4.17 GROUNDWATER HYDROLOGY

This section describes the effects of the project on the distribution and movement of groundwater in the subsurface. Potential direct and indirect effects from the project may include:

- Drawdown of groundwater around the open pit from dewatering activities, and consequent reduction of groundwater available to surrounding surface water and wetlands.
- Reduction in natural recharge to groundwater from filling drainage areas beneath large project facilities such as water management ponds (WMPs) and tailings storage facilities (TSFs).
- Changes in groundwater flow patterns from shallow groundwater interception or surface water withdrawals during road and pipeline construction.
- Drawdown of groundwater around potable wells from water supply use.
- Changes to groundwater flow from horizontal directional drilling (HDD) activities.

The Environmental Impact Statement (EIS) analysis area includes the mine site, transportation corridor, pipeline corridor, and port for all alternatives and variants, and includes the watersheds most likely to be affected by the project (see Section 3.17, Groundwater Hydrology, Figure 3.17-1). The geographic area considered in the analysis of groundwater hydrology is the near vicinity of all project components (i.e., within 0.5 mile to several miles) where project effects could be expected to occur on groundwater flow patterns. The duration of impacts would either be short-term, lasting only though construction; or long-term, lasting though the life of the mine. Long-term impacts to groundwater may not be permanent if they would be resolved post-closure.

Scoping comments were received on impacts to groundwater systems and aquifers, and the transportation of groundwater, and how it moves underground. Commenters requested that existing groundwater within the area of both the project and alternatives, including groundwater levels and flow, be characterized; and that a thorough understanding of the groundwater and surface water hydrology and how they relate to each other should be demonstrated. Impacts to groundwater and surface water quality are addressed in Section 4.18, Water and Sediment Quality.

4.17.1 Methodology for the Analysis of Groundwater Impacts

Impacts to groundwater hydrology were evaluated based on baseline data, water management plans, and groundwater modeling. The methodology applied to analyze and predict direct or indirect impacts is based on the range of effects for each of following factors:

- Magnitude – Effects on groundwater flow systems are estimated by predicting changes in water table elevation, flow direction, or distance of impact from project activity. Effects could be maintained within historic seasonal variation; could exceed baseline variations, but nearby uses and conditions would be maintained; or there could be groundwater flow changes that affect nearby uses or environment.
- Duration – The duration of effects depends on project phase, length of construction activities, and aquifer characteristics. Groundwater flow effects could last no longer than construction, then return to baseline conditions; they could remain after construction throughout life of mine, and decades afterward; or they could not return to baseline conditions for more than 100 years.
- Geographic Extent – Groundwater flow effects are described in terms of area. Effects might be limited to portions of the project footprint or component area and not

hydraulically connected to waters outside the component area; they could occur beyond local project component areas, potentially throughout the EIS analysis area; or flow effects could be hydraulically connected to areas beyond the EIS analysis area.

- Potential – Most effects on groundwater flow at the mine site are considered likely to occur. The likelihood of occurrence for other project components is correlated to the distribution of shallow groundwater-bearing deposits, which varies across the project area; and the likelihood that the water table would be intercepted during specific construction activities.

4.17.2 No Action Alternative

Under the No Action Alternative, the project would not be undertaken; there would be no mine site, transportation corridor, port development, or natural gas pipeline corridor. Under the No Action Alternative, Pebble Limited Partnership (PLP) would have the same options for exploration activities that currently exist. There are many valid mining claims in the area, and these lands would remain open to mineral entry and exploration. It is possible for permitted exploration and environmental baseline data collection to continue under this alternative (ADNR 2018-RFI 073), which could include groundwater extraction from pump tests. These tests temporarily lower groundwater elevations in the immediate area surrounding a well, which typically recover to natural conditions within a matter of hours to days.

Groundwater along the transportation corridor, pipeline corridor, and at the port sites would remain in its current state. There would be no effects on existing private wells. In summary, there would little to no direct or indirect impacts on baseline groundwater conditions from implementation of the No Action Alternative.

4.17.3 Alternative 1 – Applicant's Proposed Alternative

4.17.3.1 Mine Site

Groundwater conditions resulting from mine site activities were modeled by Piteau Associates (2018a) using an updated version of the groundwater flow model originally developed by Schlumberger (2011a). Model development and calibration to baseline groundwater and streamflow conditions are described in Section 3.17, Groundwater Hydrology, and Appendix K3.17. The results of using the model to predict project effects on groundwater are described below, with additional details provided in Appendix K4.17. Model uncertainty and reliability are also summarized in this section, and additional details are provided in Appendix K4.17.

The analysis of project impacts using the model addressed two general areas: 1) the open pit; and 2) the bulk and pyritic TSFs and main WMP. Analysis of groundwater conditions was conducted for the groundwater capture zone[1] around the pit, and the zone of influence[2] for a wider area of the mine site. For the operations phase, the model estimated the effect of open pit dewatering on groundwater flow conditions at end of mining, the groundwater inflow rate to the pit, the related reduction of groundwater discharge to Upper Talarik Creek (UTC), South Fork Koktuli (SFK), and North Fork Koktuli (NFK) drainages, impacts to wetlands, and groundwater

[1] The **capture zone** is the area in which all groundwater flow is towards a groundwater "sink" and all groundwater recharge is captured by the sink. The outer boundary of the capture zone is a groundwater divide.

[2] The **zone of influence** is the area in which man-made hydraulic stress (such as dewatering) lowers groundwater elevations. The zone of influence is typically larger than the capture zone, because groundwater elevations can be affected outside the groundwater divide that defines the capture zone.

and seepage flow from the TSFs and the WMPs. The model was also used to assess groundwater flows after mining ceases, including the time to form an open pit lake and the lake level elevation needed to maintain it as a hydraulic sink. Post-closure was defined as the time at which the pit lake reached its maximum managed level after Closure Year 20.

Pit Dewatering

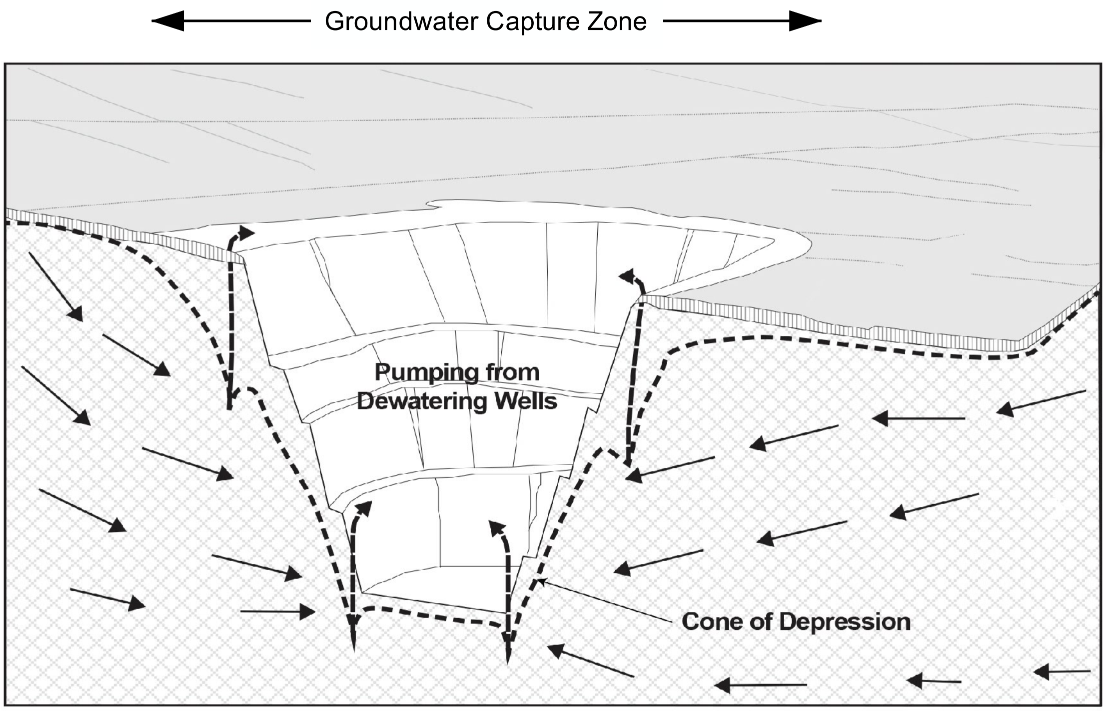
Construction and Operations. Dewatering of the open pit would be required to facilitate mining. Construction of the open pit would require lowering groundwater levels in the pit area through dewatering to establish stable pit walls and provide dry working conditions. Although a specific dewatering design has not been developed at this point, the ultimate pit dewatering design would be based on a series of interim pit phases that successively expand and deepen the pit. This phased approach would allow the pit dewatering program to be adjusted, based on the operational performance of each preceding phase (Knight Piésold 2018e).

Dewatering is typically accomplished by placement of dewatering wells around the proposed pit perimeter, wells in the pit bottom as mining progresses, and ditches and horizontal drains along the pit walls (Figure 4.17-1). Dewatering results in a groundwater "cone of depression[3]" because the water table is lowered in the pit, and the effect extends laterally beyond the pit area into the adjacent bedrock and overburden aquifers (see Appendix K3.17, Table K3.17-1 for aquifer descriptions). The cone of depression would deepen and widen as pit excavation progresses and dewatering expands, and would last as long as the dewatering system is operated during construction, operation, and closure of the mine. The magnitude and extent of impacts would be that groundwater levels would ultimately need to be lowered below the bottom of the final mine pit, which is estimated to be up to 2,200 feet below grade. Effects of groundwater drawdown on other resources such as wetlands and vegetation are described in Section 4.22, Wetlands and Other Waters/Special Aquatic Sites, and Section 4.26, Vegetation, respectively.

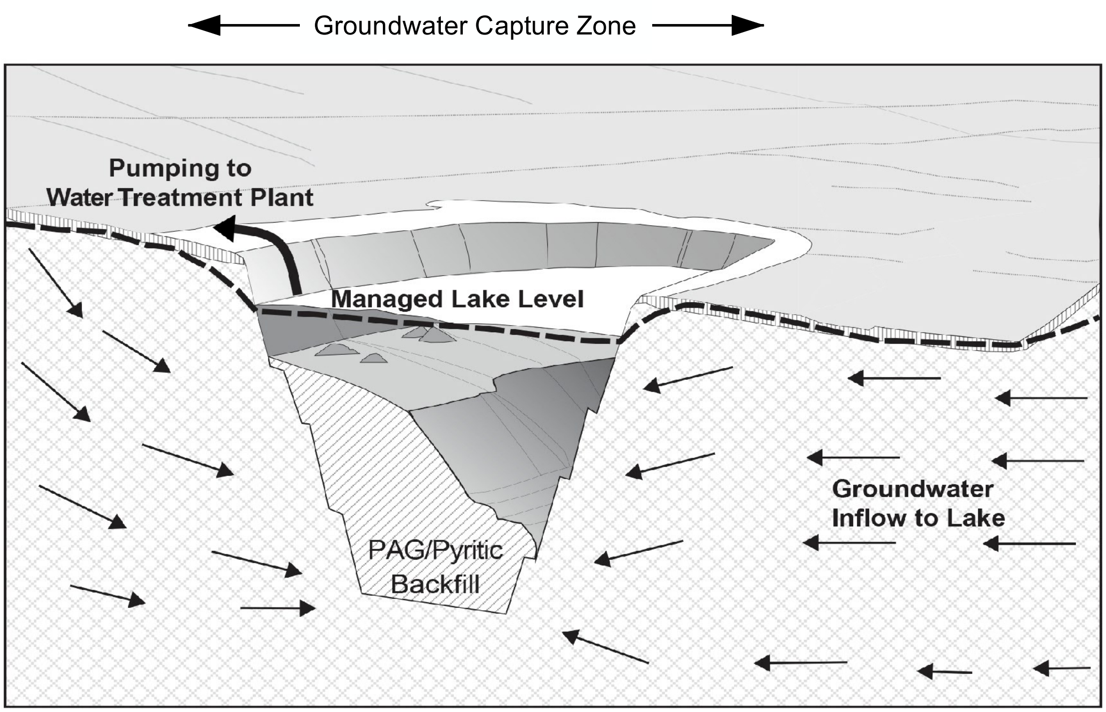
The initial dewatering well field during construction is conceptualized to consist of approximately 30 operating wells installed to a depth of 150 feet, and spaced about 200 feet apart around the starter pit perimeter (Knight Piésold 2018e). The wells would initially be pumped at a rate of 50 gallons per minute (gpm), with a total rate of approximately 1,500 gpm. The estimated groundwater inflow to the pit at the end of operations is estimated to be about 2,200 to 2,400 gpm (Piteau Associates 2018a). The well field at the end of mining is expected to include approximately 30 wells at 500-foot spacing around the pit perimeter. Sumps in the pit would capture precipitation and groundwater not captured by the dewatering system.

The rates of estimated groundwater inflow to the pit described above are based, in part, on a wide range of climate scenarios using a historical 40-year record of data (Section 3.16, Surface Water Hydrology). Potential changes in future precipitation due to climate change that result in more rain and less snow would tend to even out swings in seasonal recharge to the groundwater system, and lie within the scenarios estimated by the watershed module (AECOM 2018o). To estimate the effects of potential higher meteoric recharge on the groundwater model results, the model was run using double the amount of recharge. This would result in roughly twice the amount of inflow to the pit needing to be dewatered and treated (Piteau Associates 2018a). As described in Appendix K4.17, flexibility is built into the water management strategy in such a manner that the additional water could be stored within the capacity of the main WMP and treated at the water treatment plants (WTPs) (Knight Piésold 2018a, 2018f).

[3] **Cone of depression** refers to the geometry of the water table that develops in aquifers surrounding the pit when water is pumped from the pit or formation, creating an actual depression of groundwater levels. The surface created by connecting the water levels of many wells that penetrate the water table is shaped like an inverted cone (wider at the top).



Late Operations



Post-Closure

Sources: Modified from BGC 2014

US Army Corps
of Engineers

CONCEPTUAL GROUNDWATER SYSTEM AROUND PIT IN LATE OPERATIONS AND POST-CLOSURE

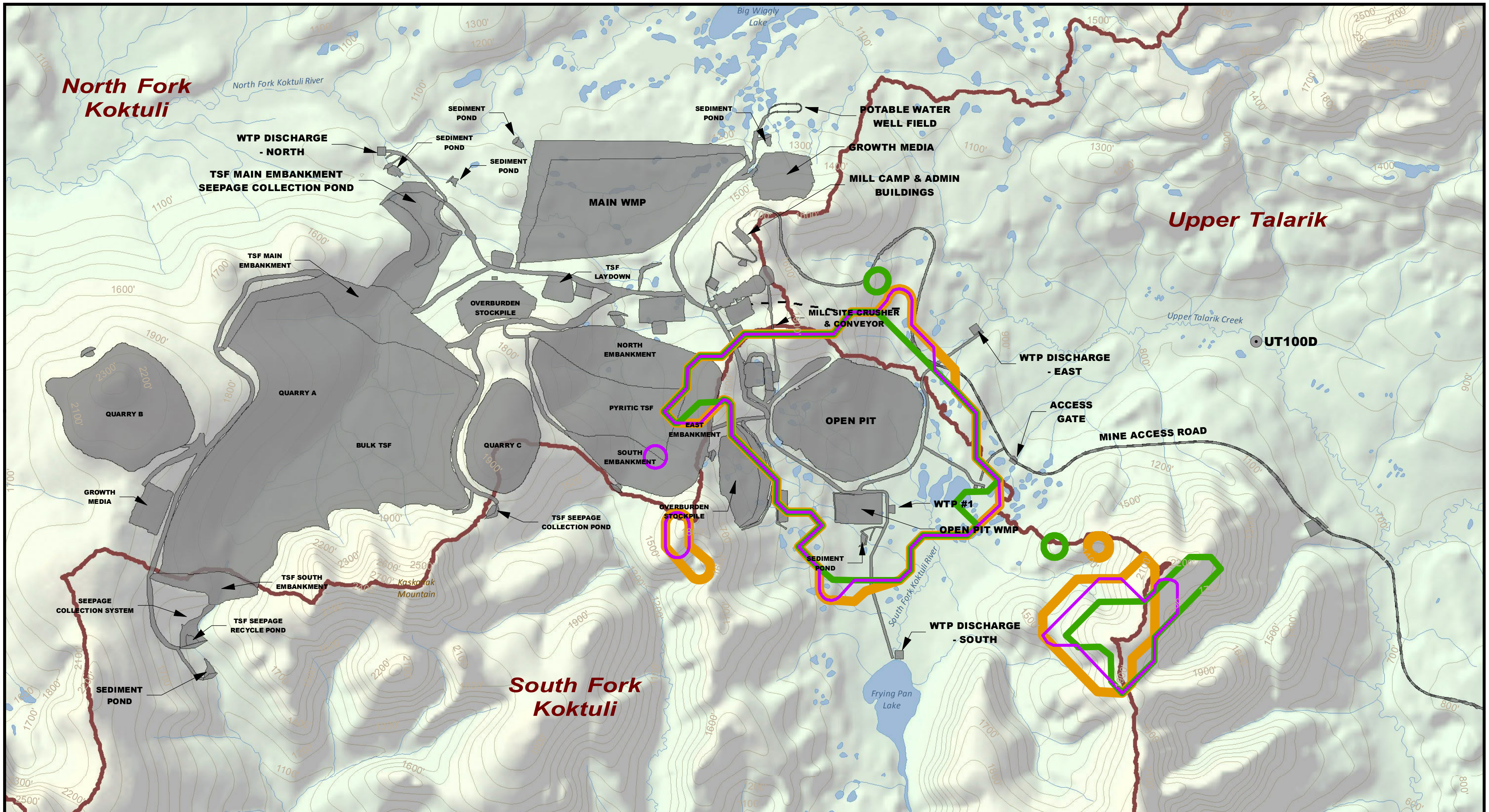
Water in the open pit would be managed using a storage pond and runoff controls. Groundwater inflows to the open pit would be pumped to the open pit WMP for storage and treatment prior to discharge from the WTPs (see Section 4.18, Water and Sediment Quality). Runoff from areas upslope of active mining would be intercepted and diverted around the open pit to the extent possible (see Section 4.16, Surface Water Hydrology). Direct rainfall, snowmelt, and runoff from the open pit walls would be collected and pumped using in-pit pumps to the open pit WMP for storage and treatment prior to discharge. WTP discharge locations would be located outside of the pit cone of depression.

Creation of a cone of depression around the pit would locally change groundwater flow patterns such that groundwater flows radially inwards and vertically upwards towards the pit. Groundwater/surface water interactions and surface water flows would also be impacted by pit dewatering. Natural groundwater discharge to seeps, wetlands, streams, ponds, or lakes in or adjacent to the proposed pit may cease or be reduced, resulting in lower surface water base flows, or pond or lake levels. In terms of magnitude and extent, some wetlands, stream segments, ponds, or lakes in the immediate pit area may be eliminated as the water table is lowered, and water leaks out of these waterbodies during construction and mining operation. The duration of this impact would be long term, lasting for the life of the project, and certain to occur if the project is permitted and built. Indirect impacts to wetlands from the lowered water table around the pit were evaluated by PLP (2018-RFI 082) by comparing the hydrogeomorphic wetlands classification codes to the permeability and recharge potential of surficial geologic units in the groundwater model to determine their susceptibility to dewatering impacts. Areas with highly permeable layers such as glacial outwash would be most affected by drawdown, whereas areas underlain by glacial lake deposits are relatively isolated from groundwater and less impacted by drawdown. Areas of drawdown that coincide with susceptible wetlands are shown on Figure 4.22-2, and acreages are provided in Section 4.22, Wetlands and Other Waters/Special Aquatic Sites.

The proposed pit would be located entirely within the headwaters of the SFK River watershed. Groundwater dewatering impacts related to the proposed project are expected to be confined to the upper reaches of the SFK watershed and the nearest portions of the UTC and NFK watersheds. In terms of magnitude, groundwater discharge from the SK100C sub-basin is estimated to be reduced by 2.9 cubic feet per second (cfs) at the end of operations without the addition of WTP flows to the basin, and is expected to be unchanged with addition of WTP discharges back into the basin (Knight Piésold 2018i). Groundwater discharge from the SK100C sub-basin is estimated to be reduced by 2 cfs during post-closure without the addition of WTP discharges, and reduced by 0.6 cfs with addition of WTP discharges. Impacts to wetlands, ponds, and small streams located upstream of the WTP discharge location would not be mitigated by WTP discharges. The extent of impacts is that pit dewatering may locally impact groundwater flow across the groundwater divide, drawing groundwater from the headwaters of the UTC watershed depending on the extent of the cone of depression around the pit (Piteau Associates 2018a). Without the addition of WTP outflows, groundwater discharge to the upper UTC drainage (above gage UT100D) is predicted to decline at a magnitude of 14 to 19 percent (Appendix K4.17, Figure K4.17-1). However, this reduction is expected to be mitigated by releases from the east WTP discharge location, so that groundwater flow would not change relative to natural conditions, and surface flows would increase slightly for both end of operations and post-closure periods on a mean annual basis, as observed at station UT100D (Knight Piésold 2018i, 2018j, 2018n). Impacts to wetlands, ponds and small streams located upstream of the WTP discharge location would not be mitigated by the WTP discharges. Pit dewatering is not expected to have any effects on groundwater flow in the NFK watershed (Knight Piésold 2018i, 2018j) Streamflow reduction during operations and closure is further addressed in Section 4.16, Surface Water Hydrology, and related effects on wetlands and fish are addressed in Section 4.22, Wetlands and Other Waters/Special Aquatic Sites and 4.24, Fish Values, respectively.

The extent of primary impacts to groundwater flow would be in the overburden and bedrock aquifers in the open pit footprint and cone of depression. Local, intermediate, and regional groundwater flow in these aquifers would radially flow towards the pit and be captured by the dewatering system. Groundwater located beneath the pit would also flow upwards towards the pit. The magnitude of impact to groundwater flow patterns would grow as mining proceeds to depth, and the cone of depression surrounding the pit becomes wider and extends to the full depth of the pit. Piteau Associates (2018a) estimates that the cone of depression at its widest extent at the end of operations would range from a distance of approximately 1,500 feet from the pit crest along its northeastern side, to as much as 14,000 feet along the ridge southeast of the pit, depending on the hydraulic character of the affected aquifers (Figure 4.17-2). The capture zone in the immediate area around the pit represents relatively shallow flowpaths, and the outlying areas represent deeper flowpaths with very low groundwater velocities. Groundwater outside of the capture zones is predicted to discharge to local streams or seeps as they do currently, and not be affected by the capture zone (Piteau Associates 2018a; Knight Piésold 2018n). The maximum area of the capture zone at the end of operations would be about 2,700 acres.

As further described in Appendix K4.17, the range of capture zones shown on Figure 4.17-2 are based on evaluating a modest range of variability in hydrogeologic properties assigned to the different layers and zones in the model to estimate the effect of uncertainty in these parameters. Although the model is a suitable tool for evaluating the effects of pit dewatering, other viable simulations of the model using different input parameters are possible. Considering the model uncertainties, the actual results of dewatering the pit may differ from projections described above. It is expected that the amount of water produced during pit dewatering could be larger than simulated, and the capture zone and zone of influence could be larger. Additional details regarding model uncertainty are provided in the Appendix K4.17.



Sources: Piteau Associates 2018a, Fig. 3

Groundwater Capture Zones
- 5th percentile
- 50th percentile
- 95th percentile

Alternative 1
- Natural Gas Pipeline
- Project Features

Other Features
- 100' Contour (Existing)
- River/Stream
- Lake/Pond
- Major Drainage Boundary

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0.5 0 0.5 1
Miles

ESTIMATED RANGE OF GROUNDWATER CAPTURE ZONES AT END OF OPERATIONS

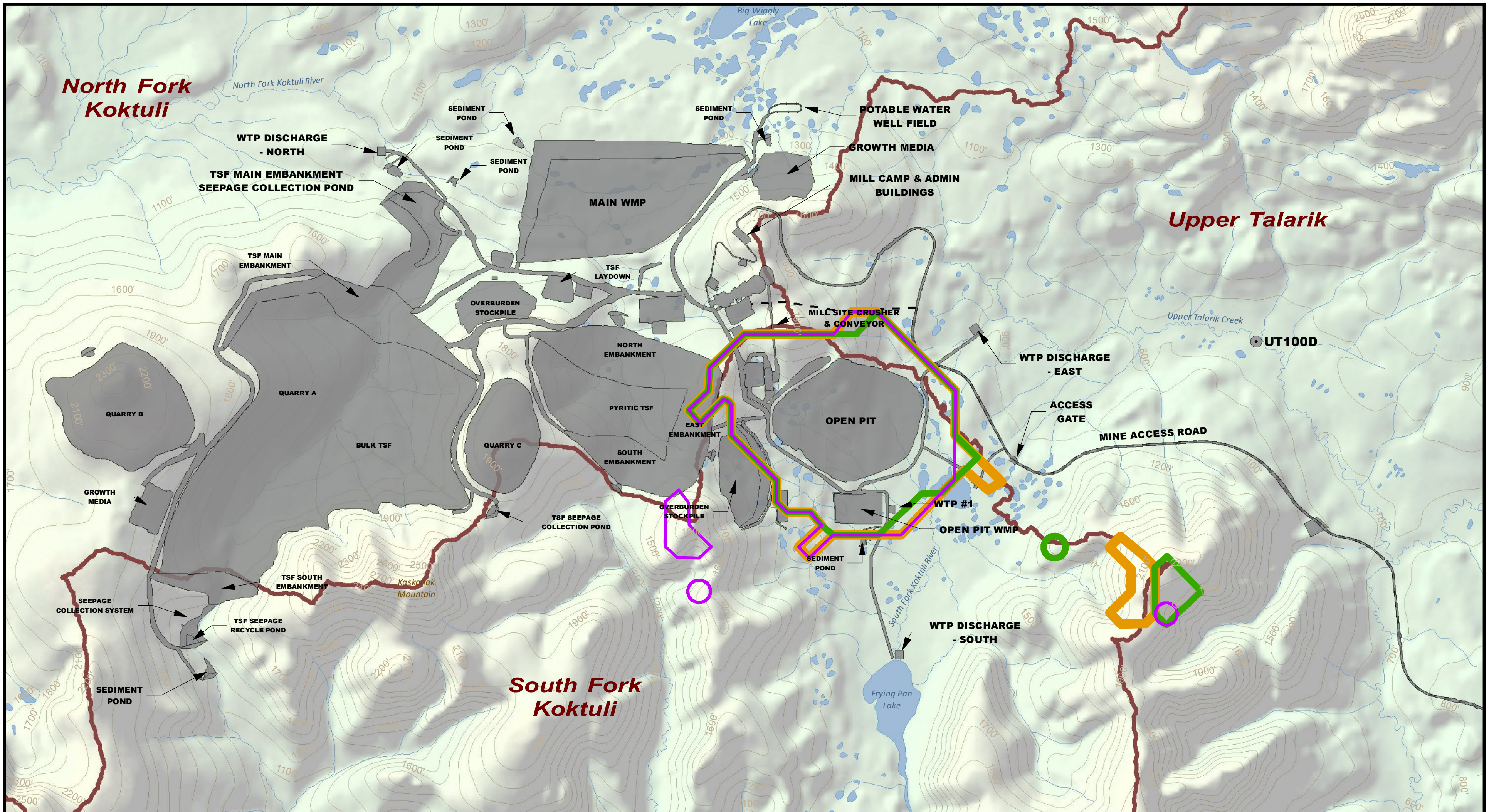
PEBBLE PROJECT EIS

FIGURE 4.17-2

Closure and Post-Closure. Once mining ceases, dewatering activities would be reduced while potentially acid-generating (PAG) waste rock and pyritic tailings are returned to the pit, and groundwater in the open pit would be allowed to rise. It is estimated it would take 19 to 21 years for the groundwater in the pit to reach the maximum management (MM) level (890 feet above mean sea level [amsl]) (not-to-exceed level would be 900 feet amsl) (Knight Piésold 2018n). The model was used to select the not-to-exceed level to prevent flow reversal and lake water seepage away from the pit, based on the elevation below which the model predicts all flow directions are towards the pit. Groundwater levels surrounding the pit would be monitored throughout closure to determine whether this control elevation would need to be adjusted to prevent groundwater outflow from the pit (Knight Piésold 2018n).

The groundwater level in the pit would be maintained to create a permanent groundwater sink to prevent pit lake water from discharging to the environment. Knight Piésold (2018d) estimates an average annual pit water surplus of 3 cfs, which would be managed by pumping and treating groundwater to maintain the MM level in the pit lake and prevent lake water from discharging into the environment. This would result in a permanent pit lake that would be pumped to maintain the MM level indefinitely (allowing for 10 feet of freeboard to accommodate the probable maximum flood and still not breach the not-to-exceed level of 900 feet). The current closure water balance and water quality models are based on monthly flows (Knight Piésold 2018g); therefore, it is assumed that the pit lake would be pumped year-round.

The presence of a permanent groundwater sink at the pit would continue to influence groundwater flow in the immediate vicinity of the pit throughout post-closure. However, the influence on groundwater flow would be smaller than in its fully dewatered state during active mining operations. Piteau Associates (2018a) estimates that the extent of the post-closure cone of depression would range from a distance of about 1,500 feet from the pit crest along its northeastern side, to as much as 13,500 feet from the pit crest to the southeast, depending on the actual hydraulic characteristics of the affected aquifer (Figure 4.17-3). Similar to operations, the post-closure model results show a capture zone in an immediate area around the pit representing relatively shallow flowpaths; several outlying zones along upland ridges east and west of the pit representing deeper flowpaths; and intermediate areas where groundwater recharge is expected to discharge to local streams and seeps and not be affected by the capture zone. The input parameters and assumptions used to estimate the range of capture zones shown on Figure 4.17-3 are described in greater detail in Appendix K4.17, Groundwater Hydrology.



Sources: Piteau Associates 2018a, Fig. 8

Groundwater Capture Zones
- 5th percentile
- 50th percentile
- 95th percentile

Alternative 1
- Natural Gas Pipeline
- Project Features

Other Features
- 100' Contour (Existing)
- River/Stream
- Lake/Pond
- Major Drainage Boundary

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0.5 0 0.5 1
Miles

ESTIMATED RANGE OF GROUNDWATER CAPTURE ZONES IN POST-CLOSURE

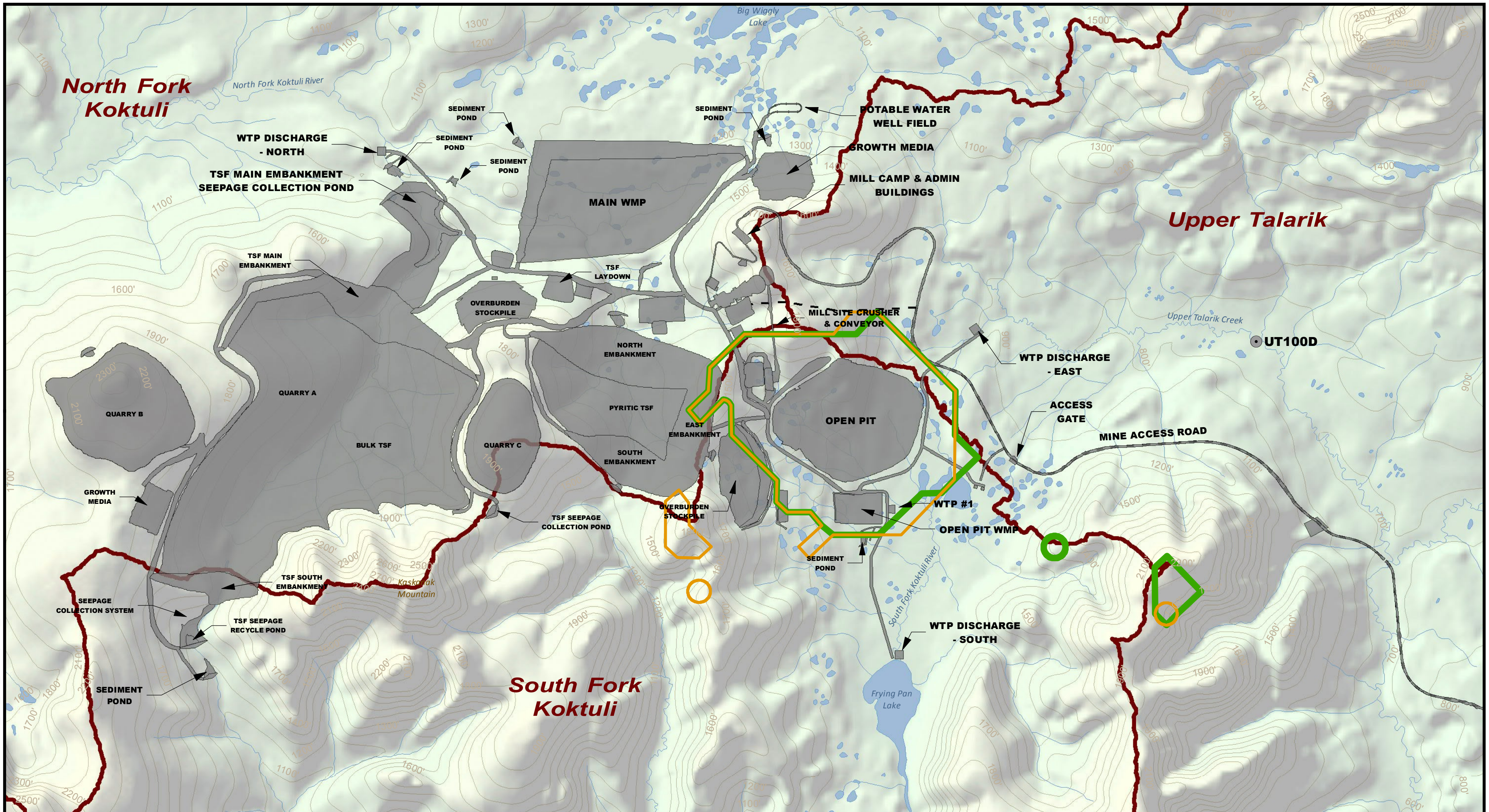
PEBBLE PROJECT EIS

FIGURE 4.17-3

A comparison between the estimated capture zones at the end of operations and post-closure is shown on Figure 4.17-4. The extent of the pit capture zone is expected to be roughly the same as during operations around the northern and southwestern sides of the pit; and in terms of magnitude, would shrink by about 1,000 to 3,000 feet elsewhere around the pit. The estimated extent of the capture zone in post-closure would be about 1,800 acres. The post-closure capture zone along the northeastern side of the pit is not much smaller than that at the end of operations, because the pit lake at its maximum elevation is below the lowest part of the bedrock ridge separating the pit from the UTC drainage, which causes shallow groundwater around the pit to continue discharging to the pit, similar to the end of operations. In contrast, the distal zone along the ridge east-southeast of the pit is predicted to be considerably smaller in post-closure, because this zone represents deeper flow paths in bedrock, where gradients would be reduced as the pit lake rises (Piteau Associates 2018a).

In terms of magnitude and extent, areas of wetlands indirectly affected by drawdown in post-closure would also shrink from those affected in operations, as shown on Figure 4.22-2 (acreages are provided in Section 4.22, Wetlands and Other Waters/Special Aquatic Sites). Duration of impacts would be long term, because impacted wetlands in the operations drawdown area outside of the post-closure area would be expected to recover after the final pit lake level is reached (PLP 2018-RFI 082). Uncertainty associated with these model projections is similar to those described as pertaining to the pit dewatering at the end of operations, as described in more detail in Appendix K4.17.

Impacts to groundwater from pit dewatering would occur if the project is permitted and constructed, and could include groundwater flow changes that affect the nearby environment. The duration of impacts would be more than 100 years, and the geographic extent could occur beyond local project component areas within the EIS analysis area.



Sources: Piteau Associates 2018a, Fig. 9

Groundwater Capture Zones

- Post-closure
- End of Operations

Alternative 1

- Natural Gas Pipeline
- Project Features

Other Features

- 100' Contour (Existing)
- River/Stream
- Lake/Pond
- Major Drainage Boundary

US Army Corps of Engineers®

N

0.5 0 0.5 1

Miles

COMPARISON OF GROUNDWATER CAPTURE ZONES IN OPERATIONS AND POST-CLOSURE

PEBBLE PROJECT EIS

FIGURE 4.17-4

Water Management Ponds

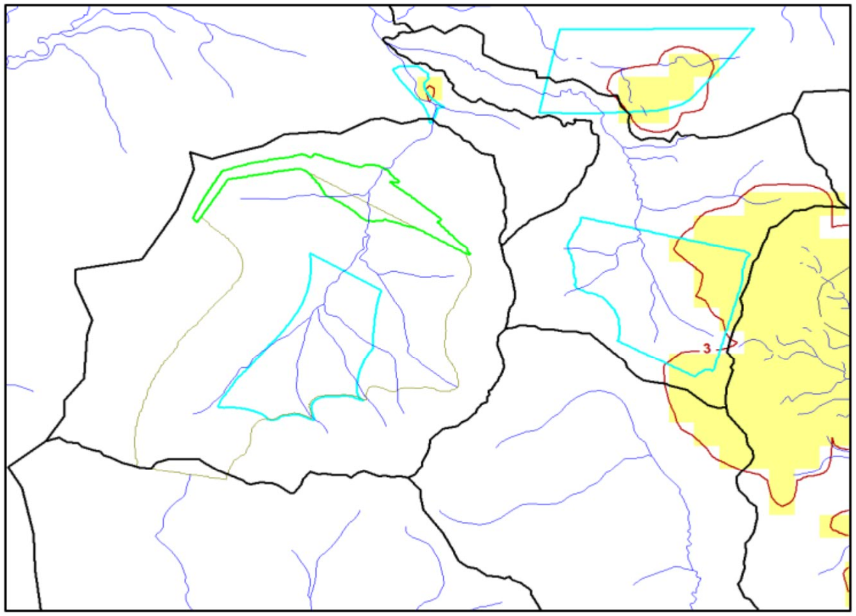
The main and open pit WMPs would be constructed at the mine site to manage water removed during pit dewatering, manage water from the milling and concentrating operations, and manage surface water runoff collected in the mine site. These ponds would be lined with high-density polyethylene (HDPE) and equipped with underdrains to minimize leakage of water with potentially elevated particulate and constituent concentrations to the underlying groundwater (PLP 2018-RFI 006). Water in the WMPs would be treated as needed, and used in the milling operations. The water may also be used in tailings disposal operations (to create a tailings slurry). Surplus water would be treated to discharge standards and released downstream of the mine site at specified discharge areas (see Section 4.16, Surface Water Hydrology, Figure 4.16-1) to mitigate surface water flow water balances downstream of the mine site (Section 4.16, Surface Water Hydrology). Surplus WMP water that is treated and discharged downstream of the mine site would help restore downgradient groundwater flow as it infiltrates into the subsurface to help maintain existing flow conditions.

Groundwater flow would be impacted by the construction of the WMPs, and local reduction in recharge caused by the presence of the liner. The groundwater model results indicate that groundwater levels would be lowered by several feet in the area of the main WMP (Figure 4.17-5). Modeling also indicates that the predicted change in groundwater levels would not change the estimated pre-mining groundwater discharge from sub-basin NF100C from 10.9 cfs compared to the end of operations scenario without treated water discharge (Knight Piésold 2018i). Removing the main WMP after closure would allow natural recharge to be re-established and groundwater elevations to recover.

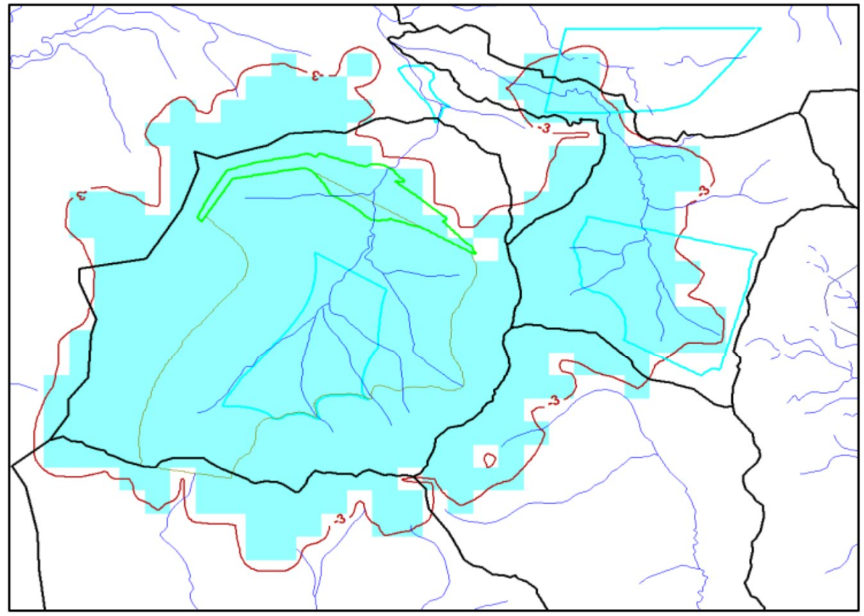
As described in Appendix K4.17, contact water that leaks through the main WMP liner to shallow groundwater would be mitigated by the monitoring/pumpback wells, which would continue to operate as long as required to intercept potential leakage. The wells would primarily be operated as monitoring wells unless leakage is detected; therefore, their impact on groundwater levels is expected to be intermittent, and limited to the immediate vicinity of the mine site. Based on data collected during construction and operations, the monitoring well network would be expanded or filled in as required (Knight Piésold 2018n).

The open pit WMP lies within the pit capture zone for all scenarios during operations (Figure 4.17-2). Therefore, any leakage from this pond is expected to report to the pit (Piteau Associates 2018a). The open pit WMP would be removed in early closure (Knight Piésold 2018d); any previously affected groundwater beneath this facility would lie within the post-closure pit capture zone (Figure 4.17-3), and continue to flow towards the pit.

Impacts to groundwater from the main WMP and open pit WMP would occur. The duration of impacts would be long term, lasting until the facilities are removed during closure. Effects could slightly exceed historic seasonal variation, but would not extend beyond project component areas.



3ft Drawdown



3ft Mounding

Sources: PLP (2019-RFI 109b)

Legend

Lower water table (Drawdown)

Higher water table (Mounding)

3 ft Drawdown/Mounding Contour

Notes:
1. Drawdown calculated as Pre-Mine Water Table minus End of Mine Water Table. Negative numbers indicate higher water levels, whereas positive numbers indicate lower water levels.
2. The Zone of Influence is defined by the 3 ft contour.

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SIMULATED ZONE OF INFLUENCE AT END OF OPERATIONS FOR TSFs AND MAIN WMP

Tailings Storage Facilities

Bulk TSF

Bulk flotation tailings primarily composed of non-acid generating finely ground rock material generated during milling operations would be stored in a bulk tailings storage facility (bulk TSF) at the mine site. With the exception of the upstream face of the bulk TSF south embankment, which would be lined with HDPE, the bulk TSF would be unlined, and the bulk TSF main embankment would operate as a flow-through structure draining towards the north (see Section 4.15, Geohazards). The bulk TSF would be constructed in the NFK watershed, with a series of embankments to impound the tailings and entrained and ponded water. A drain system at the main embankment and a grout curtain at the south TSF embankment would manage seepage water draining through the main embankment from the tailings. The thickened bulk flotation tailings discharged to the TSF would settle, and water would collect in a pond on top of the tailings.

Seepage water draining through the main embankment from the tailings would be collected by a drain system and routed to a lined seepage collection pond (SCP) north of the TSF. Piteau Associates (2018a) estimates the bulk TSF would discharge approximately 0.1 cfs to shallow groundwater beneath the TSF at the end of operations. A larger component of flow (about 9 cfs) would go through the main TSF embankment. A basin underdrain system would be constructed at various locations throughout the main TSF basin to provide preferred drainage pathways for seepage flows (PLP 2018d). Seepage through the embankment would be collected in the bulk TSF main SCP (see Section 4.16, Surface Water Hydrology, Figure 4.16-1). The SCPs would be constructed with low-permeability cores and grout curtains to block groundwater flow. Any leakage through the bulk TSF south embankment would report to the bulk TSF south SCP, and be routed to the main WMP. Water collected in the SCPs would be used for tailings dust control, or transferred to the main WMP for subsequent use in ore processing. Surplus water in the main WMP would be treated to discharge standards, and released downstream of the mine site outside of the pit cone of depression.

As described in Appendix K4.17, because tailings along the northwestern ridge of the bulk TSF would be built up higher than the two saddles along this ridge, it is possible that there would be a potential for groundwater flow paths through these saddles in late operations. Groundwater levels would be monitored during operations in piezometers along the ridge and downstream of the embankment, and operational rules established to maintain hydraulic containment. If seepage through the ridge is detected, contingencies such as relief wells and/or seepage recovery wells would be implemented (Knight Piésold 2018n).

Some of the seepage from the bulk TSF tailings that enters shallow groundwater beneath the tailings would be expected to flow laterally and report to the SCP. Seepage water could also flow vertically downwards into deeper bedrock fractures.

Construction of the bulk TSF would locally impact surface water features at the site, and potentially impact groundwater/surface water interactions; this impact is expected to be modest in extent (e.g., approximately 8,000 acres [PLP 2019-RFI109b] near the vicinity of the bulk TSF), but permanent. The extent of the higher water table resulting from the TSF is shown on Figure 4.17-5. Grout curtains installed at the south TSF embankment and SCPs would locally impact groundwater flow in the overburden and shallow bedrock, but would not affect regional flow patterns. Tailings seepage from the bulk TSF could create local groundwater mounds[4] within and beneath the TSF basin, and in the valley between the main embankment and the

[4] Groundwater mounding refers to areas of locally higher water table elevation caused by infiltration or vertical seepage of surface water.

SCP. Mounding could cause a small portion of flow to be directed towards the sides of the valley, or become entrained in groundwater flow systems that extend beyond the mine component area. The seepage collection system associated with the bulk TSF is further described in Section 4.18, Water and Sediment Quality, along with potential impacts to groundwater quality as a result of seepage.

Pyritic TSF

The PAG pyritic tailings and PAG waste rock would be stored in a separate impoundment that is fully lined with HDPE and equipped with underdrains. Tailings would be placed on top of the liner and covered with water to minimize oxidation and the potential release of acidic contact waters to the environment. Groundwater levels would be reduced several feet by the construction of this impoundment due to local reduction in recharge caused by presence of the liner, and groundwater flow exiting sub-basin NK119A would be reduced from 0.8 cfs to 0, both without return of water from the WTP (Piteau Associates 2018a; Knight Piésold 2018i) (see Appendix K4.17, Figure K4.17-5). Like the main WMP, removing the pyritic TSF after closure would allow natural recharge to be re-established and groundwater elevations to recover, with the exception that groundwater elevations in the northeastern corner of the pyritic TSF footprint would continue to be influenced by the open pit capture zone in post-closure (Figure 4.17-3).

As described in Appendix K4.17, any liner leakage that reaches groundwater beneath the pyritic TSF is expected to flow north, with a small component migrating east, both of which would be captured by SCPs backed up by monitoring/pumpback wells that would continue to operate as long as necessary following decommissioning to intercept potential leakage (Knight Piésold 2018n).

The pyritic tailings would be moved to the bottom of the open pit at the end of mining, and submerged in the pit lake to prevent oxidation. The pyritic TSF liner and embankments would be removed at closure, and the site reclaimed by removing impacted materials, regrading, and capping with growth media (Section 4.16, Surface Water Hydrology describes closure in greater detail) (Knight Piésold 2018d). Therefore, groundwater flow in this tributary drainage is expected to essentially return to pre-mining conditions post-closure (Section 4.16, Surface Water Hydrology).

Impacts to groundwater from the pyritic TSF facility would occur if the project is permitted and constructed, and would be long term, lasting until the facilities are removed during closure. The magnitude and extent of effects could slightly exceed historic seasonal variation, but would not extend beyond project component areas.

Potable Well Supply

There would be no effects on any community groundwater or surface water supplies from the changes in groundwater flows at the mine site. The closest such water systems are located about 15 to 20 miles east and southeast of—and on the opposite side of the UTC-Newhalen River watershed divide from—the pit groundwater capture zone (see Section 3.16, Surface Water Hydrology, Figure 3.16-15; and Section 3.17, Groundwater Hydrology, Figure 3.17-12).

Potable water at the mine site would be supplied by a series of groundwater wells located north of the mine site (in the Big Wiggly Lakes area), outside of the estimated cone of depression around the proposed open pit. The wells would be located upgradient or side-gradient of the main WMP (see Section 3.17, Groundwater Hydrology, Figure 3.17-9 and Figure 3.17-10, and Section 4.16, Surface Water Hydrology, Figure 4.16-1), which is the closest potential source of groundwater contamination. The wells would be pumped at rates described below to provide sufficient potable water for mine site personnel living and working at the site. The potable water supply wells would also be used for fire-fighting, if needed.

As indicated in the project description (PLP 2018d) and Knight Piésold (2018e), a 250-person camp would initially be built to support early site construction activities. This camp would then be supplemented by the main camp, which would accommodate about 1,700 workers during construction. The main camp would be converted at the end of construction into a permanent facility expected to house 850 workers. Assuming an average water requirement of 50 gallons per day (gpd) per person to support the camps (ADNR 2018f), and an additional 10 gpd per person for the other facilities, the magnitude of impacts from camp water requirements would be a maximum daily volume of 102,000 gallons. In terms of magnitude, the total average water flow requirement rate during construction for the camps is estimated to be about 80 gpm, which is near the upper end of the range of pumping rates achieved during the pumping tests. This average demand is expected to be met by the installation of a single pumping well with two backup wells to allow for regular downtime and maintenance. During operations, the potable water requirement would be reduced to about 35 gpm. The potable water would be distributed through a pump-and-piping network to supply fresh water to holding tanks at the camps and other facilities. The holding tank capacity would be sufficient for a 24-hour supply. Impacts from pumping at the potable water supply well have not been modeled; but based on borehole and well testing results, expected aquifer conditions (Section 3.17, Groundwater Hydrology), and assuming the well would be pumped intermittently to maintain holding tank capacity, the well is expected to have negligible impact on local groundwater flow. Water-level fluctuations caused by pumping are expected to be approximately of the same magnitude as natural seasonal fluctuations of water levels.

4.17.3.2 Transportation Corridor

Shallow Groundwater Interception. The transportation corridor is designed to avoid wetlands and stream crossings where feasible, and its alignment would be optimized for the most amenable soil and geotechnical conditions. Road beds are typically constructed well above the water surface elevation in adjacent ditches, and are typically of suitable materials to avoid groundwater retention in the road prism. Therefore, road construction would not have an areal effect on groundwater/surface water interactions, other than the possible need to temporarily dewater some stream or lowland crossings as construction proceeds. Local groundwater flow impacts may occur along the corridor, where the roadway is constructed across wetlands that may be supported by groundwater inflow.

Some road segments would require road cuts to maintain proper road grade. These are represented by wide areas of the road footprint on hillslopes (PLP 2017: Figures T-001 through T-046), which are prevalent throughout much of the mine and port access and spur road corridors. Because shallow groundwater is expected to be present across the mine and port access road corridors, it is possible that road cuts could intersect groundwater in some areas, and cause a local diversion of groundwater flow, as drainage controls (construction BMPs as described in Chapter 5, Mitigation) direct potential seepage away from the road. In addition, benched cuts at material sites would likely intercept groundwater. These diversions would generally not move water to a different drainage, or cause dewatering of wetlands or waterbodies extending more than a few feet from the road corridor or material sites.

Ferry Terminals. At the ferry terminals, there could be a deviation of groundwater flow on a facility footprint scale as a result of foundation materials that differ in hydraulic properties from native soil. These effects are expected to be limited to the footprint of these facilities. The lake portion of ferry terminal construction is not expected to impact groundwater.

Water Extractions. Surface water/groundwater interaction is expected to occur at locations used for surface water extraction where shallow groundwater is present. Groundwater occurrence in glacial and alluvial deposits along the mine access road is similar to that of the mine site. Shallow groundwater occurrence is limited along the port access road due to the presence of shallow bedrock. In terms of magnitude and extent, approximately 50 million gallons of surface water would be extracted from 21 water extraction sites along the port and access road corridors, mostly for use in road construction activities (PLP 2018-RFI 022) (see Figure 4.16-7). This water would be extracted at specific permitted locations along the mine and port access road corridors over months to years of construction (see Section 4.16, Surface Water Hydrology). The extraction would draw connected shallow groundwater toward extraction sites. Temporary construction camps located at Amakdedori port, Kokhanok, Iliamna, Newhalen, the mine site, and the north and south ferry terminals may be supplied by local groundwater sources, and would be authorized by Temporary Water Use Authorizations from ADNR. The extent of impacts would be limited to the immediate area of the camps, and duration would be long term, lasting throughout the mine life, but would be temporary; because once water drawdown ceases, groundwater would no longer be drawn towards the extraction facilities.

4.17.3.3 Amakdedori Port

Shallow Groundwater Interception. The port site is designed to avoid wetlands where feasible, and its footprint would be optimized for the most amenable soil and geotechnical conditions. Excavations across the port footprint may be required during port and dock construction. The elevation of the terminal area is about 15 to 20 feet above that of the Amakdedori Creek floodplain, which has a high water table in alluvial deposits that are hydraulically connected to Amakdedori Creek. The closest distance of the terminal to the floodplain would be about 700 feet (see Figure 2-28). Because of the elevation difference and distance to the floodplain, excavations are not expected to intercept shallow groundwater in this area. Mounding of groundwater is not expected to occur due to infiltration of fill placed for terminal construction, because the terminal would be paved and runoff controlled.

The marine portion of the port construction would have no effect on groundwater. Impacts to groundwater would be limited to within the footprint of material sites used for dock construction, and would occur only during construction.

Groundwater Use. Based on limited hydrogeologic information at the port site, shallow glacial and fluvial sediments in the area are likely to host groundwater (Glass 2001; Detterman and Reed 1973; Zonge 2017). A groundwater well is planned to supply potable water for port personnel and/or fresh water for operations. The precise location for the well would be identified during detailed design. The well would be sited on uplands far enough from the shore to avoid any potential for saltwater intrusion, and water would be piped to the site from the wellhead (PLP 2018-RFI 022a). It is anticipated that such a well would have a local (i.e., a few feet to a few tens of feet radius) impact on groundwater flow and quantity, depending on rate and frequency of drawdown caused by pumping. The duration of impacts would be long-term, lasting through the life of the project. Water rights authorization for water production from the well would be acquired, and the design of the well production activities would be reviewed and approved by ADEC.

4.17.3.4 Natural Gas Pipeline Corridor

Shallow Groundwater Interception. Like the transportation corridor, the water table is expected to be close to the surface along much of the pipeline corridor, as evidenced by abundant wetlands, kettle ponds, and exposed bedrock. Groundwater along the pipeline corridor coincident with the northern mine access road is expected to be held in shallow aquifers of glacial sediment, as demonstrated in similar geologic terrain at the mine site (see Section 3.13, Geology). Much of the buried pipeline in this area could intersect shallow groundwater, as shown by the distribution of wetlands on Figure K4.22-1. Shallow groundwater occurrence along the pipeline adjacent to the southern part of the mine access road is expected to be more limited, because much of this route appears to be sited on a well-drained terrace of surficial deposits several tens of feet above First Creek floodplain. Shallow groundwater along the route south of Iliamna Lake is expected to be sparse and intermittent due to lengthy segments through exposed bedrock.

Potential impacts to groundwater would involve interception of shallow groundwater during trenching activities, which could be captured and locally routed along the trench backfill. Modifications to groundwater flow would occur mostly in the immediate vicinity of the trench. Impacts could extend beyond the life of the project, because the pipeline may be abandoned in place. Low-permeability trench plugs, considered a typical best management practices (BMP) for pipeline installation (e.g., USACE 2018c), could be installed to minimize movement of groundwater along the trench; reduce erosion along the trench backfill; and minimize alteration of the natural groundwater flow path.

Horizontal Directional Drilling. On the Kenai Peninsula, the pipeline would be trenched for a short distance west of the compressor station, and then installed by HDD at the shoreline and into Cook Inlet from an elevation of about 200 feet to -12 feet mean lower low water (PLP 2018-RFI 011). Groundwater is present in this area in aquifers in glacial and alluvial deposits, and Tertiary-age (approximately 66 to 2.6 million years ago) sedimentary bedrock. Although the exact depth to groundwater is unknown at the HDD location, nearby wells drilled at similar elevations to the HDD work area encountered shallow water-bearing glacial deposits at depths between 8 and 30 feet below ground surface, as well as deeper aquifers in both glacial deposits and sedimentary bedrock units between 50 and 120 feet deep (USGS 1967; Nelson and Johnson 1981; ADNR 2018). Therefore, the HDD-installed pipeline segment would be expected to intersect these aquifers, which are used near the project footprint by private wells (see Figure 3.17-13).

Dewatering would not be required for HDD drilling (PLP 2018-RFI 051). Other effects on groundwater might include pressurization of the hole, forcing drilling fluids into aquifers (e.g., TRCA 2010). In terms of extent, it is possible for drill fluid to travel short distances from the borehole due to this pressure, and have an effect on groundwater flow patterns in the immediate vicinity of the drill-site. Drilling fluid returns would be monitored during drilling, and drilling specifications and a mud plan developed during detailed engineering to avoid the potential for injection of drill fluid into the aquifer. Typical mitigation procedures (see Chapter 5) may include lowering drill fluid pressure, temporary rig shutdown, adjusting fluid viscosity, and adding solids to the fluid to reduce loss into the formation (PLP 2018-RFI 051). These effects are expected to be temporary, recovering days or weeks after construction. Potential effects on groundwater quality from drill fluid loss are discussed in Section 4.18, Water and Sediment Quality.

4.17.3.5 Alternative 1 – Summer-Only Ferry Operations Variant

The expected magnitude, extent, duration and likelihood of effects of this alternative variant are similar to those described under Alternative 1. The main difference between Alternative 1 and this variant relates to the need to construct concentrate and fuel storage facilities at the mine site or at the Amakdedori port site (Ausenco 2018). There would be no effects on groundwater from the seasonal-only use of Iliamna Lake. The extent of the expanded container yard at the port site would reach the edge of the Amakdedori floodplain. Therefore, excavations during construction in this area are more likely to intercept shallow groundwater than under Alternative 1 without this variant.

The expanded facilities at both the mine and port sites could have a short-term impact on shallow groundwater during construction from drainage controls or fill; and longer-term impacts on surface water/groundwater interactions and groundwater recharge from the installation of liners to control leaks or spills, which would be disturbed during construction, and continue throughout the life of the project. The extent of these effects would be limited to the immediate vicinity of the mine or port. Although long term, lasting though the life of the project, they would be reasonably restored once mining ends and the port site is reclaimed (PLP 2018-RFI 024).

4.17.3.6 Alternative 1 – Kokhanok East Ferry Terminal Variant

The expected magnitude, extent, duration, and likelihood of effects of this alternative are similar to those described under Alternative 1. The main difference between Alternative 1 and this variant is that the extent of the Kokhanok east route is approximately 15 percent shorter, which would reduce potential shallow groundwater and water extraction impacts (if any) associated with access road and pipeline construction. It is also anticipated that fewer streams and wetlands would be impacted (see Section 4.16, Surface Water Hydrology, and Section 4.22, Wetlands and Other Waters/Special Aquatic Sites), because the Kokhanok east route is shorter, and the Kokhanok east spur and port access roads are located along ridge tops once they separate from the proposed route in Alternative 1. However, the footprint of material sites associated with this variant are larger than Alternative 1 (Table 2-2), and would therefore have a slightly greater impact on shallow groundwater in the immediate vicinity of the materials sites during construction. Shallow groundwater impacts from construction of the Kokhanok east ferry terminal would be short term, and similar to those of the proposed south ferry terminal, and would only occur during construction.

4.17.3.7 Alternative 1 – Pile-Supported Dock Variant

The expected magnitude, extent, duration, and likelihood of effects of this alternative are similar to those described under Alternative 1 for the onshore parts of the Amakdedori port site. Because there would be no need for fill by the dock structure, the effects of borrow material extraction on shallow groundwater interaction would be slightly less under this variant. Therefore, a pile-supported dock would have less impact than the earthfill dock proposed under this alternative.

4.17.4 Alternative 2 – North Road and Ferry with Downstream Dams

4.17.4.1 Mine Site

The expected magnitude, extent, duration, and likelihood of effects of this alternative are similar to those described under Alternative 1 for the mine site. The downstream dam (and bulk TSF south embankment) would be about 15 feet higher in elevation at its maximum height (see Table K4.15-1), and therefore would have a higher water table and be more likely to experience seepage through the topographic saddles on the eastern and western sides of the impoundment. This is expected to be mitigated by piezometer monitoring and relief wells and/or seepage recovery wells as necessary (PLP 2018-RFI 019c). The predicted seepage rates through the embankment and vertically through the tailings to shallow groundwater would be essentially the same as those predicted by the groundwater model under Alternative 1.

4.17.4.2 Transportation Corridor

The expected magnitude, extent, duration, and likelihood of effects of Alternative 2 on shallow groundwater are similar or slightly greater than those described under Alternative 1. This is because although the extent of the total access road lengths would be shorter under Alternative 2 than Alternative 1 by about 20 miles, and would have three fewer material sites, Alternative 2 is expected to intersect more shallow groundwater overall than under Alternative 1 due to the nature and distribution of surficial deposits and terrain. The eastern part of the mine access road has an abundance of surficial deposits that are more likely to contain shallow groundwater and wetlands (see Figure 3.13-4 and Figure K4.11-1). Also, the Alternative 2 port access road has steep terrain and more side-hill cut requirements, while the port access road under Alternative 1 has sparse surficial deposits and fewer cut-slope requirements.

4.17.4.3 Diamond Point Port

In terms of magnitude and extent, the onshore footprint of the Diamond Point port is larger than at Amakdedori due to the need for a dredge materials storage area. The terminal is located in an area of alluvial fan deposits at the mouth of the small drainage (see Figure 2-58), which are expected to have a shallow water table. In terms of extent and duration, construction excavations could intercept groundwater and temporarily alter natural flow patterns within this immediate area of the port. The duration of impacts would be short term, lasting only through construction. Placement of fill in this area could also result in groundwater mounding in the fill, which would likely be mitigated through drainage controls (see Chapter 5). The expected effects of Alternative 2 from groundwater use are similar to those described under Alternative 1 for Amakdedori port.

4.17.4.4 Natural Gas Pipeline Corridor

The types of effects of Alternative 2, and their magnitude, extent, duration, and likelihood on shallow groundwater along the natural gas pipeline corridor are similar to those described under Alternative 1, because the natural gas pipeline would be mostly buried in a trench along the transportation corridor roadside. The extent and duration of impacts would be an effect on shallow groundwater flow in the vicinity of the pipeline right-of-way (ROW) during construction; however, the use of trench plugs, as is typical of pipeline construction BMPs in wet areas, would reduce the alteration of the natural groundwater flow patterns and minimize erosion along the trench backfill. The extent of effects would be greater under Alternative 2 than Alternative 1 due to the greater pipeline length through areas with shallow groundwater. The extent of the onshore part of the pipeline trench under Alternative 2 is about 24 miles longer than Alternative 1, and includes a greater distance through surficial deposits that are expected to contain shallow groundwater.

4.17.4.4 Alternative 2 – Summer-Only Ferry Operations Variant

The expected magnitude, extent, duration, and likelihood of effects of Alternative 2 on shallow groundwater for the Summer-Only Ferry Operations Variant would be similar to those described for the Summer-Only Ferry Operations Variant under Alternative 1. Impacts to groundwater from the additional container storage at Williamsport would be similar to those described for the transportation corridor for this variant. The footprint at this location is slightly wider than the mine and port access road corridors under Alternative 2. Therefore, there would likely be additional groundwater intersection and diversion on the 2,500-foot-long cut-slope side of the storage area, which would last throughout operations.

4.17.4.5. Alternative 2 – Pile-Supported Dock Variant

The magnitude, extent, duration, and likelihood of expected effects of this variant on shallow groundwater for the onshore part of the Diamond Point port site are similar to those described for Alternative 2. There would be no effects on groundwater for the onshore part of this dock variant.

4.17.5 Alternative 3 – North Road Only

4.17.5.1 Mine Site

The magnitude, extent, duration, and likelihood of expected effects of Alternative 3 on shallow groundwater at the mine site are the same as those described under Alternative 1.

4.17.5.2 Transportation Corridor

The magnitude and duration of the effects of Alternative 3 on shallow groundwater in the transportation corridor are similar to those described under Alternative 1. The magnitude and extent of affected groundwater resources would be slightly greater than both Alternatives 1 and 2. This is because the north access road under Alternative 3 would be about 6 miles longer than Alternative 1, and 38 miles longer than Alternative 2. It would cross a greater distance of groundwater-bearing surficial deposits along its western part, and require a greater distance of side-hill cuts in steep terrain that could intersect groundwater.

4.17.5.3 Diamond Point Port

The expected magnitude, extent, duration, and likelihood of effects of Alternative 3 on shallow groundwater at the Diamond Point port are similar to those described under Alternative 2 for the Diamond Point port.

4.17.5.4 Natural Gas Pipeline Corridor

The magnitude and duration of the effects of Alternative 3 on shallow groundwater along the natural gas pipeline corridor are similar to those described under Alternative 2. There would be a slightly increased magnitude and extent of impacts due to the 1-mile-longer pipeline route length. The extent of affected groundwater resources under both Alternatives 2 and 3 would be greater than Alternative 1 due to the greater pipeline length through areas of groundwater-bearing deposits north of Iliamna Lake.

4.17.5.5 Alternative 3 – Concentrate Pipeline Variant

The magnitude, extent, duration, and likelihood of expected effects of this variant on shallow groundwater are similar to those described under Alternative 3 for the transportation corridor and gas pipeline, given that the concentrate pipeline would be placed in the same excavation as the natural gas pipeline along the north access road. The primary difference in water use between this variant of Alternative 3 and other alternatives is the loss of 1 to 2 percent of the water used to slurry the concentrate that would otherwise be available for discharge at the mine site to drainages affected by embankment blockage and pit dewatering. Reduced flow to surface water at the NFK, SFK, and UTC discharge sites by a similar percentage would result in slightly decreased recharge to groundwater in the upper portions of these drainages.

The magnitude, extent, duration, and likelihood of impacts to groundwater at the Diamond Point port site under this variant would be the same as Alternatives 2 and 3, because there would be no change in total footprint, and no impacts to groundwater from treatment and offshore discharge of slurry water.

4.17.6 Summary of Key Issues

See Table 4.17-1 for a summary of key issues related to groundwater hydrology.

Table 4.17-1: Summary of Key Issues for Groundwater Hydrology Resource

Impact Causing Project Component	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
Mine Site			
Groundwater diversion and reduction in recharge during construction and operations at pyritic TSF, WMPs, and other mine facilities Water-table mounding in, below, and in vicinity of bulk TSF	**Alternative 1:** Diverted groundwater at TSFs and WMPs would be largely captured, treated, and discharged to the affected drainages during construction and operations to approximately restore natural flow conditions, as described in more detail in Section 4.16, Surface Water Hydrology. Small reduction (several feet) in groundwater elevation expected beneath lined facilities during operations due to blocked recharge. Water-table mounding under and in non-lined bulk TSF and increased flow to bedrock aquifer. **Summer-Only Ferry Operations Variant:** Additional facilities at mine site and Amakdedori port for storage of materials would cause additional changes in groundwater recharge through operations phase.	**Alternative 2:** The downstream dam would have a higher maximum crest and water table elevation is more likely to create potential seepage through topographic saddles on eastern and western sides.	**Alternative 3:** Same as Alternative 1 **Concentrate Pipeline Variant:** Slightly decreased groundwater recharge at mine site due to diversion of 1 to 2% of mine site groundwater to slurry concentrate.
Groundwater use for potable water supply during construction and operations	Groundwater use would be highest during construction and operations, and is expected to largely recover to pre-mining levels once reclamation occurs in closure.	Same as Alternative 1	Same as Alternative 1
Open pit dewatering	Groundwater-level change up to 2,200 feet below baseline condition during operations, recovering to 90 to 350 feet below original level in post-closure. The large range is because of the high pre-mining water table slope across the open pit footprint (see Section 3.17, Groundwater Hydrology, Figure 3.17-9b). Groundwater flow direction	Same as Alternative 1	Same as Alternative 1

Table 4.17-1: Summary of Key Issues for Groundwater Hydrology Resource

Impact Causing Project Component	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
	change caused by flow towards open pit, which acts as hydraulic sink and would remain so in perpetuity. The areal extent of the cone of depression surrounding the open pit would increase as mining proceeds and the open pit becomes deeper. The estimated maximum area of the capture zone at end of mining would be about 2,700 acres. The areal extent of the cone of depression would decrease as the pit fills with groundwater to form a pit lake; however, a cone of depression would exist around the pit in perpetuity. The estimated area of the capture zone at post-closure and beyond would be about 1,800 acres.		
Transportation Corridor			
Groundwater diversion during construction	**Alternative 1:** Groundwater flow systems are maintained; temporary flow interruptions during construction. **Summer-Only Ferry Operations Variant:** No impacts to groundwater from seasonal lake crossings. **Kokhanok East Ferry Terminal Variant:** Similar to Alternative 1; slightly less impact during road construction due to 15% shorter route and slightly more during material extraction due to larger footprint.	**Alternative 2:** Similar to Alternative 1, although slightly more impacts due to greater route length through areas of shallow groundwater-bearing deposits and steep cut slopes. **Summer-Only Ferry Operations Variant:** Slightly more groundwater diversion at Williamsport container storage along cut slope.	**Alternative 3:** Similar to Alternative 1, although impacts slightly more than Alternatives 1 and 2 due to greater route length through areas of shallow groundwater-bearing deposits and steep cut slopes. **Concentrate Pipeline Variant:** Similar to Alternative 3. Buried in same trench as natural gas pipeline; trench is slightly larger than gas pipeline-only installation, and may slightly increase temporary groundwater impacts; groundwater flow systems are maintained; temporary flow interruptions during construction.
Water extraction and groundwater use during construction and operations	Impacts to groundwater from surface water extraction and groundwater use at the construction camps would be short term, and the aquifer would return	Same as Alternative 1	Same as Alternative 1

Table 4.17-1: Summary of Key Issues for Groundwater Hydrology Resource

Impact Causing Project Component	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
	to historical levels once operations end.		
Port Sites			
Groundwater diversion during construction	**Alternative 1:** Groundwater flow systems are maintained; temporary flow interruptions during construction. **Summer-Only Ferry Operations Variant:** Similar to Alternative 1; increased likelihood of intersecting shallow groundwater along Amakdedori Creek floodplain due to larger footprint. **Pile-Supported Dock Variant:** Slightly less impact to groundwater at borrow sites due to less fill needs.	**Alternative 2:** Types of impacts similar to Alternative 1, although construction excavations at Diamond Point terminal more likely to intersect shallow groundwater-bearing deposits than at Amakdedori. **Pile-Supported Dock Variant:** Same as Alternative 1	**Alternative 3:** Same as Alternative 2 **Concentrate Pipeline Variant:** Same as Alternatives 2 and 3
Groundwater use at port during operations	Changes in groundwater quantity from water supply well would be within historical seasonal variability.	Same as Alternative 1	Same as Alternative 2
Natural Gas Pipeline			
Groundwater diversion during construction	**Alternative 1:** Groundwater flow systems are maintained; temporary flow interruptions during construction. **Kokhanok East Ferry Terminal Variant:** similar to Alternative 1; slightly less impact due to shorter pipeline route.	Similar to Alternative 1; temporary groundwater impacts would be slightly more due to greater route length through areas of shallow groundwater-bearing deposits and steep cut slopes.	Similar to Alternative 2; trench footprint is 10% longer than Alternative 2, slightly increasing temporary groundwater impacts. Impacts slightly more than Alternative 1 due to greater route length through areas of shallow groundwater-bearing deposits and steep cut slopes.
Groundwater use during construction	Groundwater use at the construction camps would be short term, and aquifer would return to historical levels once construction ends.	Same as Alternative 1	Same as Alternative 1

4.17.7 Cumulative Effects

The geographic area considered in the cumulative effects analysis for groundwater hydrology is the near vicinity (i.e., within 0.5 mile to several miles) of all project components where project-related effects on groundwater flow patterns and use could overlap with other past, present, and reasonably foreseeable future surface and groundwater uses.

Past, present, and reasonably foreseeable future actions (RFFAs) within the cumulative impact study area have the potential to contribute cumulatively to impacts on groundwater. Section 4.1, Introduction to Environmental Consequences, details the past, present, and RFFAs considered for evaluation. Several of these are considered to have no potential for cumulative impacts on groundwater flow and quantity in the EIS analysis area. These include non-industrialized point source activities that are unlikely to result in any appreciable impact beyond a temporary basis (e.g., subsistence, tourism, recreation, hunting and fishing). Other RFFAs removed from further consideration include those sufficiently distant from the study area to eliminate groundwater co-use by other parties (e.g., Donlin, Shotgun), or those RFFAs that occur in the marine environment of Cook Inlet (e.g., lease sales or proposed pipeline crossings).

The most important potential future actions in this analysis are those that are likely to contribute to impacts on groundwater flow and quantity in close vicinity to aquifers affected by the project. RFFAs that could contribute cumulatively to groundwater quantity and flow impacts, and that are therefore considered in this analysis, are limited to those activities that would occur in the mine site vicinity, or immediately within or adjacent to the transportation corridor. These include:

- Pebble Project buildout—development of 55 percent of resource over a 78-year period.
- Exploration activities at nearby Big Chunk South and Groundhog prospects.
- Diamond Point rock quarry
- Lake and Peninsula Borough (LPB) transportation projects along Williamsport-Pile Bay, Nondalton-Iliamna, and Kaskanak-Igiugig roads.

4.17.1.1 Past and Present Actions

Past and present activities that have affected groundwater hydrology in the EIS analysis area include development of water supply wells in communities around Iliamna Lake, small-scale wells or seeps associated with cabins and camps along the pipeline route, or mining exploration near the project area (e.g., pump tests, camp water use). Impacts associated with these activities include localized changes in groundwater flow patterns, reductions in groundwater in aquifers, and use of streams that are hydraulically connected with groundwater. These past and present actions are expected to continue throughout the project area, primarily in and around Iliamna Lake villages. Other parts of the project would be located in more remote areas, characterized as having very little development, and past and present activities are seasonal in nature and do not substantially draw from groundwater resources during mining exploration (see Section 3.17, Groundwater Hydrology). Mining exploration activities on State lands are subject to exploration permits, with requirements for inspections and appropriate reclamation.

4.17.7.2 Reasonably Foreseeable Future Actions

No Action Alternative

Under the No Action Alternative, exploration activities would continue to occur at the mine site and other exploration prospects in the vicinity. During these activities, there could be limited groundwater extraction from pump tests that result in a temporary localized lowering of the water table, which would be expected to recover to natural conditions within hours or days after the tests.

__Alternative 1 – Applicant's Proposed Alternative__

Pebble Mine Expanded Development Scenario. An expanded development scenario for this project, as detailed in Table 4.1-2, would include an additional 58 years of mining and 20 years of additional milling over a substantially larger mine site footprint, and would include increases in port and transportation corridor infrastructure under Alternative 1. The Pebble Project expansion would result in additional development not included under the other alternatives:

- Increased pit footprint and depth.
- Increased TSF and PAG storage footprints with additional SCPs.
- new waste rock storage and footprints with additional SCPs.
- Additional processing infrastructure.
- Construction of a new port site with additional access road and pipelines extending to the mine site.

The buildout would correspond to about a six-fold increase in the footprint of the pit, an increase in pit depth to about 3,500 feet (PLP 2018-RFI 094), and a duration increase of up to 78 years for the operations capture zone. Assuming the expanded pit encounters similar units with a similar range of hydrogeologic parameters as those around the Alternative 1 pit (Piteau Associates 2018a; Knight Piésold 2018n), the magnitude and extent of the expanded pit capture zone would be larger to account for the deeper and wider pit. Assuming a similar slope for the cone of depression (based on similar hydrogeology), the estimated capture zone for the expanded dewatered pit during operations would be an irregular circle about 5 miles across (about 20 square miles) straddling the SFK and UTC drainages, although it could extend 1 to 2 miles further south along the ridge between these watersheds, if similar to the modeled capture zone under Alternative 1 (Figure 4.17-2).

Based on the position of the expanded pit relative to watershed divides, the expanded capture zone would likely draw roughly equal amounts of inflow from the SFK and UTC watersheds. This would include vertical seepage that reaches shallow groundwater from approximately the western quarter of the north waste rock facility (WRF) and the northern half of the south WRF (see Section 4.1, Introduction to Environmental Consequences, Figure 4.1-1).

The surface area of the expanded pit capture zone (estimated to be 20 miles) is roughly five times greater than that of the proposed pit capture zone (about 4 square miles). Assuming the volume of groundwater inflow to the pit is roughly proportional to the surface area of the capture zones, it is estimated that the expanded pit would draw about five times more groundwater than under Alternative 1; or about 12,000 gpm (27 cfs) near the end of operations and 6,500 gpm (15 cfs) in post-closure. About half of this inflow would come from the SFK watershed and half from UTC. It is assumed that there would be WTP discharge locations similar to Alternative 1 in operations and closure, with discharge locations downstream of major facilities in each of the main watersheds: NFK in approximately the same location as under Alternative 1, SFK downstream of the south WRF collection pond, and UTC downstream of the north WRF collection pond. Streamflow reductions in SFK and UTC due to the pit capture zone would be somewhat mitigated by treated water being returned to these watersheds. Effects on streamflow reduction from the expanded mine scenario are further discussed in Section 4.16, Surface Water Hydrology.

The extent of the pit capture zone would not affect existing drinking water supply wells in Newhalen or Iliamna, or the community surface water system in Nondalton (Section 3.16, Surface Water Hydrology), which are located about 10 to 12 miles east and southeast of the expanded pit capture zone, and in a different drainage on the other side of the UTC-Newhalen River watershed divide.

The estimated footprint of the lined pyritic TSF would be about 2.5 times greater than under Alternative 1 (Section 4.1, Introduction to Environmental Consequences, Figure 4.1-1). This would reduce the amount of natural recharge to groundwater and lower the water table elevation beneath the expanded facility in a fashion similar to that described under Alternative 1 (Appendix K4.17, Figure K4.17-5), but in an area about 2.5 times greater. The area of lowered water table beneath the main WMP would remain the same under the expanded mine scenario. Diverted runoff and collected seepage from unlined project facilities, such as the expanded bulk TSF and WRFs, would alter local groundwater flow patterns and natural discharge to streams over a wider area than under Alternative 1 as the flow is captured in downstream SCPs and treated and discharged to downstream areas.

The effects of the project on groundwater would be limited to the near vicinity of the mine site, and would be reduced in post-closure as the site is reclaimed and groundwater returns to pre-mining conditions in all areas except the bulk TSF, WRFs, and open pit, where groundwater impacts would remain. The post-closure pit capture zone would likely be reduced compared to the operations capture zone by an amount similar to that of Alternative 1; that is, the capture would be about one-third smaller in extent than during operations, and would remain in perpetuity to maintain a hydraulic sink towards the pit.

The potential for impacts on shallow groundwater interception along the transportation and pipeline corridors would increase under the expanded mine scenario, because both the north and south access corridors would be used, and the north corridor would eventually be wider and longer to accommodate a diesel pipeline. In addition, the development of a port at Iniskin Bay would increase the potential for localized shallow groundwater interaction effects during construction. The cumulative effects of the non-mine site components under the expanded mine scenario would be similar to the combined impacts of both Alternatives 1 and 3.

Other Mineral Exploration and Road Development Projects. Nearby RFFAs associated with mineral exploration activities (e.g., Big Chunk South and Groundhog) could have some limited impacts on groundwater in common watersheds to the Pebble project—for example, from pump tests or camp groundwater use; however, they would be seasonally sporadic, temporary, and localized, based on their remoteness.

The potential exists for greater impacts on groundwater hydrology during construction and maintenance of LPB transportation infrastructure that is co-located or close to the Pebble Project. For example, the Nondalton-Iliamna and Kaskanak-Igiugig road projects could intercept shallow groundwater during construction that is co-located with shallow aquifers intercepted during Alternative 1 road construction. Increased local groundwater flow impacts could occur where roadways are constructed across wetlands supported by groundwater inflow, or in steep areas where road cuts cause a local effect on groundwater flow as drainage controls direct it away from the road.

<u>Alternative 2 – North Road and Ferry with Downstream Dams</u>

Pebble Mine Expanded Development Scenario. The expanded mine site development and associated contributions to cumulative impacts would be the same for the mine site component of Alternative 2.

The potential for shallow groundwater interception impacts along the Alternative 2 transportation and pipeline corridors would increase under the expanded mine scenario, because the north corridor would be wider and longer to accommodate the concentrate/diesel pipelines, associated access road, and port at Iniskin Bay. These could include localized flow changes in wetland areas supported by groundwater flow, or rerouting of groundwater flow around road cuts. However, overall cumulative effects under Alternative 2 with expanded mine development would be less than that of Alternative 1 with expanded mine development, because the expanded mine scenario under Alternative 2 would not use the south access corridor or Amakdedori port site.

Other Mineral Exploration and Road Development Projects. The contribution of other mine exploration RFFAs to cumulative effects under Alternative 2 would be the same as Alternative 1. The footprint of the Diamond Point rock quarry partially coincides with the Diamond Point port footprint under Alternative 2. Cumulative impacts would be limited to a potential increase in temporary localized impacts on groundwater flow during construction, material extraction, and groundwater supply from commonly shared project footprints and infrastructure with the quarry site under Alternative 2.

The contribution of LPB transportation infrastructure projects to cumulative effects under Alternative 2 would be slightly greater than under Alternative 1, due to a greater potential for co-location with these RFFAs. In addition to the Nondalton-Iliamna and Kaskanak-Igiugig projects—portions of which could be co-located with shallow aquifers along the mine access roads under both Alternatives 1 and 2—the Williamsport-Pile Bay Road upgrade could increase local groundwater flow impacts across wetlands or steep road cuts along the eastern portion of the north access road under Alternative 2.

<u>Alternative 3 – North Road Only</u>

Pebble Mine Expanded Development Scenario. The expanded mine site development and associated contributions to cumulative impacts would be the same for the mine site component of Alternative 3.

The potential for localized shallow groundwater interception impacts for the Alternative 3 non-mine components would increase under the expanded mine RFFA, because the north access road corridor would be slightly wider and longer to accommodate diesel and concentrate pipelines and the Iniskin Bay port. However, overall cumulative effects under Alternative 3 with expanded mine development would be less than that of Alternative 1 with expanded mine development, because the Alternative 3 expanded mine scenario would not use the south access corridor or Amakdedori port site.

Other Mineral Exploration and Road Development Projects. The contribution of other mine exploration, quarry, and road development RFFAs to cumulative effects under Alternative 3 would be the same as Alternative 2.