c)	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
рН	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

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 <sub>3</sub>	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 AI, SO<sub>4</sub>, 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, CI, F, SO<sub>4</sub>, 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)  $\times$  2.497 + magnesium concentration (mg/L)  $\times$  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

		WTP #1		WTP #2 Maximum Monthly			
Parameters		Maximum Monthly					
(	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	
рН	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

		WTP #1		WTP #2				
Parameters (mg/L)		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 CaCO₃	121	141	149	982	1,299	1,585		

Table K4.18-5:	Predicted Wate	er Quality Inflows	for WTPs in	Operations
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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<sub>4</sub>, 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<sub>3</sub>) = 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<sup>1</sup>, 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

<sup>&</sup>lt;sup>1</sup> 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



US Army Corps of Engineers.

PEBBLE PROJECT EIS

**OPEN PIT SURFACE WATER ELEVATIONS** 

FIGURE K4.18-6





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<sup>®</sup> 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).

		Clos	ure Phase 1			Closure Phase 2								
Marath		Tot	al Release from WTPs	(cfs)		Mariath	Total Release from WTPs (cfs)							
wonth	1st Percentile	10th Percentile	50th Percentile	90th Percentile	99th Percentile	Month	1st Percentile	10th Percentile	50th Percentile	90th Percentile	99th Percentile			
January	7	41	50	58	67	January	0	0	0	0	0			
February	6	17	50	53	67	February	0	0	0	0	0			
March	6	9	50	51	65	March	0	0	0	0	0			
April	5	7	49	52	66	April	0	0	0	0	0			
Мау	36	55	62	65	68	May	0	0	0	0	0			
June	52	62	66	68	68	June	0	0	0	0	0			
July	36	55	66	67	67	July	0	0	0	0	0			
August	46	57	66	67	67	August	0	0	0	0	0			
September	55	58	66	67	67	September	0	0	0	0	0			
October	23	53	64	67	67	October	0	0	0	0	0			
November	19	50	55	66	67	November	0	0	0	0	0			
December	7	50	51	64	67	December	0	0	0	0	0			
Annual Average	25	43	58	62	67	Annual Average	0	0	0	0	0			
Closure Phase 3								Clos	ure Phase 4					
Marsth		Total Release	from WTPs (cfs)			Marsth		Tot	al Release from WTPs	(cfs)				
wonth	1st Percentile	10th Percentile	50th Percentile	90th Percentile	99th Percentile	Month	1st Percentile	10th Percentile	50th Percentile	90th Percentile	99th Percentile			
January	4	4	31	44	52	January	2	4	5	19	24			
February	3	4	31	35	46	February	3	3	5	10	19			
March	4	4	11	31	52	March	2	2	5	5	24			
April	2	2	11	34	43	April	1	2	5	11	19			
Мау	14	37	43	44	52	Мау	9	16	18	19	24			
June	35	44	44	45	52	June	11	19	18	22	24			
July	12	39	44	50	52	July	0	15	18	24	34			
August	24	41	44	52	52	August	10	18	18	24	34			
August September	24 35	41 43	44 44	52 52	52 52	August September	10 13	18 19	18 18	24 24	34 30			
August September October	24 35 6	41 43 36	44 44 44	52 52 52 52	52 52 52	August September October	10 13 1	18 19 16	18 18 19	24 24 23	34 30 29			
August September October November	24 35 6 4	41 43 36 28	44 44 44 41	52 52 52 52 51	52 52 52 52 52	August September October November	10 13 1 3	18 19 16 5	18 18 19 18	24 24 23 21	34 30 29 25			
August September October November December	24 35 6 4 4	41 43 36 28 5	44 44 44 41 31	52 52 52 52 51 46	52 52 52 52 52 52 52	August September October November December	10 13 1 3 2	18 19 16 5 5	18 18 19 18 7	24 24 23 21 19	34       30       29       25       24			

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

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

	Open Pit Water Management Pond			Bulk TSF		Main Embankment Seepage Collection Pond			Pyritic TSF			Main Water Management Pond			Open Pit <sup>d</sup>			
Parameters (mg/L)	Ма	ximum Mont	hly	Maximum Monthly		Ма	ximum Mont	hly	Maximum Monthly			Max	ximum Montl	nly	Ма	ximum Month	ıly	
(	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
рН	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
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Parameters (mg/L)	Open Pit Water Management Pond			Bulk TSF		Main Embankment Seepage Collection Pond		Pyritic TSF			Main Water Management Pond			Open Pit <sup>d</sup>				
	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 <sub>3</sub>	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 AI, SO<sub>4</sub>, 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, CI, F, SO<sub>4</sub>, 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<sub>3</sub>) = calcium concentration (mg/L)\*2.497 + magnesium concentration (mg/L)\*4.118 pH was not modeled

 $CaCo_3 = calcium carbonate$  mg/L = milligrams/literTSF = tailings storage facility WMP = water management pond

WTP = water treatment plant

Source: Knight Piésold 2019s

		Bulk TSF		Main Emb	ankment Seepage Colle	ection Pond	Open Pit			
Parameters		Maximum Monthly			Maximum Monthly			Maximum Monthly		
(iiig/c)	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	
рН	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

		Bulk TSF		Main Emba	ankment Seepage Colle	ction Pond	Open Pit			
Parameters (mg/L)		Maximum Monthly			Maximum Monthly		Maximum Monthly			
(··· <b>ʊ</b> ·=/	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 <sub>3</sub>	482	829	966	2,298	2,298	2,299	119	144	168	

Notes:

Tailings pond adjustment values were applied for AI, SO<sub>4</sub>, 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, CI, F, SO<sub>4</sub>, 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<sub>3</sub>) = 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

		Bulk TSF		Main Emb	oankment Seepage Colle	ction Pond	Open Pit			
Parameters (mg/L)		Maximum Monthly			Maximum Monthly			Maximum Monthly		
(	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	
рН	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

		Bulk TSF		Main Emb	oankment Seepage Collec	ction Pond	Open Pit				
Parameters (mg/L)		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 CaCO₃	45	100	163	2,310	2,311	2,311	59	64	70		

Notes: Tailings pond adjustment values were applied for AI, SO<sub>4</sub>, 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<sub>4</sub>, 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<sub>3</sub>) = calcium concentration (mg/L)\*2.497 + magnesium concentration (mg/L)\*4.118

pH was not modeled. CaCo<sub>3</sub> = calcium carbonate mg/L = milligrams per liter

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

		Bulk TSF		Main Emba	ankment Seepage Collectio	on Pond	Open Pit					
Parameters		Maximum Monthly			Maximum Monthly			Maximum Monthly				
(iiig/L)	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile			
рН	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	0.0000854	0.0000854	0.0000854	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

		Bulk TSF		Main Emba	ankment Seepage Collectio	n Pond	Open Pit					
Parameters (mg/l)		Maximum Monthly			Maximum Monthly		Maximum Monthly					
(···· <b>ɡ</b> · <b>–</b> )	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		0.01094	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 CaCO₃	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 AI, SO<sub>4</sub>, 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, CI, F, SO<sub>4</sub>, 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<sub>3</sub>) = 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

	Closure Phase 1								Closure Pha	se 3			Closure Phase 4					
<b>D</b>	WTP #	3 Open Pit I	nflows	v	VTP #2 Inflow	s	WTP	#3 Open Pit In	flows	WTF	P#3 SCP Inf	lows	WTP	#3 Open Pit In	flows	V	VTP #3 SCP In	flows
Parameters (mg/L)	Мах	kimum Mont	thly	Ма	ximum Mont	hly	Ma	aximum Month	ly	Ma	ximum Mon	thly	Ma	aximum Month	ıly		Maximum Mon	thly
	10th Percentile	50th Percentile	90th Percentile	10th Percentile	50th Percentile	90th Percentile												
pН	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

			Closur	e Phase 1					Closure Pha	ise 3			Closure Phase 4						
Dowowootowo	WTP #	3 Open Pit I	nflows	v	/TP #2 Inflow	/S	WTP	#3 Open Pit In	flows	WTF	#3 SCP Inf	lows	WTP	#3 Open Pit In	flows	W	TP #3 SCP In	flows	
(mg/L)	Max	kimum Mont	thly	Ма	ximum Mont	hly	Ma	aximum Month	ly	Ma	ximum Mon	thly	Ма	aximum Month	nly	Maximum Monthly			
	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 CaCO₃	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	

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

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, CI, F, SO<sub>4</sub>, Ca, Mg, K, Na, and Si Hardness Values were calculated based on the following: hardness (CaCO<sub>3</sub>) = 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<sub>3</sub> = 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.

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

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

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 ( $^{\circ}$ C) to 15 $^{\circ}$ 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 $^{\circ}$ 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 $^{\circ}$ 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.









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 nearsurface (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).

## K4.18.2Water 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).





**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.

Barrantan		Ор	en Pit WTP (WTP #1)				N	lain WTP (WTP #2)		
Parameter			Was	ste Streams to Pyritic	TSF			Wast	te Streams to Pyritio	: TSF
mg/L	Influent Water	Treated Water	Sludge Total	Soluble Sludge	Brine	Influent Water	Treated Water	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 <sub>3</sub> )	50.24	27.01	36.0	36.0	627.57	500.3	32.08	762.36	762.36	1309
Acidity (as CaCO <sub>3</sub> )	72.81	_	_	—	_	19.53	_	_	—	_
Chloride <sup>1</sup>	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 <sup>2</sup>	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 Qualit	y of WTP Discharge in Operations
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Devenueder		Оре	en Pit WTP (WTP #1)			Main WTP (WTP #2)							
Parameter			Was	ste Streams to Pyritic T	ſSF			Was	te Streams to Pyritic	TSF			
mg/L	Influent Water	Treated Water	Sludge Total	Soluble Sludge	Brine	Influent Water	Treated Water	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 <sub>3</sub> )	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: <sup>1</sup> 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. <sup>2</sup> 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.

	50th Percentile Water Quality Data										90th Percentile Water Quality Data										
Deremeter		Mai	n WTP (WT	P #2)				WTP #3				Mair	ו WTP (WTF	P #2)				WTP #3			
Parameter			Waste S	treams to P	yritic TSF			Waste S	treams to P	ritic TSF			Waste St	reams to Py	ritic 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%	
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	~15 lb/gal	
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	density	
TSS	20	0	150,000	0	—	20	—	149,427	—	—	20	0	150,000	-	0	20	—	149,427	—	3.66 gpm as solid	
Alkalinity (as CaCO <sub>3</sub> )	79	18	269	269	1309	131	17	601	247	—	628	18.6	1,347	1,347	1,309	150	53.8	601	1023	(55.0 lb/min)	
Acidity (as CaCO <sub>3</sub> )	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

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

	50th Percentile Water Quality Data												90th Percentile Water Quality Data								
Deremeter		Mai	n WTP (WT	P #2)				WTP #3				Mair	WTP (WTI	P #2)				WTP #3			
Parameter			Waste S	treams to P	yritic TSF			Waste St	treams to Py	vritic TSF			Waste St	reams to Py	ritic 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 <sub>3</sub> )	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:

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<sub>3</sub> = calcium carbonate gpm = gallons/minute cfs = cubic feet/second mg/L = miligrams/liter

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

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 <sub>3</sub> )	766	63	1243	1113	13449
Acidity (as CaCO <sub>3</sub> )	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	Treated	Wast	Waste Streams to Pyritic TS			
mg/L	Water	Water	Sludge Total	Soluble Sludge	Brine		
Mercury	0.000496	0.00000000 1	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 <sub>3</sub> )	2321	110	98356	2345	7776		

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

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

Parameter	lun film a mó		Waste Streams to Open Pit		
mg/L	Water <sup>1</sup>	Treated Water	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 <sub>3</sub> )	40	36	37	37	
Acidity (as CaCO <sub>3</sub> )	0.90	—	—	—	
Chloride	2.00	58	58	58	
Fluoride	0.12	0.12	0.12	0.12	
Sulfate <sup>2</sup>	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

JULY 2020

Parameter	Influent		Waste Streams to C	Waste Streams to Open Pit		
mg/L	Water <sup>1</sup>	Treated Water	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 <sup>2</sup>	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 <sub>3</sub> )	178	179	179	179		

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

Notes:

<sup>1</sup> Values are based on 90th percentile water quality data for closure year 105.

<sup>2</sup> 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.

	Baseline Concentration <sup>a</sup> Deposition from Dust					Soil/Sediment Criteria <sup>d</sup>			
Analyte	Mean <sup>b</sup> (mg/kg)	Yearly Deposition Rate (g/m²-year)ª	Incremental Increase over 20 Years <sup>c</sup> (mg/kg)	Baseline + 20 Years Dust Deposition (mg/kg)	Sediment % Increase	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 <sup>e</sup>	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 <sup>5</sup> (CrIII)	37.3	90	
Cobalt <sup>f</sup>	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 <sup>f</sup>	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	_	_	

Table K4.18-17:	Predicted Ch	hange in S	ediment Qua	lity from D	ust Deposition

Notes:

<sup>a</sup> Source: SLR 2011a; PLP 2018-RFI 009

<sup>b</sup> All sediment data are presented on a dry-weight basis

<sup>o</sup> 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)

<sup>d</sup> Source: Buchman 2008; ADEC 2017

<sup>e</sup> Bold values indicate exceedances of the most stringent water quality criteria (Appendix K3.18, Table K3.18-1)

<sup>f</sup> 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<sup>2-</sup>year = grams per square meter per year

mg/kg = milligrams per kilogram

PEL = probable effects level

TEL = threshold effects level

			Baseline Concentration			20-Year			
Location	Analyte	Sediment Mean <sup>a</sup> (mg/kg)	Surface Water-Total Mean <sup>b</sup> (mg/L)	Surface Water-Dissolved Mean <sup>b</sup> (mg/L)	20-Year Sediment Concentration <sup>c</sup> (mg/kg)	Total (mg/L)	Dissolved (mg/L)	% Increase (Total)	ADEC Most Stringent Water Quality (mg/L)
	Antimony	0.23	_	_	0.24	_	_	_	0.006
	Arsenic	14.2 <sup>f</sup>	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
ž	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
	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)
Ä	Cobalt	7.86	—	—	7.88	—	—	—	0.05
S.	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
	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)
ပ	Cobalt	7.86	—	—	7.88	—	—	—	0.05
5	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

			Baseline Concentration			20-Year S	ADEO Mart Officerent		
Location	Analyte	Sediment Mean <sup>a</sup> (mg/kg)	Surface Water-Total Mean <sup>b</sup> (mg/L)	Surface Water-Dissolved Mean <sup>b</sup> (mg/L)	20-Year Sediment Concentration <sup>c</sup> (mg/kg)	Total (mg/L)	Dissolved (mg/L)	% Increase (Total)	Water Quality (mg/L)
	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
ake	Chromium	15.4	—	—	15.5	—	—	—	0.1 (total)
an l	Cobalt	7.86	—	—	7.88	—	—	—	0.05
d Br	Copper	27.3	0.0013	0.00083	28.99	0.00135	0.000883	5.84%	0.00219
<sup>-</sup> ryir	Lead	6.9	0.00011	0.00016	6.92	0.00011	0.000165	0.30%	0.00039
L .	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:

Notes: <sup>a</sup> Sediment data (in dry weight) obtained from Appendix K3.18, Table K3.18-19 <sup>b</sup> Surface water data from Appendix K3.18, Tables K3.18-7 through K3.18-10 <sup>c</sup> 20-year sediment concentration = baseline + incremental increase over 20 years (Table K4.18-17) <sup>d</sup> 20-year surface water concentration = 20-year sediment concentration/site-specific baseline sediment-baseline surface water relationship factor <sup>e</sup> 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 <sup>f</sup> Bold values indicate exceedances of the most stringent water quality criteria (Appendix K3.18, Table K3.18-1) <sup>g</sup>Water concentrations presented total water concentrations

<sup>9</sup>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<sub>d</sub>) (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.

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

#### 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<sup>2</sup>-year), A is the surface area of Frying Pan Lake (m<sup>2</sup>), 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.

		Baseline Concentration	Effluent Discharge	Concentrations	20-Ye	20-Year Surface Water Concentration <sup>c</sup>			
Location	Analyte	Surface Water-	Predicted effluent concentrations in	ADEC Most Stringent	Predicted Concentr	Effluent ations <sup>d</sup>	Treated Water Concentrations at WQC Limit <sup>e</sup>		
		Total Mean <sup>a</sup> (mg/L)	operations WTP #1 (mg/L)	Water Quality <sup>b</sup> (mg/L)	Predicted Concentration	Predicted % Increase	Mean Total (mg/L)	% Increase Mean (Total)	
	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	_	—	—		
۲	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%	
	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%	
SFK	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

		Baseline Concentration	Effluent Discharge Concentrations		20-Ye	ear Surface Wate	er Concentrati	on <sup>c</sup>
Location	Analyte	Surface Water-	Predicted effluent concentrations in	ADEC Most Stringent	Predicted Concentr	Effluent ations <sup>d</sup>	Treated Water Concentrations at WQC Limit <sup>e</sup>	
		Total Mean <sup>a</sup> (mg/L)	operations WTP #1 (mg/L)	operations Water Quality <sup>b</sup> WTP #1 (mg/L) (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%
	Antimony	—	0.003	0.006		—	—	_
	Arsenic	0.00095	0.004	0.01	0.00128	35.2%	0.0051	436.9%
	Beryllium	—	0.0002	0.004	—	—	—	_
	Cadmium	0.000017	0.000005	0.00008	1.38E-05	-18.9%	3E-05	76.4%
	Chromium	0.00036	0.0001	0.1 (total)	0.000288	-20.0%	0.02695	7386.1%
<u>2</u>	Cobalt	_	0.008	0.05	_	_	_	_
5	Copper	0.00061	0.000001	0.00219	0.000517	-15.3%	0.000743	21.8%
	Lead	0.000089	0.000001	0.00039	7.011E-05	-21.2%	0.000139	56.7%
	Manganese	0.026	0.003	0.05	0.0204	-21.4%	0.02848	9.54%
	Mercury		0.000001	0.000012	_			_
	Nickel	0.00061	0.00005	0.0129	0.000681	11.7%	0.00833	1265.3%
	Selenium	0.0003	0.004	0.005	0.000360	20.1%	0.00140	367.0%
e	Antimony	—	0.003	0.006	—	—	—	_
Lak	Arsenic	0.00048	0.004	0.01	0.000649	35.2%	0.00258	436.9%
Pan	Beryllium	—	0.0002	0.004	—	_	_	_
bu j	Cadmium	0.000018	0.000005	0.00008	1.46E-05	-18.9%	3.17E-05	76.4%
Fryi	Chromium <sup>f</sup>	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

		Baseline Concentration	Effluent Discharge	Concentrations	20-Ye	ar Surface Water Concentration <sup>c</sup>			
Location	ation Analyte Surface		Predicted effluent concentrations in	ADEC Most Stringent	Predicted Effluent Concentrations <sup>d</sup>		Treated Water Concentrations at WQC Limit <sup>e</sup>		
		Total Mean <sup>a</sup> (mg/L)	operations WTP #1 (mg/L)	Water Quality <sup>b</sup> (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 <sup>f</sup>	0.000283	0.004	0.005	0.000340	20.1%	0.00032	367.0%	

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

<sup>a</sup> Surface water data from Appendix K3.18, Table K3.18-6 through Table K3.18-9

<sup>b</sup> 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

° 20 year total surface water concentrations calculated using Equation K4.18-5

<sup>d</sup> 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

<sup>f</sup> 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 <sup>g</sup> 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.

	<b>Baseline</b> <sup>a</sup>	Soil Concent	Deposition	Comparative Action Levels <sup>d</sup>	
Analyte	Soil Concentration Mean (mg/kg)	Incremental Increase over 20 Years (mg/kg) <sup>b,c</sup>	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 <sup>e</sup>	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 <sup>3</sup> )
Cobalt	6.55	0.0195	6.57	0.30	N/A
Copper <sup>f</sup>	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

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

Notes: <sup>a</sup> Source: SLR et al. 2011b

<sup>b</sup> Based on PLP 2018-RFI 009 total HAPs concentration in dust and EPA 2005

<sup>o</sup> 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<sup>3</sup> (EPA 2005)

<sup>d</sup> ADEC 2017b

<sup>e</sup> Bold values indicate exceedances of the most stringent water quality criteria (Appendix K3.18, Table K3.18-1)

<sup>f</sup> 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 premine 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

- $M_{\text{BL}}$  is the total baseline environmental mass flowing through the system on an annual basis.
- Q<sub>XX</sub> is the average annual streamflow for the NFK, SFK, and UTC.
- C<sub>xx</sub> 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

- $M_{\mbox{\scriptsize Op}}$  is the environmental mass flowing through the system on an annual basis during operations.
- Q<sub>Xre</sub> is the average annual reduced streamflow for the NFK, SFK, and UTC.
- C<sub>XX</sub> is the average water quality concentration of the NFK, SFK, and UTC.
- Q<sub>WTP#</sub> is the average annual discharge from WTPs (#1 and #2) into the environment.
- C<sub>WTP#</sub> 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.

## K4.18.5Effluent 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.

	Environmental Mass Loading							
Field and Physical	N	IFK	SFK		UTC		Total Environme	ntal Load
Parameters (mg/L, except where noted)	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 lons (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

	Environmental Mass Loading							
Field and Physical	N	IFK	SFK		UTC		Total Environme	ntal Load
Parameters (mg/L, except where noted)	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%

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

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.



# K4.20 AIR QUALITY

This appendix supports discussion and explanation of an analysis of project emissions and impacts to air quality presented in Section 4.20, Air Quality, of the Environmental Impact Statement (EIS). This appendix presents the approach and results of the calculation of emissions and assessment of impacts from project components (mine site, transportation corridor, Amakdedori port, and pipeline corridor) and phases (construction, operations, and closure), for which direct impacts were predicted using modeling. The analysis presented in this appendix is not intended to be applied directly to any specific alternative, but is meant instead to be representative of several action alternatives (referred to a representative project). Components and phases selected for emissions quantification and modeling were those anticipated to produce impacts with the highest magnitude, largest geographic extent, and longest duration from among those included in Alternative 1a and Alternative 1. Impacts from other components and phases are smaller than those modeled and are assessed by proxy. Because the action alternatives would have similar emission sources and locations of stationary emissions (except for the location of the port and transportation corridor), emissions estimates and air dispersion modeling for the analyzed representative project provide a proxy for all action alternatives. Differences among alternatives in road and pipeline length and location would result in different road-related emissions. These differences among alternatives, as well as differences in locations of the port, were not separately modeled, but instead were evaluated qualitatively.

In addition to the emissions and model impacts for the project, a cumulative impact assessment was completed for the combined impacts of the project and Reasonably Foreseeable Future Actions (RFFAs). The cumulative impact assessment is based on the analysis of the direct impacts that were predicted using modeling of the project components and phases.

## K4.20.1 Emission Inventory and Project Emissions Summary

The following sections present an overview of assumptions and methods used to calculate the emissions inventory, as well as the emissions for representative project components and select project phases. Additional information and details of the emission inventory calculations are provided in PLP 2018-RFI 007 and PLP 2019-RFI 007b.

## K4.20.1.1 Emission Inventory Development Methodology

Total potential criteria pollutant and hazardous pollutant emissions are calculated using vendor data, US Environmental Protection Agency (EPA) AP-42 emission factors, Motor Vehicle Emission Simulator (MOVES) model, mass balances equations, EPA Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories, and New Source Performance Standards (NSPS). The methods for estimating greenhouse gas (GHG) emissions for fuel combustion sources are applied in accordance with the guidance provided in Subpart C of the Mandatory Reporting of Greenhouse Gases Rule (40 CFR Part 98) for Tier 1 units, and EPA Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories for marine vessel emissions. The carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), and nitrous oxide (N<sub>2</sub>O) emission estimates are calculated for all stationary and mobile equipment on an individual basis using Equation C-1 from 40 CFR Part 98. In addition, to estimate emissions for the air quality impact analyses for modeled project components, several applicant agreed upon avoidance and control measures prior to the impact analysis were considered, such as Ultra Low Sulfur Diesel (ULSD) combustion in sources as outlined in PLP 2018-RFI 007 and PLP 2019-RFI 007b.

## K4.20.1.2 Calculated Emission Inventory for Direct Impacts

The calculated emissions for the representative project are addressed for each project component by project phase in the following sections.

#### Mine Site

For the mine site, the analysis area for the direct impacts and emissions encompasses the area where the mine site activities would occur. The direct emissions from the construction, operations, and closure phases are presented.

#### Construction

Direct emissions during construction would be related to quarry crushing operations, concrete batch plant operation, incineration, and power generation.

The total emissions were calculated based on a worst-case mine site construction year. Emissions were calculated assuming that each emission unit would be operated continuously 24 hours a day, 7 days a week, for a total of 8,760 hours per year, with the appropriate load factors, with the exception of those emission units, such as fire water pump engines, that would be subject to operating restrictions under an air quality permit, if issued. The potential emissions for restricted emission units were calculated with the assumption that those emission units would operate a limited number of hours per year. For the fire water pump engines, it was estimated that an expected upper limit would be 500 hours per year. The construction emission inventory for the mine site is summarized in Table K4.20-1 for a worst-case construction year.

Air Pollutant	Stationary Emission Units (tons/year)	Mobile and Non- Road Emission Units (tons/year)	Fugitive and Blasting Emission Units (tons/year)	Total Emissions (tons/year)
NO <sub>x</sub>	110	624	9	743
СО	589	72	54	715
PM10	17	14	1,030	1,061
PM <sub>2.5</sub>	16	14	124	154
VOCs	34	20	N/A	54
SO <sub>2</sub>	1.0	1.9	N/A	2.9
Pb	0.0	negligible	N/A	0.0
Total HAPs	5.5	6.5	N/A	12.0
CO <sub>2</sub>	99,302	312,446	N/A	411,748
CH <sub>4</sub>	4.6	1.7	N/A	6.3
N <sub>2</sub> O	0.9	0.1	N/A	1.0
CO <sub>2</sub> e	99,696	312,530	N/A	412,226

Notes:

 $\begin{array}{l} \mathsf{CH}_4 = \mathsf{methane} \\ \mathsf{CO} = \mathsf{carbon} \; \mathsf{monoxide} \\ \mathsf{CO}_2 = \mathsf{carbon} \; \mathsf{dioxide} \\ \mathsf{CO}_2 \mathsf{e} = \mathsf{CO}_2 \; \mathsf{equivalent} \\ \mathsf{HAPs} = \mathsf{total} \; \mathsf{hazardous} \; \mathsf{air} \; \mathsf{pollutants} \\ \mathsf{N/A} = \mathsf{not} \; \mathsf{applicable} \\ \mathsf{negligible} = \mathsf{values} \; \mathsf{less} \; \mathsf{than} \; \mathsf{0.001} \; \mathsf{ton} \; \mathsf{per} \; \mathsf{year} \\ \mathsf{N}_2 \mathsf{O} = \mathsf{nitrous} \; \mathsf{oxide} \\ \mathsf{NO}_x = \mathsf{oxides} \; \mathsf{of} \; \mathsf{nitrogen} \\ \mathsf{Pb} = \mathsf{lead} \\ \mathsf{PM}_{10} = \mathsf{particulate} \; \mathsf{matter} \; \mathsf{with} \; \mathsf{an} \; \mathsf{aerodynamic} \; \mathsf{diameter} \; \mathsf{less} \; \mathsf{than} \; \mathsf{or} \; \mathsf{equal} \; \mathsf{to} \; \mathsf{10} \; \mathsf{microns} \\ \mathsf{PM}_{2.5} = \; \mathsf{particulate} \; \mathsf{matter} \; \mathsf{with} \; \mathsf{an} \; \mathsf{aerodynamic} \; \mathsf{diameter} \; \mathsf{less} \; \mathsf{than} \; \mathsf{or} \; \mathsf{equal} \; \mathsf{to} \; \mathsf{2.5} \; \mathsf{microns} \\ \mathsf{SO}_2 = \; \mathsf{sulfur} \; \mathsf{dioxide} \\ \mathsf{VOCs} = \; \mathsf{volatile} \; \mathsf{organic} \; \mathsf{compounds} \\ \mathsf{Source:} \; \mathsf{PLP} \; \mathsf{2018} \mathsf{-RFI} \; \mathsf{007}; \; \mathsf{PLP} \; \mathsf{2019} \mathsf{-RFI} \; \mathsf{007b} \end{array}$ 

## Operations

Direct emissions during mine site operations would be related to mining activities, ore-processing activities, incineration, and power generation. The mine site stationary emission unit inventory would include a combined-cycle combustion turbine 270-megawatt power plant, fire water pump natural gas engines, a back-up diesel generator, boilers, fuel storage tanks, and a small waste incinerator. The mobile equipment inventory used for various mining activities would include haul trucks, bulldozers, graders, shovels, light-duty vehicles, and loaders. Fugitive emissions would result from blasting and drilling in the pit and quarries, vehicle traffic on unpaved roads, and material handling. The fuel-burning mobile and stationary emission units are sources of combustion-related air pollutant emissions. Table K4.20-2 is a summary of the emissions during operations at the mine site for a representative operations year.

Air Pollutant	Stationary Emission Units (tons/year)	Mobile Emission Units (tons/year)	Fugitive and Blasting Units (tons/year)	Total Emissions (tons/year)
NOx	83	1,296	31	1,410
со	133	105	179	417
PM <sub>10</sub>	159	26	2,686	2,871
PM <sub>2.5</sub>	159	26	322	507
VOC	32	37	N/A	69
SO <sub>2</sub>	14.2	4.1	N/A	18.3
Pb	0.0	negligible	negligible	0.0
Total HAPs	9.1	16.6	negligible	25.7
CO <sub>2</sub>	640,226	600,251	N/A	1,240,477
CH <sub>4</sub>	12.7	2.7	N/A	15.4
N <sub>2</sub> O	1.3	0.0	N/A	1.3
CO <sub>2</sub> e	640,940	600,320	N/A	1,241,260

Table K4.20-2: Mine	Site Operations	Emission	Summary
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Notes:

CH<sub>4</sub> = methane CO = carbon monoxide CO<sub>2</sub> = carbon dioxide CO<sub>2</sub>e = CO<sub>2</sub> equivalent HAPs = total hazardous air pollutants N/A = not applicable negligible = values less than 0.001 ton per year N<sub>2</sub>O = nitrous oxide NO<sub>x</sub> = oxides of nitrogen Pb = lead PM<sub>10</sub> = particulate matter with an aerodynamic diameter less than or equal to 10 microns PM<sub>2.5</sub> = particulate matter with an aerodynamic diameter less than or equal to 2.5 microns SO<sub>2</sub> = sulfur dioxide VOCs = volatile organic compounds Source: PLP 2018-RFI 007; PLP 2019-RFI 007b

## Closure

During closure, facilities would support operation of the camp and power generation. The reclamation emissions inventory would include internal combustion engines, a gas turbine, boilers, and an incinerator. The mobile equipment would include haul trucks, shovels, bulldozers,

compactors, graders, and service and light-duty vehicles. Fugitive dust emissions would result from stockpiled overburden handling, bulldozing, grading, vehicle traffic on unpaved roads, and wind erosion of road surfaces and active reclamation areas. The duration of the closure phase at the mine site is expected to be approximately 20 years. The maximum closure and construction activities and emissions in a given year would be similar to each other. Table K4.20-3 presents a summary of the mine site closure emissions for a representative closure year.

Air Pollutant	Stationary Emission Units (tons/year)	Mobile Emission Units (tons/year)	Fugitive Emission Units (tons/year)	Total Emissions (tons/year)
NO <sub>x</sub>	30	969	N/A	999
СО	77	53	N/A	130
PM10	28	16	978	1,022
PM <sub>2.5</sub>	28	16	139	183
VOC	11	22	N/A	33
SO <sub>2</sub>	1.7	3.2	N/A	4.9
Pb	0.005	negligible	N/A	0.005
Total HAPs	4.7	5.4	negligible	10.1
CO <sub>2</sub>	140,134	524,619	N/A	664,753
CH <sub>4</sub>	3.3	1.8	N/A	5.1
N <sub>2</sub> O	0.4	0.3	N/A	0.7
CO <sub>2</sub> e	140,331	524,750	N/A	665,081

Table K4.20-3: Mine Site Cle	osure Emission Summary
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Notes:

CH<sub>4</sub> = methane CO = carbon monoxide CO<sub>2</sub> = carbon dioxide CO<sub>2</sub> = carbon dioxide CO<sub>2</sub> = CO<sub>2</sub> equivalent HAPs = total hazardous air pollutants N/A = not applicable negligible = values less than 0.001 ton per year N<sub>2</sub>O = nitrous oxide NO<sub>x</sub> = oxides of nitrogen Pb = lead PM<sub>10</sub> = particulate matter with an aerodynamic diameter less than or equal to 10 microns PM<sub>2.5</sub> = particulate matter with an aerodynamic diameter less than or equal to 2.5 microns SO<sub>2</sub> = sulfur dioxide VOCs = volatile organic compounds Source: PLP 2018-RFI 007: PLP 2019-RFI 007b

# Transportation Corridor

This section addresses the direct emissions from the construction and operations phases of the transportation corridor facilities. For the analysis of direct impacts to air quality, the analysis area of the transportation corridor includes gravel roads, ferry terminals on Iliamna Lake, port, and spur roads. The road and onshore pipeline would be constructed in the same right-of-way (ROW) at the same time (except for the pipeline-only segment from Newhalen to the mine access road under Alternative 1a, and the pipeline-only segment between Ursus Cove and Cottonwood Bay under Alternative 2 and Alternative 3), so the emissions from the construction of both the road and onshore pipeline are calculated together.

## Construction

During construction, the main direct emission sources would be heavy-duty, non-road, and mobile construction vehicles, as well as fugitive dust generated by vehicles on unpaved roads, and wind erosion. Additional fugitive emissions would result from blasting, drilling, rock crushing, and material handling. Stationary emissions sources would include engines and vapor vented from fuel storage tanks. Emissions from material mining and crushing operations required for fill material, principally for an earthen access causeway at the port (under Alternative 1 and Alternative 2) are also included in this assessment. The representative emissions were calculated based on the total construction duration of the transportation corridor and estimated equipment operation. The duration of construction for the road corridor and onshore pipeline facilities is expected to be approximately 1 year. Table K4.20-4 presents a summary of the construction emissions for the transportation corridor.

Air Pollutant	Stationary Emission Units (tons/year)	Mobile and Non Road Emission Units (tons/ year)	Fugitive Emission Units (tons/year)	Total Emissions (tons/year)
NOx	13	200	4	217
со	80	92	23	195
PM <sub>10</sub>	2	14	1,838	1,854
PM <sub>2.5</sub>	2	14	229	245
VOC	7	18	N/A	25
SO <sub>2</sub>	0.14	0.71	N/A	0.85
Pb	0.01	negligible	N/A	0.01
Total HAPs	7.25	8.4	N/A	15.7
CO <sub>2</sub>	18,401	108,422	N/A	126,823
CH <sub>4</sub>	1.4	1.4	N/A	2.8
N <sub>2</sub> O	0.2	0.0	N/A	0.2
CO <sub>2</sub> e	18,506	108,466	N/A	126,972

Table K4.20-4: Transportation Corridor Construction Emission Summary

Notes:

CH<sub>4</sub> = methane CO = carbon monoxide CO<sub>2</sub> = carbon dioxide CO<sub>2</sub> = carbon dioxide CO<sub>2</sub> = CO<sub>2</sub> equivalent HAPs = total hazardous air pollutants N/A = not applicable negligible = values less than 0.001 ton per year N<sub>2</sub>O = nitrous oxide NO<sub>x</sub> = oxides of nitrogen Pb = lead PM<sub>10</sub> = particulate matter with an aerodynamic diameter less than or equal to 10 microns PM<sub>2.5</sub> = particulate matter with an aerodynamic diameter less than or equal to 2.5 microns SO<sub>2</sub> = sulfur dioxide VOCs = volatile organic compounds Source: PLP 2018-RFI 007; PLP 2019-RFI 007b

# Operations

Direct emissions during the transportation corridor operations would come from power generators at the ferry terminals, shipping across the waterways, vapor vented from fuel storage tanks, and other fuel-burning engines such as ferry engines, light-duty vehicles, truck/trailer vehicles,

container-handing forklifts, graders, and aircraft. Additionally, fugitive dust emissions would result from vehicle traffic on unpaved roads. Table K4.20-5 presents a summary of the operations emissions in the transportation corridor.

Air Pollutant	Stationary Emission Units (tons/year)	Mobile and Non-road Emission Units (tons/year)	Fugitive Emission Units (tons/year)	Total Emissions (tons/year)
NOx	25.9	30	N/A	56
СО	84.2	42	N/A	126
PM10	1.6	2	398.5	403
PM <sub>2.5</sub>	1.6	2	38.4	42
VOC	18.1	5	N/A	23
SO <sub>2</sub>	0.2	0.6	N/A	0.8
Pb	0.0	negligible	N/A	0.0
Total HAPs	2.6	0.07	N/A	2.7
CO <sub>2</sub>	13,111	17,015	N/A	30,126
CH₄	0.6	0.5	N/A	1.1
N <sub>2</sub> O	0.1	0.1	N/A	0.2
CO <sub>2</sub> e	13,156	17,046	N/A	30,202

Table K/ 20-5	Transportation	Corridor	Onorations	Emission	Summarv
Table K4.20-5:	Transportation	Corrigor	Operations	Emission	Summary

Notes:

 $\begin{array}{l} \mathsf{CH}_4 = \mathsf{methane} \\ \mathsf{CO} = \mathsf{carbon} \; \mathsf{monoxide} \\ \mathsf{CO}_2 = \mathsf{carbon} \; \mathsf{dioxide} \\ \mathsf{CO}_2 \mathsf{e} = \mathsf{CO}_2 \; \mathsf{equivalent} \\ \mathsf{HAPs} = \mathsf{total} \; \mathsf{hazardous} \; \mathsf{air} \; \mathsf{pollutants} \\ \mathsf{N/A} = \mathsf{not} \; \mathsf{applicable} \\ \mathsf{negligible} = \mathsf{values} \; \mathsf{less} \; \mathsf{than} \; \mathsf{0.001} \; \mathsf{ton} \; \mathsf{per} \; \mathsf{year} \\ \mathsf{N_2O} = \mathsf{nitrous} \; \mathsf{oxide} \\ \mathsf{NO_x} = \mathsf{oxides} \; \mathsf{of} \; \mathsf{nitrogen} \\ \mathsf{Pb} = \mathsf{lead} \\ \mathsf{PM}_{10} = \mathsf{particulate} \; \mathsf{matter} \; \mathsf{with} \; \mathsf{an} \; \mathsf{aerodynamic} \; \mathsf{diameter} \; \mathsf{less} \; \mathsf{than} \; \mathsf{or} \; \mathsf{equal} \; \mathsf{to} \; \mathsf{10} \; \mathsf{microns} \\ \mathsf{PM}_{2.5} = \mathsf{particulate} \; \mathsf{matter} \; \mathsf{with} \; \mathsf{an} \; \mathsf{aerodynamic} \; \mathsf{diameter} \; \mathsf{less} \; \mathsf{than} \; \mathsf{or} \; \mathsf{equal} \; \mathsf{to} \; \mathsf{2.5} \; \mathsf{microns} \\ \mathsf{SO}_2 = \mathsf{sulfur} \; \mathsf{dioxide} \\ \mathsf{VOCs} = \mathsf{volatile} \; \mathsf{organic} \; \mathsf{compounds} \\ \mathsf{Source:} \; \mathsf{PLP} \; \mathsf{2018} \; \mathsf{RFI} \; \mathsf{007}; \; \mathsf{PLP} \; \mathsf{2019} \; \mathsf{RFI} \; \mathsf{007b} \\ \end{array}$ 

## Amakdedori Port

This section presents the emissions from the construction, operations, and closure phases of the Amakdedori port. Additionally, the underwater pipeline portions in the Cook Inlet and Iliamna Lake are included in the analysis of the port construction phase.

# Construction

The construction of the port and offshore pipeline uses similar equipment and methods. Therefore, the emissions are calculated together; however, the construction would not occur at the same time. The construction of the offshore pipeline would occur after the port construction. The construction emissions are calculated based on the estimated construction time, regardless of which activity would occur first.

The port site construction activity would include construction of port facilities to support later phases of construction and mine operations. Emissions from material mining and crushing operations required for fill material are captured in the road construction emissions provided for the transportation corridor. Emissions associated with operation of the port facilities, including

trucking or offshore pipeline construction, are assumed to be similar to emissions during mine operation, and are represented by the annual transportation emissions estimate for mine operations.

The construction activity associated with the port and offshore pipeline would include engines, an asphalt plant, boilers, fuel storage tanks, and a small incinerator. The mobile equipment inventory would include bulldozers, excavators, loaders, and cranes in the port construction, and tugs, long-reach excavators, and welders in the pipeline construction. Fugitive emissions would result from site grade preparation and mobile equipment traffic. The construction of the port and offshore pipeline is expected to take approximately 1 year. Table K4.20-6 presents an emission summary for construction of the port and associated offshore pipeline.

Air Pollutant	Stationary Emission Units (tons/year)	Mobile and Non Road Emission Units (tons/year)	Fugitive Emission Units (tons/year)	Total Emissions (tons/year)
NOx	6.2	343	N/A	349
CO	13.5	144	N/A	158
PM10	17.5	16	1.3	35
PM <sub>2.5</sub>	17.5	16	0.2	34
VOC	2.5	16	N/A	19
SO <sub>2</sub>	0.4	4.4	N/A	4.8
Pb	0.007	negligible	N/A	0
Total HAPs	3.6	0.2	N/A	3.8
CO <sub>2</sub>	5,890	32,443	N/A	38,333
CH₄	0.6	0.2	N/A	0.8
N <sub>2</sub> O	0.1	1.2	N/A	1.3
CO <sub>2</sub> e	5,937	32,816	N/A	38,753

#### Table K4.20-6: Amakdedori Port Construction Emission Summary

Notes:

 $\begin{array}{l} \mathsf{CH}_4 = \mathsf{methane} \\ \mathsf{CO} = \mathsf{carbon} \; \mathsf{monoxide} \\ \mathsf{CO}_2 = \mathsf{carbon} \; \mathsf{dioxide} \\ \mathsf{CO}_2 \mathsf{e} = \mathsf{CO}_2 \; \mathsf{equivalent} \\ \mathsf{HAPs} = \mathsf{total} \; \mathsf{hazardous} \; \mathsf{air} \; \mathsf{pollutants} \\ \mathsf{N/A} = \mathsf{not} \; \mathsf{applicable} \\ \mathsf{negligible} = \mathsf{values} \; \mathsf{less} \; \mathsf{than} \; \mathsf{0.001} \; \mathsf{ton} \; \mathsf{per} \; \mathsf{year} \\ \mathsf{N}_2\mathsf{O} = \mathsf{nitrous} \; \mathsf{oxide} \\ \mathsf{NO}_x = \mathsf{oxides} \; \mathsf{of} \; \mathsf{nitrogen} \\ \mathsf{Pb} = \mathsf{lead} \\ \mathsf{PM}_{10} = \mathsf{particulate} \; \mathsf{matter} \; \mathsf{with} \; \mathsf{an} \; \mathsf{aerodynamic} \; \mathsf{diameter} \; \mathsf{less} \; \mathsf{than} \; \mathsf{or} \; \mathsf{equal} \; \mathsf{to} \; \mathsf{10} \; \mathsf{microns} \\ \mathsf{SO}_2 = \mathsf{sulfur} \; \mathsf{dioxide} \\ \mathsf{VOCs} = \mathsf{volatile} \; \mathsf{organic} \; \mathsf{compounds} \\ \mathsf{Source:} \; \mathsf{PLP} \; \mathsf{2018} \\ \mathsf{RFI} \; \mathsf{007}; \; \mathsf{PLP} \; \mathsf{2019} \\ \mathsf{RFI} \; \mathsf{007b} \end{array}$ 

# Operations

The Amakdedori port emission unit inventory would include power generator engines, heaters, vapor vented from fuel storage tanks, and a small incinerator. Mobile equipment would include light-duty vehicles, skidsteers, forklifts, and container-handing forklifts. Marine vessels would

include barges, tugs, and bulk carriers at the lightering locations. Table K4.20-7 presents a summary of the operations emissions at the port for a representative year of operations activity.

Air Pollutant	Stationary Emission Units (tons/year)	Mobile and Non Road Emission Units (tons/year)	Fugitive Emission Units (tons/year)	Total Emissions (tons/year)
NO <sub>x</sub>	53.8	265	N/A	319
СО	169	28	N/A	197
PM <sub>10</sub>	4	15	1.00E-03	19
PM <sub>2.5</sub>	4	14	1.00E-03	18
VOC	38.2	11	N/A	49
SO <sub>2</sub>	0.4	2.0	N/A	2.4
Pb	0	negligible	N/A	0
Total HAPs	8.9	0.05	N/A	9.0
CO <sub>2</sub>	30,246	16,432	N/A	46,678
CH <sub>4</sub>	1.5	0.5	N/A	2.0
N <sub>2</sub> O	0.3	0.6	N/A	0.9
CO <sub>2</sub> e	30,370	16,627	N/A	46,997

Table K4.20-7:	Amakdedori	Port C	)perations	Emission	Summarv
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Notes:

 $\begin{array}{l} \mathsf{CH}_4 = \mathsf{methane} \\ \mathsf{CO} = \mathsf{carbon} \; \mathsf{monoxide} \\ \mathsf{CO}_2 = \mathsf{carbon} \; \mathsf{dioxide} \\ \mathsf{CO}_2 \mathsf{e} = \mathsf{CO}_2 \; \mathsf{equivalent} \\ \mathsf{HAPs} = \mathsf{total} \; \mathsf{hazardous} \; \mathsf{air} \; \mathsf{pollutants} \\ \mathsf{N/A} = \mathsf{not} \; \mathsf{applicable} \\ \mathsf{negligible} = \mathsf{values} \; \mathsf{less} \; \mathsf{than} \; \mathsf{0.001} \; \mathsf{ton} \; \mathsf{per} \; \mathsf{year} \\ \mathsf{N}_2 \mathsf{O} = \mathsf{nitrous} \; \mathsf{oxide} \\ \mathsf{NO}_x = \mathsf{oxides} \; \mathsf{of} \; \mathsf{nitrogen} \\ \mathsf{Pb} = \mathsf{lead} \\ \mathsf{PM}_{10} = \mathsf{particulate} \; \mathsf{matter} \; \mathsf{with} \; \mathsf{an} \; \mathsf{aerodynamic} \; \mathsf{diameter} \; \mathsf{less} \; \mathsf{than} \; \mathsf{or} \; \mathsf{equal} \; \mathsf{to} \; \mathsf{10} \; \mathsf{microns} \\ \mathsf{PM}_{2.5} = \; \mathsf{particulate} \; \mathsf{matter} \; \mathsf{with} \; \mathsf{an} \; \mathsf{aerodynamic} \; \mathsf{diameter} \; \mathsf{less} \; \mathsf{than} \; \mathsf{or} \; \mathsf{equal} \; \mathsf{to} \; \mathsf{2.5} \; \mathsf{microns} \\ \mathsf{SO}_2 = \; \mathsf{sulfur} \; \mathsf{dioxide} \\ \mathsf{VOCs} = \; \mathsf{volatile} \; \mathsf{organic} \; \mathsf{compounds} \\ \mathsf{Source:} \; \mathsf{PLP} \; 2018 \mathsf{-RFI} \; \mathsf{007}; \; \mathsf{PLP} \; 2019 \mathsf{-RFI} \; \mathsf{007b} \end{array}$ 

## Natural Gas Pipeline Corridor

This section only addresses emissions and air quality impacts from the construction of the Kenai compressor station on the eastern Cook Inlet landfall of the natural gas pipeline corridor. The emissions from the construction of the onshore portion of the pipeline are addressed above under the transportation corridor, while the construction air quality impacts of the offshore portion of the pipeline are addressed above under Amakdedori port.

## Construction

Construction of the compressor station would involve site grading and mobile equipment use for assembly of the compressor station from pre-constructed modules. The compressor station emissions inventory would include engines and mobile equipment, as well as bulldozers, loaders, excavators, cranes, and light-duty vehicles. The fuel-burning equipment would be sources of combustion-related air pollutant emissions. Fugitive dust emissions would result from site grade

preparation and mobile equipment traffic. Table K4.20-8 presents a summary of the emissions from the compressor station construction.

Air Pollutant	Stationary Emission Units (tons/year)	Mobile and Non Road Emission Units (tons/year)	Fugitive Emission Units (tons/year)	Total Emissions (tons/year)
NO <sub>x</sub>	N/A	1.56	N/A	1.6
СО	N/A	0.64	N/A	0.6
PM10	N/A	0.11	0.53	0.64
PM <sub>2.5</sub>	N/A	0.11	0.08	0.19
VOC	N/A	0.13	N/A	0.13
SO <sub>2</sub>	N/A	0.01	N/A	0.01
Pb	N/A	negligible	N/A	negligible
Total HAPs	N/A	0.06	N/A	0.06
CO <sub>2</sub>	N/A	1,332	N/A	1,332
CH4	N/A	0.01	N/A	0.01
N <sub>2</sub> O	N/A	0.00	N/A	0.00
CO <sub>2</sub> e	N/A	1,332	N/A	1,332

#### Table K4.20-8: Compressor Station Construction Emission Summary

Notes:

 $\begin{array}{l} CH_4 = methane\\ CO = carbon monoxide\\ CO_2 = carbon dioxide\\ CO_2 = carbon dioxide\\ CO_2 = CO_2 equivalent\\ HAPs = total hazardous air pollutants\\ N/A = not applicable\\ negligible = values less than 0.001 ton per year\\ N_2O = nitrous oxide\\ NO_x = oxides of nitrogen\\ Pb = lead\\ PM_{10} = particulate matter with an aerodynamic diameter less than or equal to 10 microns\\ PM_{2.5} = particulate matter with an aerodynamic diameter less than or equal to 2.5 microns\\ SO_2 = sulfur dioxide\\ VOCs = volatile organic compounds\\ Source: PLP 2018-RFI 007; PLP 2019-RFI 007b \end{array}$ 

# Operations

During the operations of the pipeline corridor, the direct emissions from the onshore and offshore pipelines would be minimal. The Kenai compressor station, which would be the single compressor station for the natural gas pipeline, would have emissions. The Kenai compressor station inventory would include natural-gas-fired simple-cycle combustion turbines. Table K4.20-9 presents a summary of the operations emissions at the compressor station.

#### Table K4.20-9: Kenai Compressor Station Operations Emission Summary

Air Pollutant	Total Emissions (tons/year)
NOx	69.3
СО	17.8
PM10	1.4
PM <sub>2.5</sub>	1.4
VOC	0.5
SO <sub>2</sub>	0.30
Pb	negligible
Total HAPs	0.2
CO <sub>2</sub>	25,344
CH4	0.47
N <sub>2</sub> O	0.04
CO <sub>2</sub> e	25,370

Notes:

 $\begin{array}{l} \mathsf{CH}_4 = \mathsf{methane} \\ \mathsf{CO} = \mathsf{carbon} \; \mathsf{monoxide} \\ \mathsf{CO}_2 = \mathsf{carbon} \; \mathsf{dioxide} \\ \mathsf{CO}_2 = \mathsf{CO}_2 \; \mathsf{equivalent} \\ \mathsf{HAPs} = \mathsf{hazardous} \; \mathsf{air} \; \mathsf{pollutants} \\ \mathsf{negligible} = \mathsf{values} \; \mathsf{less} \; \mathsf{than} \; \mathsf{0.001} \; \mathsf{ton} \; \mathsf{per} \; \mathsf{year} \\ \mathsf{N}_2 \mathsf{O} = \mathsf{nitrous} \; \mathsf{oxide} \\ \mathsf{NO}_x = \mathsf{oxides} \; \mathsf{of} \; \mathsf{nitrogen} \\ \mathsf{Pb} = \mathsf{lead} \\ \mathsf{PM}_{10} = \mathsf{particulate} \; \mathsf{matter} \; \mathsf{with} \; \mathsf{an} \; \mathsf{aerodynamic} \; \mathsf{diameter} \; \mathsf{less} \; \mathsf{than} \; \mathsf{or} \; \mathsf{equal} \; \mathsf{to} \; \mathsf{10} \; \mathsf{microns} \\ \mathsf{PM}_{2.5} = \mathsf{particulate} \; \mathsf{matter} \; \mathsf{with} \; \mathsf{an} \; \mathsf{aerodynamic} \; \mathsf{diameter} \; \mathsf{less} \; \mathsf{than} \; \mathsf{or} \; \mathsf{equal} \; \mathsf{to} \; \mathsf{2.5} \; \mathsf{microns} \\ \mathsf{SO}_2 = \mathsf{sulfur} \; \mathsf{dioxide} \\ \mathsf{VOCs} = \mathsf{volatile} \; \mathsf{organic} \; \mathsf{compounds} \\ \mathsf{Source:} \; \mathsf{PLP} \; \mathsf{2018} \mathsf{-RFI} \; \mathsf{007} \end{array}$ 

## K4.20.2 Model-Predicted Direct Impacts

The assessment of representative project model-predicted air quality impacts is addressed for select project components and phases in the following sections. As described in PLP 2018-RFI 009, near-field ambient air quality impacts were predicted using the EPA AERMOD (American Meteorological Society/EPA Regulatory Model) dispersion modeling system. The AERMOD system is preferred and required by the EPA for applications similar to what is needed for this analysis has undergone the necessary peer scientific reviews and model performance evaluation exercises that include statistical measures of model performance in comparison with measured air quality data as described in Section 3.1, Introduction to Affected Environment, and 40 Code of Federal Regulations (CFR) Section 2.1.1, Appendix W to Part 51, Guideline on Air Quality Models.

## K4.20.2.1 Comparison of Model-Predicted Direct Impacts to Applicable Thresholds

Project direct impacts are compared to applicable thresholds using near-field dispersion models for Class II areas and far-field modeling assessments tools for federal Class I areas. Federal Class I area status is assigned to federally protected wilderness areas and allows the lowest

amount of permissible deterioration. All other areas are Class II, allowing for a moderate amount of air quality deterioration.

## Near-Field Class II Area Impact Assessments

The Clean Air Act (CAA) of 1970 (42 United States Code [USC] 7401 et seq.), as amended in 1977 and 1990, is the primary federal statute that regulates air pollution. The CAA provides states with the authority to regulate air quality within state boundaries. The State of Alaska has enacted the Alaska Ambient Air Quality Standards (AAAQS). The AAAQS establishes maximum acceptable concentrations for criteria pollutants, including nitrogen dioxide (NO<sub>2</sub>), carbon monoxide (CO), sulfur dioxide (SO<sub>2</sub>), particulate matter with an aerodynamic diameter of 10 microns or less (PM<sub>10</sub>), particulate matter with an aerodynamic diameter of 2.5 microns or less (PM<sub>2.5</sub>), ozone, ammonia, and lead. The AAAQS represent the maximum allowable atmospheric concentrations that may occur to protect public health and welfare and include a reasonable margin of safety to protect the more sensitive individuals in the population. Table K4.20-10 lists the AAAQS criteria used to evaluate both project and background impacts, based on the results of dispersion modeling. Note that lead and ammonia emissions are either minimal or not emitted at all from project components; therefore, they were not addressed as part of the impact analysis.

In addition to the AAAQS, New Source Review Prevention of Significant Deterioration (PSD) regulations are a CAA provision that is relevant to the project's impact assessment. PSD regulations under New Source Review require an analysis of potential increases in air pollutant concentration due to proposed major stationary sources (or major modification of any existing major stationary source) in areas where the baseline dates have been set (40 CFR Part 51). According to PLP 2018-RFI 012, the mine site would be the only portion of the project potentially considered a major source under PSD rules and may require this assessment.

To perform an increment analysis, modeled project-only impacts are compared to allowed maximum incremental increases in air pollutant concentrations, referred to as "PSD increments." The PSD increments for criteria pollutants are based on the PSD classification of the area. Class I areas allow the lowest amount of air quality increment consumption, while Class II designations allow higher increment consumption. The project is in a Class II area, and the project-only impacts based on near-field modeling are assessed using the PSD Class II increments as listed in Table K4.20-10. An evaluation of PSD Class I increments is qualitatively based on predicted Class II increment impacts even though screening analyses conducted in PLP 2018-RFI 012 show that the closest Federal Class I areas are too far from the project to be impacted by the project. PSD Class I increments are listed in Table K4.20-10. The comparison of impacts using PSD Class II and Class I increments has been provided for informational purposes only and does not represent a regulatory PSD increment consumption analysis. PSD increment consumption would be assessed as part of a formal increment consumption analysis during the permitting process, if required.

Also, for the purpose of this assessment, not all ambient standards and increments are addressed. The modeled project and project-only impacts are compared only to ambient standards and increments applicable to the project based on likely air quality permits requirements once the project is operational.

Table K4.20-10: Prevention of Significant Deterioration Increments and Alaska Ambient Air
Quality Standards

Avoraging		PSD	Increment	t Value (µg/m³)	AAAQS		
Pollutant	Period	Class II	Class I	Form	Value (µg/m³)	Form	
<u></u>	8-hour	N/A	N/A	N/A	10,000	Not to be exceeded more than once per year	
0	1-hour	N/A	N/A	N/A	40,000	Not to be exceeded more than once per year	
	Annual	25	2.5	Annual mean	100	Annual mean	
NO <sub>2</sub>	1-hour	N/A	N/A	N/A	188	98 <sup>th</sup> percentile of annual distribution of the maximum daily 1-hour concentrations averaged over 3 years	
	Annual	4	1	Annual mean	12	Annual mean, averaged over 3 years	
PM <sub>2.5</sub>	24-hour	9	9 2 Not to be exceeded more than once per 35 year		35	98 <sup>th</sup> percentile, averaged over 3 years	
	Annual	17	4	Annual mean	N/A	Annual mean	
PM10	24-hour	30	8	Not to be exceeded more than once per year	150	Not to be exceeded more than once per year on average over 3 years	
	Annual	20	2	Annual mean	80	Never to be exceeded	
	24-hour	91	5	Not to be exceeded more than once per year	365	Not to be exceeded more than once per year	
SO <sub>2</sub>	3-hour	512	25	Not to be exceeded more than once per year	1,300	Not to be exceeded more than once per year	
	1-hour	N/A	N/A	N/A	196	99th percentile of the annual distribution of the maximum daily 1-hour concentrations averaged over 3 years	
Lead	Rolling 3-month average	N/A	N/A	N/A	0.15	Not to be exceeded	
Ammonia	8-hour	N/A	N/A	N/A	2.1 mg/m <sup>3</sup>	Not to be exceeded more than once per year	

Notes:

AAAQS = Alaska Ambient Air Quality Standards

CO = carbon monoxide

 $\mu g/m^3$  = micrograms per cubic meter

mg/m<sup>3</sup> = milligrams per cubic meter

N/A = not applicable

NO<sub>2</sub> = nitrogen dioxide

 $PM_{2.5}$  and  $PM_{10}$  = particulate matter with an aerodynamic diameter less than or equal to 2.5 and 10 micrometers, respectively PSD = prevention of significant deterioration

 $SO_2$  = sulfur dioxide

Source: Alaska Administrative Code Title 18, Section 50.010

Because of the lack of large nearby sources, modeling was conducted only to predict project-only concentrations. Therefore, project total ambient impact concentrations were developed by

summing the project-only concentrations with a representative background concentration. The background concentrations include the contributions from non-modeled sources, which include nearby emission sources, natural sources, other unidentified sources in the vicinity of the project, and regional transport contributions from more distant sources. Project-only impacts can be inferred from the modeling results tables presented in the following sections by eliminating the background concentrations.

The background concentrations for all components were obtained from Alaska Department of Environmental Conservation (ADEC) (ADEC 2019b). As ambient air background often varies by location, the background concentrations used for each project component differ. The background concentrations for the mine site and port were calculated using data collected at the PLP Iliamna Air Quality Monitor from April 1, 2012 through March 31, 2013. Because of the monitor's close proximity to the mine site (approximately 30 miles), these background concentrations (presented in the modeling results tables) are representative of the ambient environment. The background concentrations used for the Kenai compressor station were calculated from the data collected at Chevron Swanson River Monitor from 2008 through 2009 because of the proximity of that monitor to the compressor station location. Additionally, because there are no RFFA within 31 miles of project area that would overlap in time with the project's construction and operations, the background values added to the project total are representative of the cumulative project impact.

## Far-Field Class I Area Impact Assessments

As previously discussed, according to PLP 2018-RFI 012, the mine site would be the only portion of the project potentially considered a major source under PSD rules and may require this assessment. Given that there is a large distance (greater than 90 miles) between the mine and Class I areas and that project near-field criteria pollutant impacts are minimal, it is anticipated that the far-field ambient air quality impacts at Class I areas would be even smaller and below the AAAQS. Although a quantitative PSD Class I increment assessment was not performed at nearby Class I areas, the increment impacts are implicit in the PSD Class II increment analysis presented below. That analysis shows that all modeled pollutant impacts are below Class I PSD increments at the mine site safety zone boundary, except for 24-hour PM<sub>2.5</sub> and 24-hour PM<sub>10</sub>. Although they exceed the Class I PSD increment thresholds, they are still relatively low and it is important to note that the highest 24-hour PM<sub>2.5</sub> and 24-hour PM<sub>10</sub> impacts from the modeling assessment occurred less than a kilometer away from the mine site, near or on the mine site safety zone boundary (see Figure 1.4 of PLP 2018-RFI 009). Furthermore, the analyses presented show that impacts would rapidly decrease from that point outward. Therefore, it is highly unlikely that mine site modeled impacts at the nearest Class I area, Tuxedni Wilderness, which is separated by extremely high terrain and a distance of greater than 150 kilometers, would exceed 24-hour PM<sub>2.5</sub> and 24-hour PM<sub>10</sub> PSD Class I increments. This is consistent with the screening analyses presented in PLP 2018-RFI 012, which implies that impacts at Class I areas would be insignificant and not cause or contribute to an increment violation. For this reason, a project-only quantitative PSD Class I increment analysis was not performed. Furthermore, because project impacts are not expected to contribute to a violation, a quantitative cumulative PSD Class I increment analysis was not performed.

In addition to an analysis of ambient air quality and increment impacts, a far-field impact assessment also includes describing impacts to air quality-related values (AQRVs). The US Forest Service, National Park Service, and US Fish and Wildlife Service (USFWS), collectively the Federal Land Managers (FLM), define an AQRV as "a resource, as identified by the FLM for one or more federal areas that may be adversely affected by a change in air quality. The resource may include visibility, or a specific scenic, cultural, physical, biological, ecological or recreational resource identified by the FLM for a particular area" (Federal Land Managers' Air Quality Related Values Workgroup [FLAG] 2010). The AQRV analysis is typically limited to either a plume blight or regional haze analysis depending on impact magnitude and an acidic deposition analysis. The FLAG 2010 document provides guidance on methods used to assess the potential AQRV impacts.

For similar projects that have relatively low emissions and are far from the Federal Class I areas, FLAG 2010 offers a Q/D<sup>1</sup> screening approach to potentially avoid the need to quantify impacts for direct comparison to AQRVs. The Q/D value is calculated by dividing the sum of potential oxides of nitrogen (NO<sub>x</sub>), total suspended particulate matter (PM), and SO<sub>2</sub> emissions by the distance to the closest boundary of a Class I area. A Q/D value of greater than or equal to 10 would indicate possible AQRV impacts to the Federal Class I from the project; below 10, and the project is considered to have minimal impacts to AQRVs in the Class I area.

Critical load values for federal Class I areas are used to assess acidic deposition, if such analysis is needed. To assess the magnitude of acidic nitrogen deposition, the National Park Service has developed nitrogen deposition critical load values for federal Class I areas based on the amount of deposition that could lead to harmful changes in an ecosystem. As presented in Section 3.20, Air Quality, the nitrogen deposition critical loads for Denali National Park, Tuxedni National Wildlife Refuge, and other nearby federal Class I areas are between 1.2 and 17 kilograms per hectare per year (kg/ha/yr). Cumulative project impacts below this threshold are acceptable.

## K4.20.2.2 Discussion of Model-Predicted Criteria Pollutant Impacts for the Representative Project Components

The approach and results of the assessment of emissions and impacts of the representative project are addressed for select project components (mine site, transportation corridor, Amakdedori port, and natural gas pipeline corridor) and phases (construction, operations, and closure) for which direct impacts were predicted using modeling. Components and phases selected for modeling were those anticipated to produce impacts with the highest magnitude, largest geographic extent, and longest duration. Impacts from all other phases would be less impactful and were assessed by proxy to the phases modeled.

The federal action consists of the discharge of fill material into waters and wetlands, and authorization to work in and place structures in wetlands and other waters. For the project, the federal action that could cause an air impact includes the construction and operations of the Amakdedori port, construction and operations of the ferry terminals at Iliamna Lake, and construction and operations of the offshore pipeline across Iliamna Lake and Cook Inlet. Discussion of the assessed magnitude, duration, extent, and probability for each of these components is provided in the sections below. Based on the modeling assessments described in the sections below, for those project activities directly related to the federal action, impacts would be minimal and localized, and are likely to occur while the components are being constructed and/or operated. Once the construction and operations would cease and would no longer contribute to cumulative impacts.

# <u>Mine Site</u>

Potential direct impacts from the mine site were developed by completing a project impacts assessment using dispersion modeling. For the dispersion modeling of the mine site, a safety zone was established around the mine site. This safety zone provided a buffer between the mine

<sup>&</sup>lt;sup>1</sup> **Q/D** is the sum of certain pollutant emissions (tons per year) divided by distance (kilometer) from Class I area.

site and public access areas to ensure that the public would not be exposed to work site safety risks. Therefore, model receptors were placed only along and outside of the safety zone boundary to capture public access areas. The assessment was conducted based on a modeling analysis of the emissions presented under "Emissions Inventory," in Section 4.20, Air Quality. The analysis of modeling needs was based on likely air quality permits required once the mine is operational, which resulted in only select pollutants being modeled. The full permit applicability analysis is provided in PLP 2018-RFI 007.

## Construction

The concentration of PM attributed to the increase in emissions from construction activities of a new permitted source lasting less than 24 months is excluded from PSD increment consumption analysis under 18 Alaska Administrative Code (AAC) 50.306(b)(2). Therefore, PM<sub>10</sub> and PM<sub>2.5</sub> PSD increments were not part of the dispersion modeling assessment. However, in accordance with the requirements for potential future air permit authorizing the construction and operations of a stationary source, dispersion modeling was conducted to demonstrate compliance with the NO<sub>2</sub>, PM<sub>10</sub>, and PM<sub>2.5</sub> AAAQS. Although ADEC has not approved or reviewed modeling performed, the modeling is consistent with ADEC minor air quality dispersion modeling permitting requirements. In addition, modeling was performed to demonstrate that the level of project-related air quality deterioration is lower than the applicable NO<sub>2</sub> PSD Class II increment. Table K4.20-11 and Table K4.20-12 present the modeling results relative to the AAAQS and the PSD Class II increment, respectively. The maximum modeled near-field impacts are shown in Figure K4.20-1 and the modeled PSD Class II increments are shown in Figure K4.20-2. The star points in the figures represent the locations of the maximum modeled impact, which all occur along the mine site safety zone boundary. Additional details regarding the near-field modeling configuration, emissions, and assessments are provided in PLP 2018-RFI 009. Minimal and localized impacts would only occur during the construction of the mine site. Impacts would dissipate once the construction was complete. Far-field modeling was not conducted or warranted because the impacts would be temporary, and only occur when the construction activities are ongoing. Furthermore, because the construction impacts are temporary, the potential impacts would be lower than those during the operations phase, for which far-field impacts are analyzed in the following section.

Pollut- ant	Averag- ing Period	Maximum Project-only Predicted Concentration (µg/m <sup>3</sup> )	Background Concentration (µg/m³)	Maximum Concentration (µg/m³)	AAAQS (µg/m³)	Percent of the AAAQS
	1-Hour	77.9	2.3	80.2	188	43%
NO <sub>2</sub>	Annual	0.3	0	0.3	100	0.3%
PM10	24-Hour	23.2	12.4	35.6	150	24%
	24-Hour	2.2	4.1	6.3	35	18%
PM <sub>2.5</sub>	Annual	0.3	0.9	1.2	12	10%

Table K4.20-11: Mine Site Construction Maximum Modeled Project Impacts Compared to the
AAAQS

Notes:

AAAQS = Alaska Ambient Air Quality Standards

 $\mu g/m^3 = micrograms per cubic meter$ 

 $NO_2$  = nitrogen dioxide

 $PM_{2.5}$  and  $PM_{10}$  = Particulate matter with an aerodynamic diameter less than or equal to 2.5 and 10 micrometers, respectively Source: PLP 2018-RFI 009

# Table K4.20-12: Mine Site Construction Maximum Modeled Project-Only Impacts Compared to Class II PSD Increment Limit

Pollutant	Averaging Period	Maximum Project-only Predicted Concentration (μg/m <sup>3</sup> )	Class II PSD Increment (µg/m³)	Percent of the Class II PSD Increment
NO <sub>2</sub>	Annual	0.3	25	1.2%

Notes:

µg/m<sup>3</sup> = micrograms per cubic meter

NO<sub>2</sub> = nitrogen dioxide

PSD = prevention of significant deterioration

Source: PLP 2018-RFI 009



#### Figure K4.20-1: Mine Site Construction Maximum Modeled Project Impacts (AAAQS)



Figure K4.20-2: Mine Site Construction Maximum Modeled Project-Only Impacts (PSD)

# Operations

A near-field modeling assessment was completed for mine site operations. Although ADEC has not approved or reviewed the modeling performed, the modeling is consistent with ADEC air quality permitting requirements, which require a permit to construct and operate a stationary source. The modeling assessment was prepared to address the potential air quality impacts related to the operation of the mine site. Table K4.20-13 and Table K4.20-14 summarize the modeling results relative to the AAAQS and the PSD Class II increments, respectively, that are likely to be required for an air quality permit. The maximum modeled impacts are shown for modeled pollutants compared to AAAQS in Figure K4.20-3; and the modeled pollutants compared to the PSD Class II increments are shown in Figure K4.20-4. The star points in the figures represent the locations of the maximum modeled impact, which both occur along the mine site safety zone, that would preclude public access. Additional details regarding the near-field modeling configuration, emissions, and assessments are provided in PLP 2018-RFI 009. Through modeling, compliance with applicable AAAQS has been demonstrated. In addition, modeling has demonstrated that the level of project-related air quality deterioration is lower than the applicable PSD increment. Minimal and localized impacts would occur only during operations at the mine site. Once the operations phase is complete, all emissions and impacts associated with operations would cease and would no longer contribute to cumulative impacts.
# Table K4.20-13: Mine Site Operations Maximum Modeled Project Impacts Compared to the AAAQS

Pollutant	Averaging Period	Maximum Project-Only Predicted Concentration (µg/m³)	Background Concentration (μg/m³)	Maximum Concentration (μg/m³)	AAAQS (μg/m³)	Percent of the AAAQS
	1-Hour	99.1	2.3	101.4	188	54%
NO <sub>2</sub>	Annual	0.1	0	0.1	100	0.1%
PM <sub>10</sub>	24-Hour	26.3	12.4	38.7	150	26%
	24-Hour	3.2	4.1	7.3	35	21%
PM <sub>2.5</sub>	Annual	0.5	0.9	1.4	12	12%

Notes:

AAAQS = Alaska Ambient Air Quality Standards  $\mu g/m^3 =$  micrograms per cubic meter

 $NO_2$  = nitrogen dioxide

 $PM_{2.5}$  and  $PM_{10}$  = Particulate matter with an aerodynamic diameter less than or equal to 2.5 and 10 micrometers, respectively Source: PLP 2018-RFI 009

#### Table K4.20-14: Mine Site Operations Maximum Modeled Project-Only Impacts Compared to Class II PSD Increment Limit

Pollutant	Averaging Period	Maximum Project-only Predicted Concentration (μg/m³)	Class II PSD Increment (µg/m³)	Percent of the Class II PSD Increment
NO <sub>2</sub>	Annual	0.1	25	0.4%
PM10	24-Hour	26.3	30	88%
	Annual	1.6	17	9.4%
PM <sub>2.5</sub>	24-Hour	8.0	9	89%
	Annual	0.5	4	13%

Notes:

µg/m³ = micrograms per cubic meter

 $NO_2$  = nitrogen dioxide

PSD = prevention of significant deterioration

 $PM_{2.5}$  and  $PM_{10}$  = Particulate matter with an aerodynamic diameter less than or equal to 2.5 and 10 micrometers, respectively Source: PLP 2018-RFI 009





Source: PLP 2018-RFI 009



Figure K4.20-4: Mine Site Operations Maximum Modeled Project-Only Impacts (PSD Increment)

Source: PLP 2018-RFI 009

To assess the far-field AQRV impacts, the Plume Visual Impact Screening Model (VISCREEN) was used to determine whether air pollutant emissions from the mine site would cause visibility impacts at Federal Class I areas in the general vicinity of the mine site. Like AERMOD, VISCREEN is recommended by the EPA for visual impact screening applications similar to the current analysis and has undergone the necessary peer scientific reviews and model performance evaluation exercises that include statistical measures of model performance. A discussion of model applicability is described in 40 CFR Section 6.2.1.1, Appendix W to Part 51.

Based on the combination of inputs, distances modeled, and conservative model assumptions, the model-predicted impacts show that the visibility screening criteria established for federal Class I areas would not be exceeded at any federal Class I area, obviating the need for a cumulative impact analysis to demonstrate that this project would not adversely contribute to regional haze. Further details of this assessment are provided in PLP 2018-RFI 012.

Although far-field deposition impacts from the mine site operations were not evaluated in PLP 2018-RFI 012, conservative estimates of potential far-field deposition impacts can be inferred from predicted near-field annual NO<sub>x</sub> and SO<sub>2</sub> impacts using a screening technique detailed in the Level I Analysis of Long Range Transport and Depositional Impacts (EPA 1993), and conservatively assuming total conversion of NO<sub>x</sub> and SO<sub>2</sub> emissions to depositional nitrogen and sulfur. NO<sub>x</sub> and SO<sub>2</sub> contribute to deposition when these compounds are converted into other compounds that are readily removed from the atmosphere and deposited to soils, vegetation, and waterbodies. SO<sub>2</sub> emissions from the mine site operations are below the modeling requirement,

based on likely permitting needs. Therefore, the SO<sub>2</sub> impacts were not modeled for the mine site, and it is unlikely that the SO<sub>2</sub> emissions from the mine site operations would be large enough to contribute to sulfur deposition impacts. Unlike SO<sub>2</sub>, annual NO<sub>2</sub> concentrations were predicted, as shown in Table K4.20-13, and were used to estimate acidic nitrogen deposition. Using the maximum project-only concentration at the mine site safety zone as input to the screening approach discussed above yields a conservatively high nitrogen deposition impact of 0.5 kg/ha/yr. Deposition impacts at the Class I areas that are more than 62 miles from the safety zone would be smaller.

As discussed in Section 3.20, Air Quality, the nitrogen deposition critical loads for Denali National Park and Preserve, Tuxedni Wilderness in Alaska Maritime National Wildlife Refuge, and other nearby federal Class I areas range from 1.2 kilograms of nitrogen per hectare per year (kgN/ha/yr) for lichens and bryophytes, to 17.0 kgN/ha/yr for forests and nitrate leaching (NPS 2018e). The critical loads are for total (wet plus dry) deposition, while the project nitrogen deposition impact is representative of dry deposition for the project only. Representative measured wet and dry deposition values can be added to the project-only nitrogen deposition impact to provide an estimated total deposition, which can be compared to criteria loads to assess the mine site operation's deposition impact. Measured wet and dry deposition values representative of nearby Class I areas (Tuxedni and Denali) were measured at Denali National Park and Preserve. As presented in Table 3-20-4, for 2015, the measured nitrogen dry deposition value at the park was 0.3 kg/ha/yr, while the wet deposition was 0.4 kg/ha/yr (1.5 micro-equivalent per liter). When added to the project-only deposition, the total deposition is 1.2 kg/ha/yr. This estimated total deposition is equal to the lowest critical load for lichens and bryophytes, which is an ecosystem found in Denali National Park and Preserve, Tuxedni Wilderness in Alaska Maritime National Wildlife Refuge, and other nearby Federal Class I areas. Although the calculated total nitrogen deposition value is a conservatively high estimate, the analysis still shows impacts equal to the lowest critical load value, and below the other criteria loads at a distance of 1 kilometer from the source. Therefore, because Denali National Park and Preserve, Tuxedni Wilderness in Alaska Maritime National Wildlife Refuge, and other nearby Federal Class I areas are more than 62 miles from the source, minimal impacts are expected.

# Closure

The closure phase of the mine site was not explicitly modeled, because the impacts are expected to be similar to those of the construction phase. The duration of the closure phase at the mine site is expected to be approximately 20 years, compared to fewer than 5 years of construction. However, the closure and construction activities and emissions in a given year would be similar. Assuming impacts would be similar to those from the construction phase, near-field impacts may be possible, but far-field impacts are unlikely to occur. Impacts are limited to the duration of mine site closure. Impacts would return to the baseline conditions at the end of the closure.

# Transportation Corridor

For analysis of impacts to air quality, the transportation corridor includes all-season gravel roads, ferry terminals on Iliamna Lake, port, and spur roads, and the onshore pipeline segment at the port, because the pipeline and road would be constructed jointly. The transportation corridor would be operational through the life of the project.

The emissions are presented previously in the "Emissions Inventory and Project Emissions Summary" subsection above. Due to lower levels of activity and emissions at the transportation corridor relative to the mine site, it is anticipated that the construction, operations, and closure of the transportation corridor would have lower near-field and far-field impacts than those predicted for the mine site. Therefore, modeling was not conducted for this project component phase, and impacts are assessed by proxy to those predicted for the mine site.

#### Amakdedori Port

Potential direct impacts from the port were developed by completing a project impacts assessment using dispersion modeling. The assessment was conducted based on the emissions previously presented above and an analysis of modeling needs based on likely air quality permits required once the port is operational. The permit applicability analysis is provided in PLP 2018-RFI 007. In the future, development of the port would be required to undergo complete permitting analysis.

#### Construction

Because of the lower level of construction activity and emissions at the port relative to the mine site, it is anticipated that the construction of the Amakdedori port would have lower near-field and far-field impacts than those predicted for the mine site; therefore, modeling was not conducted for this project component phase, and applicable impacts are assessed by proxy to those predicted for the mine.

### Operations

Based on the air quality permitting assessment, a minor source permit to construct and operate a stationary source could be required for NO<sub>x</sub> emissions, and not the other pollutants. A near-field modeling assessment was completed to determine the annual NO<sub>2</sub> impact of the NO<sub>x</sub> that would occur from the Amakdedori port. Although ADEC has neither reviewed nor approved the modeling performed, the modeling is consistent with ADEC minor air quality permitting dispersion modeling requirements. Table K4.20-15 presents the modeling results relative to the pollutant modeled in the form of the AAAQS. Figure K4.20-5 presents the maximum modeled impacts for NO<sub>2</sub> in the form of the annual NO<sub>2</sub> AAAQS. The star point in the figure represents the location of the maximum modeled impact, which is along the port boundary. Additional details regarding the near-field modeling configuration, emissions, and assessments are provided in PLP 2018-RFI 009. Results of this modeling show that AAAQS would not be exceeded under the port operations, and operations would result in minimal impacts, which would be localized, and remain only while the port is operational.

# Table K4.20-15: Amakdedori Port Operations—Maximum Modeled Project Impacts Compared to the AAAQS

Pollutant	Averaging Period	Maximum Project-Only Predicted Concentration (μg/m <sup>3</sup> )	Background Concentration (µg/m³)	Maximum Concentration (µg/m³)	AAAQS (µg/m³)	Percent of AAAQS
NO <sub>2</sub>	Annual	89.98	0	90	100	90%

Notes:

 $\mu$ g/m<sup>3</sup> = micrograms per cubic meter AAAQS = Alaska Ambient Air Quality Standards NO<sub>2</sub> = nitrogen dioxide Source: PLP 2018-RFI 009





To assess the far-field impacts, per the FLAG 2010 guidance, a Q/D screening assessment was conducted to determine if the emissions from the port would affect the AQRVs in the nearest federal Class I area. The Q/D value for the port is less than 1. As a result, AQRVs would not likely be affected at any of the federal Class I areas as a result of the port operations.

### Closure

Although near-field and far-field air quality impacts from port closure were not explicitly modeled, the impacts are expected to be similar to those outlined for the port construction, because the activities that would occur in a given year are similar. Near-field impacts may be possible, but far-field impacts are unlikely to occur. If the near-field impacts occur, they would be localized, minimal, and only occur during port closure activities.

### Natural Gas Pipeline Corridor

Potential direct impacts from the pipeline corridor were developed by completing a project impacts assessment using dispersion modeling. The assessment was conducted based on the emissions presented above and an analysis of modeling needs based on likely air quality permits that would be required once the pipeline is operational. The full permit applicability analysis is provided in PLP 2018-RFI 007. In the future, emissions sources associated with the pipeline would be required to undergo a complete permitting analysis.

Source: PLP 2018-RFI 009

#### Construction

It is anticipated that the construction associated with the pipeline corridor and compressor station would have lower near-field and far-field impacts than those predicted for the mine site, because the construction of the pipeline and compressor station would have fewer activities and lower emissions than the mine site. Therefore, modeling was not conducted for this project component phase, and impacts are assessed by proxy to those predicted for the mine.

### Operations

During the operations of the pipeline, the emissions and associated impacts from the onshore and offshore pipeline segments would be minimal. The Kenai compressor station would have emissions and possible air impacts. Therefore, for the operations phase, only the potential emissions from the compressor station were modeled.

A near-field modeling assessment for the operation of the compressor station was completed to address possible air quality impacts. Because a requirement to obtain a minor air quality permit might be triggered, a dispersion modeling assessment was completed. Although ADEC has neither reviewed nor approved of the modeling performed, the modeling is consistent with ADEC minor air quality dispersion modeling permitting requirements. Based on the estimated emissions, only NO<sub>x</sub> emissions would require modeling. Per permit requirements, dispersion modeling was used to determine the annual NO<sub>2</sub> impact of the NO<sub>x</sub> emissions that would occur from the Kenai compressor station. Table K4.20-16 presents the modeling results relative to the AAAQS. Figure K4.20-6 presents the maximum modeled impacts for NO<sub>2</sub> in the form of the annual NO<sub>2</sub> AAAQS. The star point in the figure represents the locations of the maximum modeled impact, which occur along the ambient air boundary of the compressor station. Additional details regarding the near-field modeling configuration, emissions, and assessments are provided in PLP 2018-RFI 009. This modeling shows that AAAQS would not be exceeded under compressor station operations. If near-field impacts occur from the compressor station, those impacts would be minimal, localized, and would only occur when the compressor station would be operating.

# Table K4.20-16: Kenai Compressor Station Operations—Maximum Modeled Project Impacts Compared to the AAAQS

Pollutant	Averaging Period	Maximum Project- only Concentration (μg/m <sup>3</sup> ) <sup>1</sup>	Background Concentration (μg/m³)	Maximum Concentration (µg/m³)	AAAQS (µg/m³)	Percent of AAAQS
NO <sub>2</sub>	Annual	17.7	13.2	30.9	100	30%

Notes:

AAAQS = Alaska Ambient Air Quality Standards  $\mu g/m^3$  = micrograms per cubic meter  $NO_2$  = nitrogen dioxide



Figure K4.20-6: Compressor Station Operations Maximum Modeled Project Impacts

To assess the far-field impacts, per the FLAG 2010 guidance, a screening assessment was conducted to determine if the emissions from the compressor station would affect the AQRVs in the nearest Federal Class I area. The Q/D value for the compressor station is less than 2. As a result, AQRVs would not likely be impacted at any of the Federal Class I areas as a result of the compressor station operations.

### Closure

Although the air quality near-field and far-field impacts from the closure activities were not explicitly modeled, the applicable impacts are anticipated to be similar to those presented for the construction phase, because the activities are similar in a given year. Near-field impacts may be possible, but far-field impacts are unlikely to occur. If the near-field impacts occur, they would be localized, minimal, and only occur during closure.

# K4.20.3 Discussion of Cumulative Impact Analysis for the Representative Project

Past, present, and RFFAs in the cumulative impact study area have the potential to contribute cumulatively to impacts on air quality. Section 4.1, Introduction to Environmental Consequences, details the past, present, and RFFAs that may impact air quality. The potential future actions are similar to the proposed project in how they impact air quality by emitting combustion-related air pollutant emissions from fuel-burning equipment and generating fugitive emissions from blasting, drilling, vehicle traffic on unpaved roads, and material handling.

There is no indication that development of the nearby RFFAs within roughly 30 miles of the Pebble Project (e.g., Pebble South/PED, Big Chunk South, Groundhog) would occur in the operations phase of the proposed Pebble Project. It is likely that some exploration activities from the nearby RFFAs would occur during the project operations, which could cause a small increase of emissions in the area. The exploration activities could likely result in a slight increase of emissions in and near the Pebble Project's transportation corridor, because the corridor could be used as a transportation corridor for other projects, as well. Beyond a slight increase of traffic through the transportation corridor, it is unlikely that the exploration activities would generate enough emissions to result in a change the Pebble Project's near-field impact, as presented above. Therefore, the near-field impacts assessed for the Pebble Project would be representative of the near-field cumulative impacts.

There are several RFFAs (e.g., Shotgun, Donlin Gold Mine, Alaska Liquefied Natural Gas [LNG]) that could be undergoing development and operations during the operations timeframe of the proposed Pebble Project. However, all these RFFAs are beyond 30 miles from the Pebble Project and would not influence the near-field impacts. The proposed Donlin Gold Mine would be situated roughly 174 miles northwest of the proposed Pebble mine site, and the proposed Alaska LNG facility would be roughly 137 miles east of the proposed Pebble mine site. These RFFAs would have their own impact on Federal Class I areas that could overlap with Pebble mine site operations. However, given the distance from the Pebble Project and the prevailing wind direction, it is unlikely these RFFAs would contribute to a far-field cumulative impact resulting from project emissions are too small and too far away from federal Class I areas to contribute to an adverse cumulative impact. Therefore, it is concluded that the magnitude of cumulative impacts associated with project emissions would be minimal.

As discussed in Section 4.1, Introduction to Environmental Consequences, the Pebble project expansion scenario, if approved, would begin at the end of the operations phase of the proposed project. Therefore, overlapping activities between the proposed project and the expansion that would add to cumulative impacts would be largely limited to a small number of years when there are still emissions associated with the closure of the proposed project and the expansion construction phase. During these limited years of overlap, the proposed project is ramping down and project emissions are decreasing. At the same time, activities associated with the expansion scenario would begin to increase over a period of years along with expanded emissions. It is reasonable to assume that decreases would approximately balance the increases leading to no meaningful change during the period of overlapping operations between the proposed and expansion activities. This is even the case for the power plant, which would increase in size, and the processing facilities, which would have increased throughput. Consider for these sources that the modifications required to increase capacity would not happen right away, and once modified. these sources would not achieve full operating capacity immediately. Therefore, in the few years of overlap between the proposed and expansion activities, these modified sources would not likely achieve full capacity and the emissions increases compared to those from the proposed project would not be as large as the potential change in throughput would suggest. Considering this example and the preceding discussion, it is reasonable to assert that cumulative emissions would not be meaningfully different from those analyzed for Alternative 1a. Therefore, the expansion scenario and the project would likely result in impacts of similar magnitude, duration, and geographic extent to those air quality impacts described under Alternative 1a for a given year.

# K4.20.3.1 Pebble Project Ambient Ozone

The entire project and all of its components are in an ozone unclassified area, with measurement showing no evidence of attainment issues. Additionally, there are minimal nearby anthropogenic

sources of NO<sub>x</sub> and volatile organic compounds (VOCs), which are ozone precursors. The area surrounding the mine site has naturally occurring VOCs. As demonstrated in Section 3.20, Air Quality, the ambient NO<sub>x</sub> concentrations surrounding the mine site are low. This results in a NO<sub>x</sub>-limited ozone environment, meaning that ozone formation is capped, because the reactions that result in ozone are limited by the amount of available NO<sub>x</sub>. Because the project NO<sub>x</sub> sources are dispersed over a large area and the potential to emit NO<sub>x</sub> from the project components would be low and are unlikely to accumulate to any large degree under stagnant atmospheric conditions, project air pollutant emissions would result in minimal ozone formation, if any formation would occur as a result of the project. Therefore, project impacts to ambient ozone concentrations would be minimal.