4.9 SUBSISTENCE

This section describes potential impacts of the project on subsistence in communities near Iliamna Lake, in the Kvichak and Nushagak river drainages, and on the southwest coast of Kenai Peninsula. The magnitude, geographic extent, and duration of impacts are assessed for each project phase. The magnitude of impact from the project depends on the past and current level of subsistence use that would be impacted, the extent to which opportunities to harvest and experiences are altered, as well as the ability of subsistence users to relocate to another area with similar harvest opportunities and experiences. The duration and geographic extent of impacts depends on the location and season in which the disturbance occurs during construction, operations, or closure, as well as the changes to subsistence use areas. Duration would be considered long term if the effect lasted throughout the life of the project (i.e., years to decades) while a short-term effect would be expected to last no longer than the construction phase (i.e., months to years). The potential of impacts is related to how likely the project would be to alter subsistence opportunities, experiences, and use level.

Potential impacts include:

- Changes in resource availability – construction and operation of project facilities may impact fish and wildlife habitat, and decrease or displace fish, wildlife, and vegetative resources used for subsistence.
- Changes in access to resources – project facilities and transportation corridors may open or remove areas from subsistence activities, or facilitate or restrict access to subsistence resources. In addition to physical access, project activity may change the character of the subsistence activities.
- Changes in competition for resources – changes to local population from direct and indirect employment and construction of project transportation access corridors may result in increased competition for subsistence resources.
- Changes in sociocultural conditions – direct/indirect employment opportunities for local residents and the presence of new large scale industrial facilities may have adverse and beneficial sociocultural effects.

The Environmental Impact Statement (EIS) analysis area for subsistence includes the resources that could be affected by the proposed mine site (including material sites), port, transportation corridor, and natural gas pipeline corridor for each alternative. This includes habitat and migration routes for subsistence resources, community subsistence search and harvest areas, and areas used by harvesters to access resources.

Scoping comments not only requested that all subsistence hunting practices be considered in the analysis of effects, but requested consideration of the heavy reliance on fish for all users in the area. Specific impacts due to disturbance from mine transportation needs and potential effects of contaminants from the project on subsistence resources were also addressed by commenters.

4.9.1 No Action Alternative

Under the No Action Alternative, the project would not be undertaken. No construction, operations, or closure activities would occur. Although no resource development would occur under the No Action Alternative, permitted resource exploration activities currently associated with the project may continue (ADNR 2018-RFI 073). Pebble Limited Partnership (PLP) would retain the ability to apply for continued mineral exploration activities under the State's authorization process, as well as any activity that would not require federal authorization. In addition, there are many valid mining claims in the area; these lands would remain open to mineral entry and exploration by PLP and other entities. Therefore, no additional future direct or indirect effects to subsistence resources or access to subsistence resources would be expected and existing habitat and resource trends discussed in Section 3.9, Subsistence, would continue. It should be noted that exploration activities associated with the project provided some local employment and income; the latter could contribute to pursuit of subsistence activities.

PLP would be required to reclaim any remaining sites at the conclusion of their exploration program. If reclamation approval is not granted immediately after the cessation of reclamation activities, the State may require continued authorization for ongoing monitoring and reclamation work as deemed necessary by the State of Alaska.

4.9.2 Alternative 1 – Applicant's Proposed Alternative

4.9.2.1 Changes in Resource Availability

During the 4-year construction phase, project activities would, in varying degrees, affect the availability and abundance of traditional and subsistence resources through habitat loss; individual mortality, behavioral disturbance and displacement resulting from increased noise, vehicle/aircraft/ferry traffic, and human activity; fugitive dust deposits on vegetation; concerns about contamination of resources; avoidance of traditional use areas; and increased costs and times for traveling to more distant areas (see Section 4.23, Wildlife Values; Section 4.24, Fish Values; Section 4.25, Threatened and Endangered Species; and Section 4.26, Vegetation, for discussions of project impacts on fish, wildlife, and vegetation).

During the operations phase, the effects of project activities would be similar. However, the effects would last for 20 years, and occur with less intensity along the transportation corridor than during construction because operations activities would be less disruptive than construction activities. Regular vehicle and ferry traffic and the physical presence of transportation corridor elements would continue to affect availability of subsistence resources over the long term, lasting though the life of the project and closure. At the mine site, effects could occur with more intensity, associated with mining activity, noise, and expansion of the open pit and the waste rock and tailings storage.

Resources and species of concern that have been identified through the scoping process and environmental baseline documents include salmon, caribou, moose, seal, berries, small mammals, and firewood. With regard to the mine site, displacement and individual mortality of fish would occur in the upper portions of the North and South Fork Koktuli rivers directly affected by mine facilities, but given the limited number of fish observed in that area and the quality of fish habitat, impacts would not be noticeable downstream from the affected channels (see Section 4.24, Fish Values). Similarly, there would be displacement of any moose, caribou, small land mammal, and upland birds that use the mine site, but this would represent a small percentage of available habitat. These impacts to fish and wildlife would not be expected to impact harvest levels, since there would be no population-level decrease in resources and alternative, and in many cases more productive, habitats are available.

With regard to transportation facilities such as the mine and port access roads, spur roads, and Iliamna Lake ferry operations, the magnitude of impacts would be in the loss of habitat from the facility footprint, potential displacement of individual fish and wildlife from human activities and noise, and potential injury and mortality from ferry traffic (salmon and seals) and strikes with truck traffic (large and small land mammals and birds) (see Section 4.23, Wildlife Values, and Section 4.24, Fish Values). However, the facility footprint would be small in comparison to the total habitat available, and culverts would be required on the access roads to allow for fish passage. Ferry injury and mortality associated with entrainment of salmon and seal strikes, and vehicle collisions with large and small land mammals and birds, would not have a population-level effect. There would be some site-specific habitat fragmentation from project facilities, causing behavioral disturbance to terrestrial wildlife and birds and localized changes in distribution. These impacts would occur if the project is permitted and built.

The magnitude, duration, and extent of direct impacts would be a long-term loss of resource availability for berries and firewood in the project footprint and the immediate area of mine and transportation facilities; but these resources are commonly available in the analysis area, and there are alternative gathering areas available that are traditionally used.

The extent of impacts from fugitive dust impacts would occur within a narrow corridor on either side of the roadways as described in Section 4.26, Vegetation. The heaviest dust deposition would be anticipated to occur within 35 feet of the road, and vegetation and berry picking activity may avoid dusted areas. Some localized impacts of dust settlement in stream channels where fishing occurs may be noticeable, but implementation of dust suppression and enforcement of slow speed limits at all stream crossings would minimize dust-related impacts to aquatic ecosystems (see Chapter 5, Mitigation). Impacts would be expected to extend through the life of the project and would be localized to the area of disturbance. Fugitive dust from construction, roadways, and mining activities deposited in streams and on berries, other traditionally used plants, plants that animals eat, and water, would discourage subsistence users from harvesting these resources near the areas affected by the mine site and the transportation corridor. Subsistence users also may avoid harvesting waterfowl because of concerns about birds becoming contaminated from landing on and using open water at mine site facilities. These impacts would be realized if the project were permitted, constructed and built.

The communities closest to project infrastructure and transportation activities, including the mine site, transportation corridor, the ferry and terminals, port, and airports, would be the most affected by changes in resource availability. These communities include Nondalton, Iliamna, Newhalen, Pedro Bay, Igiugig, and Kokhanok. In contrast, communities in the Nushagak River drainage and in the Kvichak River drainage below Igiugig would experience little to no impact on resource availability as the potential impact on fish and wildlife would be small (see Section 4.23, Wildlife Values). Residents in Port Alsworth use an area in the vicinity of the mine site and along the mine access road to harvest caribou, moose, other land mammals, waterfowl, upland birds, and berries though the areas closer to and surrounding this community see higher concentrations of use and it is expected that there would be little to no impact on resource availability in the concentrated use areas closer to the community during operations. On the east side of Cook Inlet, the construction and decommissioning of the natural gas pipeline would disturb a small area of about 5 acres near the Sterling Highway. This is distant from communities traditionally pursuing subsistence activities.

During construction and operations, the effects of project activities on resource availability would be primarily localized in the vicinity of project facilities and activities. While the mine site is within subsistence harvest areas used by five communities, it provides relatively poor fish and wildlife habitat and is not within the area of highest intensity overlapping subsistence users. Portions of the transportation corridor, primarily in the vicinity of Upper Talarik Creek (UTC) and Gibraltar Lake and River are more heavily used (see Section 3.9, Subsistence, and Appendix K3.9). Truck traffic along these portions of the transportation corridor could displace moose and other land mammals in the immediate vicinity of the access roads. Subsistence users that harvest resources in the immediate vicinity of the transportation corridor, particularly those from Iliamna, Newhalen, and Kokhanok, would likely need to make some adjustments to where they harvest some subsistence resources to target resources that would be less affected by project activities. These adaptive approaches would likely sustain harvest levels for affected communities, but would likely increase the expense and time needed to harvest subsistence resources. The duration of effects would be long term, lasting through the life of the project and closure and they would be certain to occur under Alternative 1.

Many project features would be removed or reclaimed, or both, during closure. Once restoration activities have been completed, impacts on the availability of subsistence resources would be reduced as these areas would revegetate and return to a more natural state. The pit lake at the mine site would fill during the decades after mine closure. This would introduce a new standing waterbody, and concern about contamination of waterfowl was expressed during scoping. While there would be exceedance of water quality standards for specific metals, during closure (see Appendix K4.18), exposure of wildlife and birds from potential contaminants exposure would be limited and short-term. The pit lake would not support habitat that is attractive to many species of waterfowl and shorebirds, and alternate habitat, including open water for staging, is common and available in the area. Some project facilities, including the pipeline, power plant, limited camp and storage facilities, access roads, and mine water treatment plant, would remain in use after mine closure as long as needed to support closure activities. Impacts on resource availability would be localized, in the vicinity of remaining infrastructure and activities (see Section 4.26, Vegetation, and Section 4.23, Wildlife Values, for discussions on vegetation restoration and impacts to wildlife).

The magnitude and extent of impacts to subsistence resources would be: disturbance; displacement; individual mortality from vehicle collisions and physical loss of stream habitat; and the loss of habitat due to placement of project components. However, population level effects to fish and wildlife would not be expected (see Section 4.24, Fish Values, and Section 4.23, Wildlife Values) and similar habitat is generally available. The duration of impacts on subsistence resources would be long term, lasting throughout the life of the mine and post closure because there could remain a perception of contamination. Impacts from the transportation corridor and associated uses would be intermittent to prolonged over the construction period and 20-year operations period. The duration of impacts would extend beyond the life of the mine but would decrease in intensity after closure. Some impacts on subsistence would be certain to occur under this alternative.

4.9.2.2 Changes in Access to Resources

Subsistence harvest patterns are dynamic and strategic, as users concentrate their efforts in areas likely to be productive, with abundance and distribution of resources that change year by year. The magnitude, extent and duration of impacts would be to impair or restrict access to resources during construction in the immediate vicinity of the project components. Such restrictions would affect communities located near project infrastructure that use this land for or to access subsistence fishing, hunting, gathering, education of youth on subsistence traditions, and other customary practices. Construction of linear features, such as the roads and pipeline, could interrupt travel to resources or communities on the other side of the right-of-way (ROW). For example, construction of the natural gas pipeline and port access road could inconvenience residents of Kokhanok accessing subsistence areas south and west of the community during 1 of the 4 years of construction. Additionally, construction-related vessel traffic crossing Iliamna Lake could inconvenience other vessel traffic and subsistence activities. Safety considerations and presence of project equipment and personnel may restrict hunting activities in proximity to project facilities, and would be subject to consultation with potentially affected communities. These impacts would be expected to occur under Alternative 1.

During the operations phase, the magnitude and extent of impacts would be the restriction of access to subsistence resources at the project footprint of the mine site, Iliamna Lake ferry terminals, mine and port access roads, and Amakdedori port. The duration of the impact would be long term, lasting throughout the life of the project and closure. Hunting may be restricted in the vicinity of those areas, and a raised gravel road may present a barrier to snowmachine and all-terrain vehicle (ATV) crossing. There could also be disruption to access to marine resources in Cook Inlet from barge activity and pipeline construction. However, such restrictions would have minimal impact on access to subsistence resources because these project components would occupy a relatively small portion of the nearby communities' harvest areas related to the available area, and because mitigating measures would be in place to minimize or avoid impact. These measures, such as providing marked crossing points across the transportation corridor and around the ferry terminals (PLP 2018-RFI 027), are discussed in Chapter 5, Mitigation; however, crossing at designated points or avoidance of barge traffic may add travel time and expense for subsistence users. These adverse impacts would be long term, lasting for the life of the project, and would be certain to occur.

PLP would work with local communities to identify safe, practicable ways for residents to use the access roads, such as scheduled escorted convoys for private vehicle transport, and address hunting guidelines in proximity to project facilities. Trails and crossing points would be sign-posted and appropriate traffic controls would be established to ensure public safety (PLP 2018-RFI 027). Once constructed, the transportation corridor roads and the natural gas pipeline corridor ROW could have a positive, long-term effect on access to subsistence resources (depending on the level of access agreed to between the State, PLP, and the Lake and Peninsula Borough [LPB]) because these cleared routes could facilitate some overland travel by ATVs and snowmachines.

The magnitude and extent of impacts from the Iliamna Lake ice-breaking ferry would be to disrupt winter travel over the frozen lake by creating a corridor of open water and potentially adding to travel time and increasing fuel expenditures by subsistence users. In addition, the open water in the ferry's wake would present a safety hazard for subsistence users. However, the PLP would work with communities (and supply funding) to provide for the marking and maintenance of snowmachine trails between communities across Iliamna Lake when lake ice is thick enough to support such traffic (PLP 2018-RFI 071a) (see Section 3.12, Transportation and Navigation). PLP would work with local communities to find solutions for ferry transportation use (PLP 2018-RFI 027). However these effects would be long term and certain to occur.

At closure, roads in the transportation corridor would remain in place for monitoring purposes and potentially local traffic, and could continue to facilitate overland travel for subsistence access. The ferry facilities would be removed and supplies would be transported across the lake using a summer barging operation; thus, there would be no impacts from ice-breaking ferries after closure. Many of the other project features would be removed and/or reclaimed; therefore, adverse impacts on access to subsistence resources would be greatly reduced.

The magnitude and extent of impacts of the transportation corridor on subsistence users would be potential restrictions to access in the EIS analysis area. The impact would be limited in geographic extent and subsistence users would be able to access other areas for harvest of resources. This is primarily because the UTC portion of the transportation corridor is identified as a high overlapping area for subsistence users for two communities (Iliamna and Newhalen) and is used by two others (Nondalton and Igiugig). Additionally, the Gibraltar River and Lake portion of the transportation corridor is a high overlapping subsistence use area for Kokhanok that is also used by Igiugig. Impacts of the transportation corridor and associated uses would be intermittent to prolonged over the 24-year period of project construction and operations. The duration of impacts would be long term, extending beyond the life of the mine. In terms of likelihood, the impacts would be certain to occur.

The following sections evaluate project impacts on access to subsistence resource harvest areas for the six communities located closest to the project components (i.e., Iliamna, Newhalen, Pedro Bay, Nondalton, Igiugig, and Kokhanok) as project facilities and activities may restrict access in areas of overlapping subsistence use by these communities. It is based on reported and historical use of these areas as described by SRB&A (2011b), Fall et al. (2006), and Krieg et al. (2009), and presented in Section 3.9, Subsistence. For most of the communities, the contemporary use areas mirror the traditional use of the lands used to harvest subsistence resources, while in some communities the movement of animals (e.g., the Mulchatna caribou herd) to different areas has changed patterns of use and hunters have focused attention on different areas or resources. The figures in Section 3.9, Subsistence, and Appendix K3.9 show the multi-year subsistence use areas and the relative number of subsistence users for the six communities closest to the project components. It is possible that some downriver communities in the Kvichak and Nushagak River drainages may occasionally use the analysis area for subsistence activities, but their high frequency use areas are closer to the location of their communities (see Appendix K3.9).

The impacts to use areas and access to these areas from construction and operations of the natural gas pipeline would be the same as described for the transportation corridor.

The mine site would impact all six of the listed communities in similar ways. Construction, operations, and closure may affect access to subsistence hunting and fishing on these lands. Project-related activities, such as blasting and operation of heavy equipment and helicopters, would adversely restrict access. Lake community residents that may have otherwise traveled through the mine site area to reach subsistence resources further north and west would have to take alternative routes and potentially travel farther distances to avoid the mine site and infrastructure. However, the mine site is not shown as a high frequency overlapping use area for any of the six communities.

The magnitude and extent of impacts to accessing the mine site for subsistence use and harvest would be most concentrated near the mine site area and would diminish with distance. The effects would be limited in geographic extent; there is availability of alternate areas in traditional subsistence areas for activities. Impacts of the mine site and associated uses would be intermittent to prolonged. The duration of impacts would extend beyond the life of the project, with diminishing intensity as the site is reclaimed during closure. The impacts would be certain to occur.

Iliamna

The magnitude and extent of impacts from construction and operations of the mine access road (including a bridge over the Newhalen River) and the north ferry terminal under Alternative 1 would be the disruption of access to a portion of the overall harvest areas near Upper and Lower Talarik creeks, which are medium- to high-use areas for Iliamna subsistence users, particularly for moose and other land mammals. While there are other areas shown as medium to high uses areas for moose and other land mammals, hunters who traditionally use the Upper and Lower Talarik creeks areas would be affected. The south ferry terminal and port access road would be located in lower overlapping use areas that Iliamna residents' access for resources. The duration of the impacts would be long term and they would be certain to occur if the project is permitted and built.

Until Iliamna Lake is connected to Cook Inlet through the transportation corridor at the southern ferry terminal, the Williamsport-Pile Bay Road may be used to transport supplies to Iliamna Lake during construction (PLP 2018-RFI 037). If this route were to be used, the volume of traffic on

Williamsport-Pile Bay Road would increase during construction, which could affect access to resources.

Newhalen

The magnitude and extent of impacts on subsistence use from construction and operations of the mine and port access roads (including a bridge over the Newhalen River) and the north ferry terminal under Alternative 1 may be a disruption of access to a portion of the overall harvest areas near Upper and Lower Talarik creeks, which are medium- to high-use areas for Newhalen subsistence users. Impacts to access would be similar to those described above for Iliamna. The south ferry terminal and port access road would be located in an area with lower overlapping uses that Newhalen residents access for resources. The impacts would be long term and would be certain to occur.

If the Williamsport-Pile Bay Road is used during construction, the volume of traffic on this route would increase, which could affect access to resources.

Pedro Bay

The magnitude and effects of construction and operations of the mine access road and north ferry terminal under Alternative 1 on subsistence use would be to displace access to a small portion of the overall harvest areas in comparison to the total harvest area available near the Upper and Lower Talarik creeks, which show overlapping uses for Pedro Bay harvesters. The duration of the impact would be long term and it would be expected to occur.

If the Williamsport-Pile Bay Road is used during construction, the volume of traffic on this route would increase, which could affect access to resources; this would be in an area accessed by a moderate to high number of residents.

Nondalton

With respect to the magnitude and extent of the impacts, construction and operations of the mine and port access roads (including a bridge over the Newhalen River) and ferry terminals under Alternative 1 would be to restrict access to the documented subsistence use areas near the Upper and Lower Talarik creeks. Impacts on access in this area would be similar to those described for Iliamna and would be long term and certain to occur.

Igiugig

The magnitude and extent of impacts due to construction and operations of the mine and port access roads and the north ferry terminal under Alternative 1 would be the disruption of access to a small portion of the overall harvest areas near Upper and Lower Talarik creeks, although they are low-use areas for Igiugig subsistence users. The impacts would last though the life of the project through closure and would be expected to occur. The south ferry terminal, and port access road would be located in areas that Igiugig residents have reported accessing for resources.

The ferry traffic would be noticeable to those using Iliamna Lake to access areas at the north east end of the lake, in the Sid Larson Bay and areas around the community of Kokhanok. These areas are all used by a low number of subsistence users in Igiugig. The impact would be of higher magnitude in the winter, when the ice-breaking ferry would be operating.

Kokhanok

The magnitude and extent of impacts from construction and operations of the mine and port access roads, ferry terminals, and the east Kokhanok ferry terminal on Kokhanok residents would be to impede access to portions of the overlapping harvest use areas in the immediate area surrounding the community, and the Gibraltar River and Lake areas. Portions of overlapping use areas near the Upper and Lower Talarik creeks where large land mammals are hunted would also be affected. These impacts would be long term and certain to occur under Alternative 1.

During the winter when the ferry would be breaking ice, ferry traffic would be noticeable to those using Iliamna Lake to access areas at the north east end of the lake, in the Sid Larson Bay and areas around the community of Kokhanok. Traditional access routes used by some Kokhanok residents would be affected.

The magnitude and extent of construction and operations of the Amakdedori port under Alternative Action 1 would be to impede access for residents of Kokhanok to overlapping use areas for taking of marine invertebrates and seals in Kamishak Bay. The impacts would last throughout the life of the project and would occur if the port is permitted and constructed. Construction of the Amakdedori port under Alternative 1 is not expected to impact access to resources for communities other than Kokhanok because resident of other communities do not harvest resources in that area.

4.9.2.3 Changes in Competition for Resources

The project would result in employment opportunities for non-local workers during construction and operations; the duration of this impact would be short term, lasting only though the construction phase. However, such opportunities are unlikely to increase competition for subsistence resources from sport hunting and fishing in areas where project employees are working or housed. Employees would be prohibited from hunting, fishing, and gathering while onsite to minimize competition for local subsistence resources. Non-local mine site employees would be transported to and from the mine site by aircraft, so that non-local employees could continue to live outside the region and commute to project work sites. Similarly, access to and use of project roads and other facilities for non-resident sport hunting would be prohibited. The magnitude of the impact would be that non-local workers would not contribute to an increase in recreational use, although some may occasionally stay in the area when off duty or visit for recreational trips to nearby destinations including for the purpose of sport fishing or hunting.

There is the potential for a slight population increase in communities closest to the mine site (see Section 4.3, Needs and Welfare of the People—Socioeconomics), which could increase resource competition among local residents. The magnitude and extent of the effect of an increase in population would be an increase in recreational and sport hunting; however, such activities would be subject to the management of the Alaska Department of Fish and Game (ADF&G). It is also possible that increased local access and adjustments to hunting areas in response to project facilities and activities could result in changes in resource competition among local residents. The largest impacts could occur in Iliamna, which may see a small increase in population related to businesses developed to support the project. The duration of impacts would be long term, lasting for the life of the project and they are likely to occur if the project is permitted and built as described.

After closure, the potential for non-local project employees to increase competition for subsistence resources would decrease.

4.9.2.4 Changes in Sociocultural Dimensions of Subsistence

Project construction and operations would result in both beneficial and adverse effects on sociocultural dimensions of subsistence. Subsistence activities are both cash dependent and highly cash-efficient. Cash income is required to pay for equipment, supplies, and operating costs, but modest cash investments can result in successful subsistence harvests and well-being. Increased incomes from project employment for local employees would be partially invested in subsistence activities, increasing the efficiency and reliability of subsistence equipment and providing financial resources for a greater level of subsistence activities. Project activities would increase employment opportunities for residents of the analysis area, particularly for those living in communities surrounding Iliamna Lake. The number of local people who would be hired during the construction phase is not known, but PLP intends to prioritize opportunities for area residents or those with close ties to the area (PLP 2018-RFI 027). The magnitude and duration of the effect would be that during operations, an estimated 50 employees would come from communities connected to project sites by road and an additional 200 employees would come from surrounding communities (out of 850 total employees during operations) (PLP 2018-RFI 027). These effects on sociocultural dimensions would be expected to occur.

The effect of income on subsistence success (i.e., subsistence production) is evident among households with unique demographic structures. The magnitude of the effect of income is such that in many communities, 30 percent of households produce 70 percent of the subsistence harvest. These “super households” are distinguished because they include multiple working-age males, tend to have high incomes, and often are involved in commercial fishing. These three factors support high-producing households to be able to combine subsistence activities with paid employment and to arrange considerable labor in flexible ways that maximize harvests of subsistence foods, which are then shared with other households in the community and region. In contrast, the low-producing households usually have lower incomes, and are led by a single female or non-Native head of household, are single-person households, or households composed of elders (Wolfe et al. 2010).

At the same time, subsistence activities are labor intensive and require large investments of time and effort in hunting, fishing, and processing subsistence foods. Many subsistence resources are available only at certain times of the year. To the extent that project related employment reduces the time available for these employees to participate in subsistence activities and to pass on skills and knowledge to the next generation, their harvest effectiveness may decline. Proposed shift-work schedules, with two weeks at the project site and two weeks off in the community would likely reduce, but not eliminate, the conflict between project employment and subsistence activities.

Increased employment of adults and changes in work schedules would impact the nature of time spent training young people to subsistence hunt and fish. The magnitude of this effect could be a change in the amount and quality of traditional knowledge passed on to younger generations and could potentially result in an adverse effect to communities. Households and communities would have to adjust to new roles of subsistence labor, changes in sharing networks, and possible changes in harvest levels. Rotational work schedules could affect levels of subsistence in different ways, since some families could adapt positively and some would find this an adverse effect. Legal hunting seasons are short, and if work schedules conflicted with seasons, then the effect on subsistence harvests could be greater. A main hunter’s absence from the community at important times of the season or year could have a greater impact. However, the effects could be reduced, but not eliminated, with planned periods of leave options that allow for continuation of traditional subsistence practices and schedules during subsistence harvest periods.

Out-migration of mine project employees from local communities has been identified as an adverse sociocultural effect on subsistence. At the Red Dog Mine, nearly 50 percent of the workforce from local communities eventually migrated to lower cost, higher amenity communities like Anchorage and Wasilla, because the mine operator provided no-cost transportation to the mine site for workers' shifts (Tetra Tech 2009). To the extent that high-harvesting households relocated away from the community, the reduction in subsistence foods available in the community would be disproportionately larger. Similarly, the increased availability of jobs for local residents could result in some ex-residents returning to communities. While a large in-migration or out-migration of population is not anticipated, Alternative 1 may lead to changing population patterns in the region (see Section 4.3, Needs and Welfare of the People—Socioeconomics). The population in some potentially affected communities has been declining due to out-migration. The project could reduce or eliminate the decline because of the increase in employment opportunities and indirect effects improving education and infrastructure. Therefore, the impacts on population and effects to sociocultural changes of subsistence are difficult to anticipate.

Local residents participate in subsistence activities to a high degree. The level of participation may be affected by changes in resource abundance and quality, season and bag limits, changes in physical access, changes in cultural perceptions of resources (e.g., fish and animals are seen as tainted/contaminated, or water as polluted), the physical presence of project facilities in an area that was previously undeveloped and comfort level pursuing subsistence activities in their vicinity, and the times and funds available for subsistence activities. Changes in harvest participation are a leading indicator of cultural changes; continued participation is important to the transfer of knowledge and skills across generations, to the formation of social relationships within and between communities, and to cultural continuity. To the Yup'ik and Dena'ina cultures in the analysis area, salmon provide a large proportion of their nutritional food resources and represent an essential part of the language, spirituality, and social relations. In particular, subsistence and customary practices are the foundation of culture, maintain the connection of people to their land and environment, and support healthy diet and nutrition (Boraas and Knott 2013).

To the extent that project activities would have adverse impacts on resource abundance, availability, quality, and access, corresponding adverse sociocultural impacts on affected communities would occur, related to community health/well-being, spiritual ties to subsistence, and cultural identity. Under routine operating conditions, the communities affected would likely be limited to those closest to the project's infrastructure and transportation activities: Nondalton, Iliamna, Newhalen, Pedro Bay, Igiugig, and Kokhanok. However, there could still be perceived concerns regarding potential contamination and the safety of subsistence resources in communities downriver from the analysis area. These impacts would be long term, potentially lasting post-closure, and likely to occur if the project is permitted and constructed.

At closure, both time commitments for and cash income from project employment would cease. Households would have to adjust to reduced cash income to support the maintenance and operating costs of a subsistence lifestyle. Workers who moved out of local communities may choose not to return. The indirect effects of mine employment and income on subsistence practices would decrease. Some long-term impacts may include loss of subsistence knowledge and skills, and a decrease of participation during mine operations continuing after closure.

4.9.2.5 Alternative 1 – Kokhanok East Ferry Terminal Variant

The Kokhanok East Ferry Terminal Variant would result in similar impacts to those described above for changes in resource availability, access to resources, changes in competition for resources, and changes in the sociocultural dimension. However, the eastern location could cause additional subsistence conflicts compared to the proposed location.

Under the Kokhanok East Ferry Terminal Variant, snowmachine access to Iliamna Lake would be provided to the east of the terminal to enable access to the Sid Larson Bay area without crossing the ferry route (PLP 2018-RFI 078). PLP would work with local communities to find solutions for ferry transportation use (PLP 2018-RFI 027). The duration of these impacts would be long term and they would be certain to occur.

4.9.2.6 Alternative 1 – Summer-Only Ferry Operations Variant

The Summer-Only Ferry Operations Variant would result in similar impacts to those described above for changes in resource availability, access to resources, changes in competition for resources, and changes in the sociocultural dimension. However, under the Summer-Only Ferry Operations Variant, the magnitude and extent of the impact would be a doubling in the volume of haul trucks on the mine and port access roads in the summer, which could result in a greater impact in terms of access to resources in the use areas near the ferry terminals and access roads. Summer ferry traffic would also double, increasing from one daily round-trip to two; however, boat traffic by subsistence users would only be minimally affected by the increase. The impact would last throughout the life of the project and would be expected to occur.

The Summer-Only Ferry Operations Variant would have no impact to winter access, harvest activities, or safety concerns for travel across Iliamna Lake.

4.9.2.7 Alternative 1 – Pile-Supported Dock Variant

The Pile-Supported Dock Variant would result in similar impacts to those described above for changes in resource availability, access to resources, changes in competition for resources, and changes in the sociocultural dimension.

4.9.3 Alternative 2 – North Road and Ferry with Downstream Dams

In general, the type of impacts from the changes in resource availability, access to subsistence resources, and competition for resources would be the similar as Alternative 1 at the mine site. Impacts from the changes in the sociocultural dimension of subsistence would be the same as Alternative 1 for all project components. Along the transportation corridor and natural gas pipeline, impacts would be similar to Alternative 1, except for differences described below.

Changes in resource availability along the transportation corridor and the natural gas pipeline for Alternative 2 would be similar to Alternative 1, but would affect a different area for the access roads, ferry, pipeline, and port, and would therefore affect the lake communities to a different degree. Individual mortality and behavior disturbance to and displacement of subsistence resources would occur at approximately the same levels as described under Alternative 1. The primary difference is that there are fewer communities using the area in between Pile Bay and Williamsport for subsistence, and so the magnitude and geographic extent of the impact would be less than Alternative 1. Based on the frequency of areas of overlapping subsistence users, Nondalton, Newhalen, and Pedro Bay use the mine access road alignment to the Eagle Bay ferry terminal to a lesser degree, and Iliamna has a higher frequency use. Pedro Bay has high frequency overlapping use of the area of the Pile Bay terminal and portions of the port access road from Pile Bay to Williamsport. Kokhanok would be affected to a lesser degree. All six analysis area communities use the eastern end of Iliamna Lake for seal hunting to some degree.

Along the ferry route there would be a higher magnitude of impact to resource availability for seals, than Alternative 1 because the ferry would pass through more seal hunting areas under Alternative 2.

Under Alternative 2, there would be an overland natural gas pipeline ROW from Pile Bay to the mine site, including the area between ferry terminals. This could introduce some competition to subsistence users from recreational sport hunting and fishing, however, the area is not highly used by recreationists.

4.9.3.1 Changes in Access to Resources

<u>Iliamna</u>

The mine access road from Eagle Bay would be located in medium- to high-use areas accessed by residents of Iliamna and would be likely to impact access. There are overlapping use areas near the Newhalen River and further inland, and near the site of the ferry terminal at Eagle Bay. The ferry under Alternative 2 would traverse the eastern portions of Iliamna Lake that are accessed by residents with low to medium overlapping uses. The ice-breaking ferry would disrupt access to these areas, and similar to Alternative 1, safe winter travel routes would need to be developed with arrangements between PLP and affected communities.

The magnitude of the impact of the addition of a pipeline ROW would be to potentially create an overland route that could be used by Iliamna residents to access additional subsistence resources.

Diamond Point port construction and operations under Alternative 2 could affect Iliamna residents' access to harvests locations in Cook Inlet. However, though long-term, the changes to access would affect areas that are reported as low-use areas for harvested resources near Iliamna Bay and north of Augustine Island. The effect would be expected to occur under Alternative 2.

<u>Newhalen</u>

The mine access road of Alternative 2 would be located in the vicinity of a medium to high overlapping use area near the Newhalen River and would impact access to resources in the areas inland north of the community. The ferry route would be south of the islands in Iliamna Lake that are accessed by residents, but would not pass close to the islands and would not likely disrupt access in the summer. In the winter, the ice-breaking ferry could disrupt access to all resource use areas on the northeast end of the lake.

The addition of a pipeline ROW would potentially create an overland route that could be used by Newhalen residents to access additional subsistence resources. The duration of the impact would be long term and would be likely to occur under Alternative 2.

Diamond Point port construction and operations under Alternative 2 would not be expected to affect Newhalen access to harvests locations, as they do not access resources in that location.

<u>Pedro Bay</u>

The mine and port access roads and use of the Williamsport-Pile Bay Road under Alternative 2 would likely impact access to resource harvest areas for Pedro Bay residents in high overlapping use areas near the community, on Iliamna Lake, inland from Iliamna Lake, and in Pile Bay, and have similar impacts to access as described in Alternative 1. However, there is the existing Williamsport-Pile Bay Road, and Pedro Bay has experience with the adverse and beneficial effects of a road on subsistence access. The ferry route would be south of the islands in Iliamna Lake that are used by residents of Pedro Bay, and so access to those islands and their resources would not be likely to be affected. As described for Iliamna, winter ferry operations would impact traditional access and create travel safety concerns that would need to be mitigated in consultation with PLP.

The addition of a pipeline ROW would potentially create an overland route that could be used by Pedro Bay residents to access additional subsistence resources, particularly during the winter when there is snow cover. The impact would be long term and likely to occur.

The magnitude of effects on access to resources from Diamond Point port construction and operations under Alternative 2 would be to impede access to subsistence activities and fishing and marine invertebrate harvesting for Pedro Bay residents in Iliamna Bay and near Augustine Island as the port would be located in the vicinity of these use areas. However, there is existing vessel traffic to Williamsport during the summer months, and some vessel traffic associated with the quarry at Diamond Point. The impacts would last for the life of the project and would be certain to occur.

This community has a smaller population than the other lake communities and residents do not harvest subsistence resources as far away from their community as residents of the other lake communities do. Therefore, disruption could have a greater intensity of impact to this community.

Nondalton

The mine and port access roads of Alternative 2 are likely to impact access to resource harvest areas for Nondalton residents as they would be located in the vicinity of medium overlapping use areas. Impacts would be similar to those described for Iliamna. The ferry route would be south of the islands in Iliamna Lake that are used by residents of Nondalton; therefore, access to those islands and their resources would not likely be affected. However, winter subsistence harvest of seals would be affected by ferry operations, similar to impacts discussed for Iliamna.

The addition of a pipeline ROW would potentially create an overland route that could be used by Nondalton residents to access additional subsistence resources. The duration of this impact would be long term and it would be expected to occur.

Diamond Point port construction and operations under Alternative 2 would not be expected to affect Nondalton access to harvests locations as they do not access resources in that location.

Igiugig

Neither the transportation corridor, ferry, nor Diamond Point port of Alternative 2 are anticipated to impact access to resource harvest areas for Igiugig residents as fewer subsistence users search for and harvest resources in these areas.

Kokhanok

The mine and port access roads of Alternative 2 are less likely to impact access to resource harvest areas for Kokhanok residents as fewer subsistence users search and harvest in areas inland from the north side of Iliamna Lake and closer to the mine site.

The ferry route would be south of islands in Iliamna Lake that are accessed by residents for seal hunting, but would not pass close to the islands and would not likely disrupt access in the summer. In the winter, the ice-breaking ferry could disrupt access to seal hunting in winter which is the preferred time of year when this activity occurs.

Diamond Point port construction and operations under Alternative 2 would not be expected to affect Kokhanok residents' access to harvest locations, as they do not typically access resources in that location.

4.9.3.2 Alternative 2 – Summer-Only Ferry Operations Variant

The Summer-Only Ferry Operations Variant would result in similar impacts to those described above for changes in resource availability, access to resources, changes in competition for resources, and changes in the sociocultural dimension. However, under the Summer-Only Ferry Operations Variant, the magnitude of the impact would be that the volume of haul trucks on the mine and port access roads would double in the summer, which could result in a greater impact in terms of access to resources in the use areas near the ferry terminals and access roads. Summer ferry traffic would also double, increasing from one daily round-trip to two; however, boat traffic by subsistence users would only be minimally affected by the increase. The duration of the impact would be long term and the impact would occur under this variant.

The Summer-Only Ferry Operations Variant would have no impact to winter access or safety concerns for travel across Iliamna Lake.

There would be less impact to seal hunting under the summer-only ferry operations as they do not tend to congregate in this area of the lake in the summer months and the preferred time for hunting seals is in the winter (see Section 4.23, Wildlife Values).

4.9.3.3 Alternative – Pile-Supported Dock Variant

The Pile-Supported Dock Variant would result in similar impacts to those described above for changes in resource availability, access to resources, changes in competition for resources, and changes in the sociocultural dimension.

4.9.4 Alternative 3 – North Road Only

In general, the type of impacts from the changes in resource availability, access to subsistence resources, and competition for resources at the mine site would be similar to Alternative 1. Impacts from changes in the sociocultural dimension of subsistence would be the same as Alternative 1 for all project components. Along the transportation corridor and natural gas pipeline, impacts would be the same as Alternative 1, except that there would be no ferry operations and access would be provided entirely by road.

Changes in resource availability along the transportation corridor and the natural gas pipeline alignment for Alternative 3 would be similar to Alternative 1, but would occur over a different geographic area. Individual mortality and behavioral disturbance to, and displacement of, subsistence resources would occur at approximately the same levels on land but would avoid impacts to seals in Iliamna Lake. As with Alternative 2, there are slightly fewer communities using the area between Pile Bay and Williamsport for subsistence (Iliamna, Newhalen, Nondalton, and Pedro Bay). However, there are a high number of overlapping use areas along the road corridor of Alternative 3 from Pedro Bay to the mine site for Iliamna and Pedro Bay, and so the magnitude of the impact to those communities would be slightly higher than Alternative 1.

Under Alternative 3, there would be a road from Pile Bay to the mine site, alongside the natural gas pipeline. The magnitude of the effect of this road would be to increase the level of activity along that route compared to Alternative 2. This north access road would be under controlled access, limiting potential competition to subsistence uses of resources from non-local recreational sport hunting and fishing. The duration of the impact would be long term and it would occur under Alternative 3.

Access to subsistence resource use areas would be the similar to Alternative 2 for residents of Iliamna, Newhalen, Pedro Bay, Nondalton, Igiugig, and Kokhanok. The primary difference is the road from Pile Bay to the mine site, which would affect access in ways similar to the discussion for Alternative 1. There would be no ferry operations, and therefore no impacts to winter seal hunting or access on Iliamna Lake.

4.9.4.1 Alternative 3 – Concentrate Pipeline Variant

A concentrate pipeline would be built from the mine site to Diamond Point, alongside the natural gas pipeline; additional disturbance to the gas pipeline and road construction corridor would not be expected. Water treatment for dewatering the concentrate would occur at Diamond Point, and discharged to marine waters in compliance with state water quality standards. There would be little to no additional effect on subsistence resources or access.

4.9.5 Summary of Key Issues

See Table 4.9-1 for a summary of key issues.

Table 4.9-1: Summary of Key Issues for Subsistence

Impact	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
Impacts to availability of subsistence resources	Reduced availability of subsistence resources through habitat loss, disturbance and displacement of resources, fugitive dust deposits on resources, and increased costs and time for traveling to harvest areas. Variants would not affect the availability of resources.	Similar impacts to Alternative 1 would affect subsistence resources in the Alternative 2 analysis area. The Summer-Only Ferry Operations Variant would reduce disturbance to freshwater seals in the winter. The Pile-Supported Dock Variant would have the same impacts as Alternative 2	Similar impacts to Alternative 1 would affect subsistence resources in the Alternative 3 analysis area. Concentrate Pipeline Variant would not affect the availability of resources.
Impacts to access to subsistence resources	Snowmachine access could be disrupted in the winter by the ice-breaking ferry, and could also create a safety hazard. PLP would put measures in place to minimize impacts, such trail marking and crossings. The Kokhanok East Ferry Terminal Variant would allow for access to Sid Larson Bay without crossing the ferry route. The Summer-Only Ferry Operations Variant would eliminate disruptions to snowmachine travel.	Impacts would be the same as for Alternative 1, except that the routes affected would be trails from Pedro Bay and the north and east end of the lake instead of the mid-lake region. The Summer-Only Ferry Operations Variant would eliminate disruptions to snowmachine travel. The Pile-Supported Dock Variant would have the same impacts to access as Alternative 2.	Impacts would be similar to Alternative 2, except the impacts from the road from Pile Bay to the mine site would be more similar to the road under Alternative 1. The Concentrate Pipeline Variant would have the same impacts to access as Alternative 3.

Table 4.9-1: Summary of Key Issues for Subsistence

Impact	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
	The Pile-Supported Dock Variant would have the same impacts to access as Alternative 1.		
Impacts in competition for resources	There would be some availability to access other areas for harvest of resources, which could increase competition in some areas by providing additional access for local residents. Variants would be the same as Alternative 1.	The addition of the pipeline ROW may increase competition for resources in that area by providing additional access for local residents. Variants would be the same as Alternative 2.	Similar to Alternative 1 and the Concentrate Pipeline Variant would not affect competition.
Impacts to sociocultural dimensions of subsistence	Beneficial effects from new income to invest in subsistence activities. Challenges in balancing time required for employment and time for subsistence activities. Adverse effects from out-migration, particularly if high-harvesting households leave. Variants would be the same as Alternative 1.	Same as Alternative 1. Variants would be the same as Alternative 2.	Same as Alternative 1 and the Concentrate Pipeline Variant would not affect competition.

4.9.6 Cumulative Effects

The cumulative effects analysis area for subsistence is the same as the EIS analysis area for subsistence, which includes habitat and migration routes for subsistence resources, community subsistence search and harvest areas, and areas used by harvesters to access resources (see Section 3.9, Subsistence). Potential cumulative impacts to subsistence include changes to resource availability, access to resources, competition for resources, and sociocultural issues.

Past, present, and reasonably foreseeable future actions (RFFAs) as described in Section 4.1, Introduction to Environmental Consequences, have the potential to contribute cumulatively to effects on subsistence resources and uses. These RFFAs may result in direct and indirect effects on subsistence resources and uses. The RFFAs listed below apply to the consideration of cumulative effects on subsistence resources and uses. Each of these RFFAs contribute to the increased potential for impacts on subsistence resources, as each involves some aspect of ground-disturbing activity that could lead to the disturbance and displacement of subsistence resources at those locations.

- Pebble Project build-out—develop 55 percent of delineated resources over a 78 year period
- Pebble South/PEB*
- Big Chunk South*
- Big Chunk North*
- Fog Lake*
- Groundhog*
- Shotgun
- Johnson Tract*
- Donlin Gold
- Diamond Point Rock Quarry
- Alaska Stand Alone Pipeline

- Alaska LNG
- Drift River Oil Pipeline
- Cook Inlet Lease Sales
- Hydrocarbon Exploration*
- Lake and Peninsula Borough Transportation Projects
- LPD Capital Improvement Projects
- US Department of Agriculture (USDA) Rural Development Projects
- LBP Renewable Energy Projects
- Nushagak Intertie Project
- Subsistence Activity
- Tourism, Recreation, Hunting, Fishing
- Scientific Surveys and Research

**Indicates exploration activities only.*

4.9.6.1 Past and Present Actions

Past and present actions have caused noticeable effects to subsistence resources. Such activities include subsistence activities, sport fishing and hunting, mining exploration, and non-mining related projects, such as transportation, oil and gas development, or community development actions. As described in Section 3.9, Subsistence, the subsistence harvest of sockeye salmon in the Kvichak River drainage has decreased over the past 20 years. Several communities observed that habitat change in southwest Alaska is affecting the Mulchatna caribou herd, causing the herd to move farther away from communities in the EIS analysis area, which impacts subsistence harvest. Habitat changes include warming temperatures and increased shrub habitat, preferred by moose. Consequently, these habitat changes have benefitted moose, which is resulting in increased moose harvest by local residents in the EIS analysis area in the last 10 years. Additionally, Nondalton local residents have noted declines in caribou numbers due to disturbance from helicopters, and declines in caribou and moose numbers due to overharvest by sport hunting. Residents of Pedro Bay also observed a decline in Dolly Varden in the Iliamna River due to overharvest by sport fishing and habitat disturbance from motorized boats. Subsistence harvest of Cook Inlet beluga whales prior to 2000 led to population decline and severe limitation on the subsequent subsistence harvest. Mining and oil/gas exploration have caused some site specific disturbance to subsistence resources, limitation to subsistence access, and sociocultural dimension of subsistence, but such effects have been seasonal and short term in nature, with no population levels effects on subsistence resource populations. The same is generally true of community and transportation infrastructure. Construction and operation of the Williamsport-Pile Bay Road disturbed subsistence activities and resources in the vicinity of the road during summer months, and has potentially created some non-resident competition for fish and wildlife resources, particularly in the vicinity of Pedro Bay.

4.9.6.2 Reasonably Foreseeable Future Actions

<u>No Action Alternative</u>

The No Action Alternative would not contribute to cumulative effects associated with changes to resource availability, access to resources, or competition for resources. If there were fewer local employment opportunities associated with future exploration of the Pebble deposit, there could be less income that could contribute to support subsistence activities. However, that could be offset by exploration of other nearby mineral deposits.

Alternative 1 – Applicant's Proposed Alternative

Pebble Mine Expanded Development Scenario – The Pebble mine expanded development scenario would increase the geographic area affected by the project by combining project elements of Alternatives 1 and 3, with potential combined impacts to resource availability, access to resources, competition, and sociocultural dimensions of subsistence. The expanded development scenario at the mine site would affect more fish habitat in the upper reaches of the North Fork and South Fork of the Koktuli River, as well as UTC, and would contribute to the cumulative effects with additional infrastructure, habitat loss, and disturbance over a long period of time, up to an additional 58 years depending on the period of post-mining milling and closure activities. This additional habitat loss associated with the mine site is not expected to have population levels effects on fish and wildlife (see Section 4.23, Wildlife Values, and Section 4.24, Fish Values).

Diesel and concentrate pipelines and an access road would be constructed to a deepwater port in Iniskin Bay. Under Alternative 1, two transportation corridors would eventually be developed; one to Amakdedori and one to Diamond Point/Iniskin Bay. This would increase both the area of disturbance and availability of local access. The ferry would cease operations at year 20 and the concentrate pipeline would reduce truck traffic associated with shipment of copper/gold concentrate, reducing subsistence impacts associated with those project components. All six lake communities would be affected to some degree over the expanded operating life.

These potential impacts can affect the quality and cultural experience of subsistence activities, leading to adverse impacts on subsistence resources that are central to cultural belief systems and the way of life of local people. Effects such as habitat fragmentation, noise, and potential for increased access for recreational hunting and fishing disrupt subsistence cycles, which may result in direct impacts on resource gathering areas and harvest quantities. Local residents have observed that there has already been a loss to subsistence opportunities and the way of life due to planning and exploration activities that are associated with the Pebble Project from helicopter traffic and that there have been disruptions to local wildlife. The cumulative impacts would be long-term over extended operations, and decrease in magnitude as closure is implemented. See Section 4.23, Wildlife Values, and Section 4.24, Fish Values, for discussion on cumulative effects to fish and wildlife.

Other Mineral Exploration Projects – Actions that expand mineral development near the Pebble deposit and around Iliamna Lake contribute to landscape-level effects, where there is continuous introduction of additional impediments to the movement of people and animals; increased noise, vibration, and atmospheric pollution; and increased numbers of people to the area. This would lead to similar effects to resource availability, access to resources, competition for resources, and sociocultural conditions described above for the Pebble mine expanded development scenario. These potential effects would be seasonal in nature, as mineral exploration activities have historically been conducted during summer months. Since the other mineral exploration RFFAs are generally close to the Pebble Project, subsistence use areas would experience continued and increasing pressure which would continue to affect subsistence uses. Specifically, subsistence users in Nondalton noted that their community uses traditional trapping and hunting areas near Groundhog Mountain (Fall et al. 2006). Impacts to Nondalton from the Groundhog project (listed above) would be additive to impacts from the proposed Pebble Project and the Pebble expansion RFFA, likely causing them to travel farther and expend more time to trap and hunt. Similar additive impacts would result from other mineral exploration RFFAs.

Oil and Gas Exploration and Development – An increase in resource development actions along the coast of Cook Inlet could impact those communities that use the Amakdedori area, and potentially the east side of Cook Inlet, for subsistence resources and access to sites that are important for harvest and cultural practices central to the healthy relationship of people with the land they inhabit. The cumulative impacts would be long-term and geographically broad in scope (i.e., regional level).

Road Improvement and Community Development Projects – Anticipated road improvement projects in the region include new transportation corridors, which are currently being studied in the LPB, such as the Williamsport-Pile Bay Road upgrade and the Nondalton – Iliamna River Road Corridor and Bridge and Kaskanak Road / Cook Inlet to Bristol Bay road projects. These transportation projects would increase access to the area, which could improve access to subsistence resources but also introduce additional disturbance to and competition for resources, affecting all communities in the cumulative effects analysis area.

Additional RFFAs that have the potential to affect subsistence in the cumulative effects area include energy and utility projects, the Diamond Point rock quarry, and various village infrastructure development projects. These projects would have similar effects to the Pebble Project, but would be of lesser magnitude and geographic extent. However; when considered in combination with the Pebble Project, impacts to resource availability, access to resources, and competition for resources would increase.

Alternative 2 – North Road and Ferry with Downstream Dams

Pebble Mine Expanded Development Scenario – Expanded mine site development and associated contributions to cumulative impacts would be similar to but less than Alternative 1, as the Amakdedori port and connecting transportation infrastructure would not be built. Under Alternative 2, project expansion would continue to utilize the existing Diamond Point port facility, would use the same natural gas pipeline, and would use the constructed portion of the access roads. After 20 years, ferry operations would be discontinued, road connections between ferry terminals would be constructed similar to what is described for Alternative 3, and the port site and associated facilities would be constructed at Iniskin Bay as discussed under Alternative 1, above. The concentrate pipeline from the mine site to Iniskin Bay would be constructed similar to Alternative 3, and a diesel pipeline from the mine site to Iniskin Bay would be constructed as discussed under cumulative effects for Alternative 1. Cumulative impacts from Alternative 2 combined with the Pebble mine expanded development scenario to resource availability, access to resources, and competition for resources would be of lesser magnitude and geographic extent than Alternative 1 since the south transportation system/ferry would not be in place. As a result, potential cumulative impacts to Kokhanok would also be less under this alternative.

Other Mineral Exploration Projects, Road Improvement and Community Development Projects – Cumulative effects of these activities would be similar to those discussed under Alternative 1.

Alternative 3 – North Road Only

Pebble Mine Expanded Development Scenario – Expanded mine site development and associated contributions to cumulative impacts would be similar to Alternatives 1 and 2. Under Alternative 3, project expansion would continue to use the existing Diamond Point port facility, would use the same natural gas pipeline, and would use the same north access road and Concentrate Pipeline Variant but extend the concentrate pipeline to Iniskin Bay. The port site and associated facilities would be constructed at Iniskin Bay as discussed under Alternative 1 above. A diesel pipeline from the mine site to Iniskin Bay would be constructed as discussed under cumulative effects for Alternative 1. Since the Pebble mine expanded development scenario would use the north access road system that would already be built under Alternative 3 and not include any ferry operations, cumulative impacts from Alternative 3 combined with the Pebble mine expanded development scenario to resource availability and access to resources would be less than Alternatives 1 or 2. Potentially affected communities would be similar to Alternative 2.

Other Mineral Exploration Projects, Road Improvement and Community Development Projects – Cumulative effects of these activities would be similar to those discussed under Alternative 1.

4.10 HEALTH AND SAFETY

The evaluation of impacts on human health and safety is a required component of the National Environmental Policy Act (NEPA) as it pertains to negative and beneficial consequences of a proposed project on potentially affected communities. There are federal and state laws and regulations, such as the Clean Air Act, Clean Water Act (CWA), and various Alaska statutes that have been enacted to ensure protection of human health. Compliance with these laws and regulations is taken into consideration in the evaluation of health and safety impacts in an integrated manner in this assessment; and in a more singular, medium-specific manner in individual sections such as Section 4.20, Air Quality, and Section 4.18, Water and Sediment Quality.

This evaluation identifies and ranks the project-related positive (beneficial) and negative (adverse) health and safety consequences for the project and alternatives. Health and safety are related and complementary concepts. In the context of evaluating the impacts of a project, “health” is broadly considered to represent a state of physical and mental well-being of communities; while “safety” is more narrowly interpreted as engineering design, operation, and handling of project infrastructure, equipment, and materials in a manner that seeks to reduce hazards and prevent the occurrence of incidents and accidents (IFC 2007). It is also important to note that regulatory programs, agencies, and compliance procedures may be overlapping or very different for the health versus the safety aspects of a project. For example, the Occupational Safety and Health Administration (OSHA) regulations cover health and safety only for workers, and do not cover untrained workers or the general public.

Scoping comments expressed that the Environmental Impact Statement (EIS) consider or include: a Health Risk Assessment or Health Impact Assessment to determine the direct, indirect, and cumulative impacts to health; public health concerns related to infrastructure development in rural communities; cancer and non-cancer health effects associated with air toxins and identify sensitive receptor populations that may be exposed to these emissions; increased risks of accidents and injuries; exposure to hazardous materials; impacts on food nutrition and subsistence; increased potential for infectious diseases, and risks to health and human services from population-stressed infrastructure and services; and social and psychological impacts.

In this section, health is described in a manner that is consistent with the State of Alaska’s guidelines for Health Impact Assessment (ADHSS 2015); safety is discussed in the context of relevant regulatory requirements under OSHA, Mine Safety and Health Act (MSHA), and other types of hazard assessment and prevention.

4.10.1 Health Impacts Methodology

The Alaska Department of Health and Social Services (ADHSS) defines health as “the reduction in mortality, morbidity and disability due to detectable disease or disorder and an increase in the perceived level of health” (ADHSS 2015). Because health is a multi-dimensional concept with physical, mental, and social aspects, the proposed project may affect aspects of health at a localized or individual level, a community level, a regional level, or a statewide level, depending on the nature and extent of the effect. Potential impacts include:

- Potential for increases and/or decreases in household incomes, employment rates, education attainment, stress and family stability, food costs, food security, and access and quantity of subsistence resources.

- Potential for increases and/or decreases of unintentional accidents and injuries, intentional injury (suicide rate), infectious diseases, and non-communicable and chronic diseases, as well as access to healthcare.
- Potential for increases and/or decreases in illnesses or exacerbation of illnesses due to potential direct or indirect exposure to hazardous materials associated with the project.

Human health impacts were evaluated in accordance with NEPA practice, and generally followed the ADHSS methodology. The terminology used for descriptions and rankings of health impacts in this section generally correspond to the terms and ratings used in the ADHSS Health Impact Assessment (HIA) guidance. This guidance uses the concept of Health Effect Categories. A Health Effect Category (HEC) groups similar health effects so that they can be discussed and evaluated more easily and efficiently. A health effect can be a health outcome (e.g., a documented health event, such as a clinic visit, the birth of an infant, incidence of a disease) or a health determinant (a social, environmental, or economic reality that influences health outcomes, such as education level, income, or access to healthcare). By evaluating both determinants and outcomes, the HIA can develop an assessment of health status, health needs, health impacts, and mitigation/monitoring recommendations (if warranted) that are based on a good understanding of the proposed project and its connections with the affected communities.

A characteristic of this guidance is that the individual dimensions of health impacts (i.e., nature of health effect, duration, magnitude, extent, and likelihood) are each given their own descriptive terms for the estimated relative degree of occurrence; and a final consolidated health impact rating for each health metric or HEC is numerical (Category 1 through 4). The guidance suggests that impact ratings of 2 or higher may markedly increase or decrease illness and injury rates, and may warrant interventions, if negative (ADHSS 2015).

In accordance with NEPA practice and ADHSS (2015), the scope of this assessment is limited to affected communities “outside of the fence,” (outside the mine site and other mine-related components including material sites). Accordingly, this assessment does not include a direct evaluation of the anticipated workforce safety and health issues (“inside the fence”), because the project would be governed by the OSHA and the MSHA regulations in the areas where project activities would occur. However, this assessment does consider “crossover issues,” such as health impacts where workers may be housed in work camps, or where workforce behaviors result in interactions/overlap with the affected communities.

The analysis of potential consequences to human health for the affected communities using ADHSS (2015) criteria is consistent with the principles of analysis required by NEPA, and uses four steps. The first step is to determine the impact score, which takes into consideration four impact dimensions: severity of potential health effects (which can be positive or negative, and considers the need for intervention if the impact is negative), duration, magnitude, and extent of the impact (Table 4.10-1). Each component of the impact dimension is assigned a score of 0, 1, 2, or 3 to derive the overall impact rating score.

Table 4.10-1: Step 1 – Impact Dimensions

Step 1				
Impact Rating Score	**A – Health Effect (+/-)**	**B – Duration**	**C – Magnitude**	**D – Extent**
0	Effect is not perceptible	Less than 1 month	Minor	Individual cases
1	(+/-) minor benefits or risks to injury or illness patterns (no intervention needed)	Short-term: 1 to 12 months	Those impacted would: 1) be able to adapt to the impact with ease and maintain pre-impact level of health; or 2) see noticeable but limited and localized improvements to health conditions.	Local: small, limited impact to households
2	(+/-) moderate benefits or risks to illness or injury patterns (intervention needed, if negative)	Medium-term: 1 to 6 years	Those impacted would: 1) be able to adapt to the health impact with some difficulty, and would maintain pre-impact level of health with support; or 2) experience beneficial impacts to health for specific populations; some maintenance may still be required.	Entire Potentially Affected Communities; village level
3	(+/-) severe benefits or risks: marked change in mortality and morbidity patterns (intervention needed, if negative)	Long-term: more than 6 years/life of project and beyond	Those impacted would: 1) not be able to adapt to the health impact or to maintain pre-impact level of health; or 2) see noticeable major improvements in health and overall quality of life.	Extends beyond Potentially Affected Communities; regional and statewide levels

Source: ADHSS 2015

Next, the severity and likelihood of each type of impact is evaluated, and those ratings are used to develop an overall significance impact rating category of 1, 2, 3, or 4 (Table 4.10-2). Recommended actions for negative impacts are listed by category below:

- Category 1: Actions to reduce negative impacts are not needed.
- Category 2: Recommend that decision-makers assess whether actions to reduce negative impacts would be helpful for negative impacts.
- Category 3: Recommend that decision-makers develop and implement actions to reduce negative impacts.
- Category 4: Strongly recommend that decision-makers develop and implement actions to reduce negative impacts.

Table 4.10-2: Steps 2, 3, and 4 – Likelihood and Overall Impact Ratings

Step 2	Step 3						
Impact Severity Level (Sum Scores from Step 1 to choose range)	Likelihood Rating						
	Extremely Unlikely (<1%)	Very Unlikely (1-10%)	Unlikely (10-33%)	About as likely as Not (33-66%)	Likely (66-90%)	Very Likely (90-99%)	Virtually Certain (>99%)
1 to 3	♦	♦	♦	♦	♦♦	♦♦	♦♦
4 to 6	♦	♦	♦	♦♦	♦♦	♦♦	♦♦♦
7 to 9	♦♦	♦♦	♦♦	♦♦♦	♦♦♦	♦♦♦	♦♦♦♦
10 to 12	♦♦♦	♦♦♦	♦♦♦	♦♦♦♦	♦♦♦♦	♦♦♦♦	♦♦♦♦
Step 4	Impact Rating						
	Category 1 = ♦	Category 2 = ♦♦		Category 3 = ♦♦♦		Category 4 = ♦♦♦♦	

Source: ADHSS 2015

For each alternative, the consequences of the project activities, both beneficial and adverse impacts, are described with regard to relevant issues and concerns associated with the eight HECs described in the HIA guidance (ADHSS 2015):

- **HEC 1: Social Determinants of Health**, which evaluated potential impacts to household incomes, employment and education attainment, as well as potential impacts to psychosocial stress of individuals, and to family stress and stability.
- **HEC 2: Accidents and Unintentional Injuries**, which covered potential impacts to rates of accidents and unintentional injuries (e.g., transportation accidents, falls, fires, drownings, food poisoning).
- **HEC 3: Exposure to Potentially Hazardous Materials**, which evaluated the potential for increases and decreases in illness, or exacerbation of illnesses commonly associated with exposure to site-related chemicals of potential concern through inhalation, physical (dermal) contact, and direct or indirect ingestion (e.g., incidental soil ingestion or ingestion of impacted subsistence foods).
- **HEC 4: Food, Nutrition, and Subsistence Activity**, which evaluated the potential impacts on food costs, food security, and access to and quantity of subsistence resources.
- **HEC 5: Infectious Diseases**, which covered the potential impacts on rates of infectious diseases, including sexually transmitted infections, to the affected communities, as well as workers living at the on-site camp.
- **HEC 6: Water and Sanitation**, which evaluated the potential impacts of increases in morbidity and mortality rates due to the availability and quality of water and sanitation services.
- **HEC 7: Non-Communicable and Chronic Diseases**, which covered the potential impacts of increases in non-communicable and chronic morbidity, as well as mortality rates (e.g., cancer, cardiovascular, and respiratory).
- **HEC 8: Health Services and Infrastructure and Capacity**, which evaluated the potential impacts on access to routine healthcare, as well as potential impacts to healthcare from large-scale emergency situations and overwhelming local and regional healthcare capacities.

Although all components were considered, the project was primarily analyzed as a whole because effects could not be attributed to a single component (i.e., there was overlap of affected communities for multiple components). Finally, the health consequences are summarized by HEC for each alternative as a whole, and expressed as Category 1, 2, 3, or 4. ADHSS does not provide narrative descriptions for these numeric impact category rankings, and only suggests that they be used to propose recommendations for actions. Appendix K4.10 presents the detailed discussion of consequences per HEC, as well as associated uncertainties with the HIA.

For the purposes of this assessment, the EIS analysis area is defined as an area that may be affected by physical releases to the environment from project-related activities, or changes in economic, subsistence, and health resources and activities. Overall, it includes eight communities in the Lake and Peninsula Borough (LPB), seven communities in the Dillingham Census Area, three communities in the Kenai Peninsula Borough, two communities in Bristol Bay, as well as the surrounding regions and the Municipality of Anchorage. Not all communities are assessed for all health effects, because some effects may be more relevant to some communities than others. A complete listing of the communities in the EIS analysis area, and the HECs for which they are evaluated, is provided in Section 3.10, Health and Safety.

4.10.2 No Action Alternative

The purpose of this health assessment is to evaluate the impacts of the proposed project and its alternatives against baseline conditions, as represented by the No Action Alternative. The current baseline condition is assumed as a reasonable proxy to qualitatively evaluate the future in the No Action Alternative. As a result, no quantitative discussion (i.e., rating) is presented for this alternative. Although there may be some uncertainty associated with the many factors and variables that could impact the health of communities in the EIS analysis area in the future, current trends can be assumed to continue in the absence of the proposed project.

The No Action Alternative would have direct impacts related to the Pebble Limited Partnership (PLP) exploration activities, as discussed in Section 4.3, Needs and Welfare of the People–Socioeconomics. PLP exploration-related employment and income, which were realized in the Bristol Bay region over the previous decade, has ceased. The PLP employed around 100 to 150 local community members annually at the site during the pre-development phase of the project, which ended in 2012 (Loeffler and Schmidt 2017). Since then, PLP has had a minimal number of workers at the site for exploration and maintenance activities. The exploratory phase of the project revealed that the income earned by residents employed by the project was an important part of the total income earned in local communities, especially those communities close to the mine site; and the income earned by residents close to the mine was greater than the income earned for commercial fishing, indicating that even the limited employment during the exploratory phase had large impacts on the communities. In communities that were further from the mine site, commercial fishing was a larger part of total income. Overall, the current number of direct and indirect jobs would remain roughly the same, and there would be no impact to the regional economy.

Human health impacts associated with the loss of employment opportunities (and subsequent decrease in median household income) primarily concern potential impacts on social determinants of health (SDH) (e.g., income, psychosocial stress, substance abuse, and family stability). Changes in SDH, if any, would be relatively small in magnitude, relative to the baseline, and would largely be confined to the communities closest to the mine site (Nondalton, Iliamna, and Newhalen). There would be no impact to more distant communities in the lower Bristol Bay watershed, such as Dillingham, other than removing uncertainty about the fate of this project. Other health factors would likely be similar to current conditions (baseline), such as potential rates of accidents and injuries, communicable and non-communicable diseases, exposure to hazardous constituents, and access to healthcare services.

Health impacts from the No Action Alternative would not be perceptible, or those impacted would be able to adapt to the impact with ease and not require medical intervention. Direct effects would be largely similar to baseline levels of health. Current health conditions and trends, as described in Section 3.10, Health & Safety, would continue in the EIS analysis area.

4.10.3 Alternative 1 – Applicant's Proposed Alternative

This section presents the environmental consequences to community health and safety for Alternative 1. This evaluates potential impacts (both beneficial and adverse) to the affected communities from the project during all three phases. The HIA includes summaries of the more extensive health and safety evaluations provided in Section 4.27, Spills Risk, regarding human health impacts from potential spills or failures. The potential health impacts from exposure to chemicals due to a spill or failure are of low likelihood, and are typically short-term, acute exposures, but may also lead to chronic exposure, depending on the nature, duration, and migration testing and monitoring of the spill. Hypothetical spills of diesel fuel, natural gas, copper-gold ore concentrate, chemical reagents, bulk and pyritic tailings, and untreated contact water, are assessed using estimates of release rates, volume, and likelihood of occurrence, based on their spill potential and potential spill consequences (see Section 4.27, Spill Risk). Project design features, Standard Permit Conditions, and best management practices would be implemented for preventing and reducing impacts from potential spills (see Chapter 5, Mitigation). Health impacts related to spills may include psychosocial stress and anxiety regarding the possible or actual occurrence of spills; potential temporary releases of hazardous chemicals to air, water and soil; and possible exposures to chemicals by subsistence resources that are ultimately consumed by humans. Planned and recommended measures to address these potential impacts include prompt measures for spill containment, rapid community outreach and notifications, and testing and monitoring of environmental media such as air, water and subsistence food resources. Additional details are provided in Section 4.27, Spill Risk.

The communities potentially affected by the project range from small, remote rural communities, to larger regional and urban centers, as discussed in Section 3.10, Health and Safety. The eight communities identified in the LPB would be most closely affected by multiple project components. In addition, three Nushagak/Bristol Bay communities in the Dillingham Census Area were also identified as potentially affected by project components. The Kenai Peninsula Borough and Anchorage would also be potentially affected economically by all components of the project—at a relatively minor level—due to their larger population size, as noted in Section 4.3, Needs and Welfare of the People—Socioeconomics. In addition, more communities have been identified as using the EIS analysis area for subsistence; therefore, these communities could also be potentially affected by all of the components of the project (see Section 3.9, Subsistence). The consequences for all project components would be expected to be more noticeable in smaller, rural communities, and less perceptible in Anchorage.

A summary of the impact ratings for these HECs under Alternative 1 is presented in Table 4.10-3. Human health impacts resulting from Alternative 1 would be more noticeable in smaller, rural communities, and less perceptible in the Municipality of Anchorage, as discussed in Section 3.3, Needs and Welfare of the People—Socioeconomics, and Section 4.4, Environmental Justice. As stated above, Appendix K4.10 presents the detailed discussion of consequences per HEC, as well as associated uncertainties with the HIA.

Table 4.10-3: Summary of Alternative 1 Impact Levels by HEC

Health Effects Categories[1]	Summary Impact Category	Beneficial (+)or Adverse (-)Rating
HEC 1: Social Determinants of Health		
Increase in household incomes, employment, and education attainment	2 to 3	+/-
Psychosocial stress (substance abuse, mental health, and suicide)	2 to 3	+/-
Family stress and instability	1 to 2	+/-
HEC 2: Accidents and Injuries		
Increase in unintentional accidents and injuries, morbidity, and mortality rates due to transportation/navigation	2	-
Increase in other unintentional injury (falls, poisoning, etc.)	2	+/-
Increase in Intentional Injury (suicide rate)	2	-
HEC 3: Exposure to Potentially Hazardous Materials		
Air quality impacts	1 to 2	-
Surface water and sediment impacts	1 to 2	-
Groundwater impacts	1 to 2	-
Soil impacts	1 to 2	-
Bioaccumulated chemicals in subsistence foods	1 to 2	-
HEC 4: Food, Nutrition, and Subsistence Activity		
Decrease in food costs relative to income	2	+
Access to and quantity of subsistence resources	2 to 3	+/-
Decrease or increase in food security	2	+/-
HEC 5: Infectious Disease		
Increase in rates of sexually transmitted infections (gonorrhea, chlamydia, etc.)	1 to 2	-
Increase in rates of respiratory disease morbidity and mortality (influenza, pneumonia, etc.)	1 to 2	-
Increase in rates of foodborne illness and zoonotic disease	1	-
HEC 6: Water and Sanitation		
Increase in morbidity and mortality rates due to the availability and quality of water and sanitation facilities	1	-
HEC 7: Non-communicable and Chronic Disease		
Increase in cancer, respiratory, and cardiovascular morbidity rates due to changes in diet, nutrition, and physical activity	2	+/-
Increase in cancer, respiratory, and cardiovascular morbidity and mortality rates due to exposure from hazardous chemicals	1	-
HEC 8: Healthcare Services Infrastructure and Capacity		
Access to routine healthcare	1	+/-
Access to healthcare due to large-scale emergency situations and overwhelming local and regional healthcare capacities	2	-

Overall, the economic and health benefits of improvements in economic status is expected to be substantial for the residents of the affected communities. Project-related economic benefits are rated Category 3 (construction and operations phases), and would be expected to result in benefits to many supplementary aspects of human health and well-being of residents, including increased income, employment, and educational attainment due to increased income. Economic benefits would likely have positive effects on helping to stem the current trend of out-migration, increasing or maintaining the number of schools in the region, and other indirect economic benefits (e.g., taxes, sales/revenue, and other fiscal effects to the regional and local communities). The benefits would be more apparent in the small, rural communities closest to the mine site (LPB communities), where even small changes in their economies could have a measureable impact on their overall health and well-being. Impacts on psychosocial stress (construction and operations); and access to, quantity of, and quality of subsistence resources (mine site construction and operations for all components) were rated Category 3 for both positive and negative effects.

Benefits that are rated as Category 2 include reduced food costs relative to income for those members of the community who would realize economic benefits from the project. Negative health consequences rated as Category 2 may be related to cessation of economic benefits (at mine closure) due to job losses and decreased income; potential transportation-related accidents and injuries for all phases (due to accidents by air, water, and surface transportation); intentional injuries (suicide); increased risk of exposure to potentially hazardous chemicals in the air, soil, surface water, groundwater, and bioaccumulated[1] in subsistence foods (during operations and closure); increase in sexually transmitted infections (during construction); decreased access to healthcare in emergency situations if adequate project emergency planning and periodic monitoring of the adequacy of emergency preparedness services is not maintained, and increased infectious (respiratory) diseases rates (during transportation infrastructure and pipeline construction) from proximity and likely increased interaction with the affected communities. Impacts on psychosocial stress (at mine closure); family stress and stability (during operations and closure); other unintentional injuries (e.g., falls, poisoning); access to, quantity of, and quality of subsistence resources; food security and impacts on rates of non-communicable diseases due to changes in diet, nutrition, and activity are also rated Category 2 for both positive and negative effects. Intentional injuries are rated as Category 2, primarily because of the severity of the consequence, although it is considered very unlikely to occur, relative to baseline conditions. Other potential impacts were rated Category 1.

Alternative 1, as a whole, is rated as a Category 2 for both adverse and beneficial potential impacts. These effects determinations take into account the implementation of impact-reducing design features proposed by PLP, and also the Standard Permit Conditions and best management practices that would be implemented (see Chapter 5, Mitigation).

4.10.3.1 Safety

Safety requirements are a condition of obtaining regulatory permits and approvals to construct, operate, and close the proposed project. Safety issues are typically addressed under state and federal regulatory programs designed to ensure physical safety pertaining to engineering design and structural integrity of the project components and infrastructure, and safe storage, use, transportation, and disposal of materials, product, and waste streams. It also includes operational safety for workers, and the safety of visitors to the facility and the general public in the vicinity.

[1] Bioaccumulation is the accumulation over time of a substance and especially a contaminant (such as a pesticide or heavy metal) in a living organism.

For this project, relevant safety requirements will be followed and compliance will be achieved with the regulations of the MSHA, OSHA, Alaska Department of Transportation and Public Facilities (ADOT&PF), and other relevant regulatory programs.

4.10.3.2 Alternative 1 – Kokhanok East Ferry Terminal Variant

Under this variant, the creation of an alternate winter travel route along the Kokhanok east spur road with an access point to the lake east of the terminal would mitigate impacts, but may add travel time, distance, and fuel costs. Navigation on Iliamna Lake at the Kokhanok east ferry terminal site would be more sheltered from wind and waves, but would contain more navigational hazards such as shallow water and a longer ferry route (HEC 2).

Despite these differences, the Kokhanok East Ferry Terminal Variant would have the same impact levels by HEC as described above for health and safety impacts.

4.10.3.3 Alternative 1 – Summer-Only Ferry Operations Variant

The Summer-Only Ferry Operations Variant would lower the income earned by community members in the EIS analysis area. Overall, the high cost of living for the communities near the transportation corridor would still be lowered under this variant, but not to the extent of the proposed year-round ferry operations (HEC 1). There would not be an impact to winter transportation across the lake, eliminating those impacts (HEC 4). Truck and ferry trips would double in the summer, meaning winter snowmachine traffic across the lake would not be interrupted by an ice-breaking ferry, but vessels on the lake in the summer would experience double the ferry traffic (HEC 2).

Despite these differences, this variant would have the same impact levels by HEC as described above for health and safety impacts.

4.10.3.4 Alternative 1 – Pile-Supported Dock Variant

The Pile-Supported Dock Variant would have the same impact levels by HEC as described above for health and safety impacts.

4.10.4 Alternative 2 – North Road and Ferry

Impacts to health and safety from the project would be the same as or similar to Alternative 1, with few exceptions. The area of Iliamna Lake used for the ferry would be different, because it encompasses the areas at the northern end of the lake around Pedro Bay (as opposed to Kokhanok). This alternative's natural gas pipeline alignment would follow the north road alignment, and not go across Iliamna Lake; there would be no hazards or impacts at Iliamna Lake during construction of the pipeline, as would occur under Alternative 1. Impacts from the port at Diamond Point port would be the same or similar to those for Amakdedori port.

Overall, the HEC for which Alternative 2 consequences may be most noticeably different from Alternative 1 is HEC 2: Accidents and Injuries due to transportation. However, even given the differences noted above, the transportation-related accidents and injury summary impact to human health would remain the same, and would be Category 2 for all phases and transportation types (see Appendix K4.10).

4.10.4.1 Alternative 2 – Summer-Only Ferry Operations Variant

Under the Summer-Only Ferry Operations Variant, transportation impacts on the lake would be eliminated during the winter, but double during the summer. The likelihood of accidents and injuries for surface transportation may increase under this variant, because traffic on

Williamsport-Pile Bay Road would include doubled mine-related summer traffic, and continuing or increasing levels of public boat portage. The potential for a greater likelihood of accidents would be reduced if the road was built to handle this increased summer capacity (HEC 2).

Despite these differences, this variant would have the same impact levels by HEC as described above for health and safety impacts.

4.10.4.2 Alternative 2 – Pile-Supported Dock Variant

The Pile-Supported Dock Variant would have the same impact levels by HEC as described above for health and safety impacts.

4.10.5 Alternative 3 – North Road Only

Impacts to health and safety from the project would be the same as or similar to Alternatives 1 and 2, with few exceptions. The use of Iliamna Lake for a ferry would be eliminated, shifting project-related transportation impacts to the area around Pedro Bay, rather than around Kokhanok. Impacts from the port at Diamond Point would be the same or similar to those for Amakdedori port. For the region as a whole, the impacts on the cost of living for Alternative 3 would be largely the same as the impacts of Alternative 1, and would likely lower the high cost of living for the communities near the transportation corridor, similar to Alternative 2. However, because of the different alignments of the transportation corridor and natural gas pipeline, Kokhanok would likely experience less of a benefit, while Pedro Bay would likely experience more of a benefit over the long term.

Similar to Alternative 2, the HEC for which Alternative 3 consequences may be most noticeable from other alternatives is HEC 2: Accidents and Injuries due to transportation. However, even given the differences noted above, the transportation-related accidents and injury summary impact to human health would remain the same, and would be Category 2 for all phases and transportation types (see Appendix K4.10).

4.10.5.1 Alternative 3 – Concentrate Pipeline Variant

The Concentrate Pipeline Variant would build a concentrate slurry pipeline from the mine to the port, and include a dewatering and treatment plant at Diamond Point so that the slurry water could be discharged at the port, or returned to the mine site for reuse, by constructing a second pipeline. Potential hazardous materials impacts would remain the same as under Alternative 1, because the effluent would be treated to meet the Alaska water quality criteria prior to discharge (HEC 3). This variant would likely decrease employment of truck operators and increase employment at the water treatment plant and dewatering facility, but with lower overall employment (HEC 1).

Despite these differences, this variant would have the same impact levels by HEC as described above for health and safety impacts.

4.10.6 Summary of Key Issues

Table 4.10-4 presents a summary of key issues.

Table 4.10-4: Summary of Key Issues for Health and Safety

<table>
<tr><th>Impact-causing Project Component</th><th>Alternative 1 and variants</th><th>Alternative 2 and variants</th><th>Alternative 3 and variant</th></tr>
<tr><td rowspan="2">All Project Components</td><td>Increase in affected community household incomes, employment, and education attainment. The Summer-Only Ferry Operations Variant would lower the cost of living and increase employment opportunities, but not by as much as Alternative 1 because of seasonal vs. year-round employment (+ Category 3 during construction and operations). Decrease in food cost relative to income (+ Category 2).</td><td>Same as Alternative 1, including Summer-Only Ferry Operations Variant, although impacts would shift more toward Pedro Bay instead of Kokhanok.</td><td>Same as Alternative 1. The Concentrate Pipeline Variant would have similar impacts to the Summer-Only Ferry Operations Variant under Alternative1.</td></tr>
<tr><td colspan="3">Increase and decrease in psychosocial stress (+/- Category 3 during construction and operations; +/- Category 2 during closure).
Increase and decrease in family stress and stability (+/- Category 2 during operations and closure).
Increase and decrease in unintentional injury (falls, cuts, poisoning, etc.) (+/- Category 2).
Increase and decrease access to, quantity of, and quality of subsistence resources (+/- Category 2 to 3 depending on component and phase).
Decrease or increase in food security (+/- Category 2).
Increase in cancer, respiratory, and cardio-vascular morbidity and mortality rates due to change in diet, nutrition, and physical activity (+/- Category 2).</td></tr>
<tr><td></td><td colspan="3">Decrease in household incomes, employment, and education attainment (- Category 2 during closure).
Increase in intentional injury (suicide) (- Category 2).
Increased risk of exposure to hazardous chemicals in abiotic media and to bioaccumulated chemicals in subsistence foods (-Category 2 during operations and closure).
Decreased access to healthcare due to emergency situations and overwhelming local and regional healthcare capacities (- Category 2).</td></tr>
<tr><td>Transportation Corridor</td><td>Increase in unintentional accidents and injuries and morbidity and mortality rates due to air, surface, and water transportation, particularly regarding winter access across Iliamna Lake from the ice-breaking ferry. PLP would put some measures in place to minimize impacts, such as trail marking and crossings.
The Kokhanok East Ferry Terminal Variant would include access to Sid Larson Bay without crossing the ferry route.
The Summer-Only Ferry Operations Variant would eliminate the potential hazards to snowmachine winter lake crossings, but increase summer lake and road traffic (- Category 2).</td><td>Impacts would be similar to Alternative 1, except that the routes and closest communities affected would be around Pedro Bay and the northern end of the lake, instead of Kokhanok and the mid-lake region.
The Summer-Only Ferry Operations Variant could increase the likelihood of surface transportation accidents and injuries along Williamsport-Pile Bay Road from an increase in truck traffic if mitigation measures are not taken to build to meet the increased mine-related and public</td><td>Impacts would be similar to Alternatives 1 and 2, except that the elimination of the ferry on Iliamna Lake would shift project-related transportation impacts to the area around Pedro Bay, rather than around Kokhanok. Impacts from the port at Diamond Point would be the same or similar to those for Amakdedori port.
The Concentrate Pipeline Variant impacts would remain the same as under Alternative 1 because the effluent would be treated to meet</td></tr>
</table>

Table 4.10-4: Summary of Key Issues for Health and Safety

Impact-causing Project Component	Alternative 1 and variants	Alternative 2 and variants	Alternative 3 and variant
		summer capacity (- Category 2).	Alaska water quality criteria prior to discharge. (- Category 2)
Transportation Corridor and Natural Gas Pipeline	Increase in sexually transmitted infection rates (- Category 2, during construction) Increase in infectious (respiratory) disease morbidity and mortality rates (- Category 2, during construction).	Same as Alternative 1.	Same as Alternative 1.

4.10.7 Cumulative Effects

The cumulative effects analysis area for Health and Safety encompasses the same as that discussed above. Potential cumulative impacts include impacts to transportation (e.g., increase in Cook Inlet and Iliamna Lake vessel traffic, Williamsport-Pile Bay Road), water and soil quality (e.g., other sources of contamination), socioeconomics (e.g., increased household income from other employment opportunities), and subsistence (e.g., impacts on cultural resources and disturbance of wildlife). In addition, based on these categories, there would be contributions to cumulative psychosocial stress at the family, community and regional levels from concerns about additional development activities.

Past, present, and reasonably foreseeable future actions (RFFAs) in the cumulative impact study area have the potential to contribute cumulatively to impacts on health and safety. These potential future actions are similar to the proposed alternatives in that each may result in direct and indirect effects to the project-affected communities. To varying degrees, all the RFFAs identified in Section 4.1, Introduction to Environmental Consequences, have the potential to impact cumulative health and safety. RFFAs in the EIS analysis area have the greatest potential to impact health and safety to the affected communities due to the more-direct nexus to the project. Of these, the following RFFAs have the greatest potential to impact cumulative health and safety:

- Pebble Project buildout – develop 55 percent of the resource over a 78-year period
- Continued mineral exploration at nearby mineral deposits, such as Pebble South, Groundhog, and the Big Chunk Mineral deposits
- Lake and Peninsula Borough Transportation Projects
- Lake and Peninsula Borough Community Development and Capital Improvement Projects
- Rural Alaska Village Grant Program Projects
- Lake and Peninsula Borough and other regional Renewable Energy Initiatives
- Nushagak Electric Cooperative Village Intertie Project
- Industrial Pollutants and Contaminated Sites within Project Area Communities

4.10.7.1 Past and Present Actions

Past and present actions have contributed to the current state of baseline health status in the affected communities. They have the most noticeable impacts affecting health and safety in the areas relating to socioeconomics, subsistence, and transportation. Past and present actions that have contributed to the existing socioeconomic conditions of potentially affected communities include natural resource extraction, commercial and subsistence fishing activities, commercial recreation and tourism, community development and infrastructure, mining exploration activities, and the construction and operation of the Williamsport-Pile Bay Road, as discussed.

Commercial fishing has been the mainstay of the regional economy, although there are geographic differences in the distribution of benefits. These benefits and associated psychosocial stress have varied over time based on factors such as run size and fish price. Subsistence is a cultural and economic foundation of the region and its communities, and has seen cycles in availability of and access to resources, which results in beneficial and adverse health impacts. Community and transportation improvements have improved the quality of life through increased access to education and social services, and lowering the cost of living to a degree. Construction of the Williamsport-Pile Bay Road has decreased the cost of transported goods for some communities such as Pedro Bay. Mineral exploration has seasonal employment opportunities, but also created aircraft and ground noise and restricted access to subsistence resources on a site specific basis. Concerns regarding development of mineral resources in the Bristol Bay watershed, and potential impacts on commercial fishing and subsistence, have created a substantial amount of discussion and psychosocial stress. At the same time, the limited number of jobs and economic opportunities, particularly in Iliamna Lake communities, has contributed to outmigration, population declines, and closing of some local schools. This also contributes to the psychosocial stress in the region.

Finally, past and present actions may be perceived to have the potential to add to the cumulative health impacts relating to exposure to hazardous materials for nearby communities. However, pre-existing contaminated sites are relatively limited and under regulatory oversight. Therefore, the potential for hazardous chemicals-related impacts to affected communities is expected to be low.

4.10.7.2 Reasonably Foreseeable Future Actions

<u>No Action Alternative</u>

The No Action Alternative would not contribute to cumulative effects on the regional and state economy, infrastructure, cost of living, and population characteristics; nor would it contribute to cumulative effects associated with changes to resource availability, access to resources, or competition for subsistence resources. Although there may be fewer local employment opportunities associated with future exploration of the Pebble Project, exploration activities could continue at a reduced level and result in less income to support households and subsistence activities and maintain the current level of health. However, these could be offset by exploration of other nearby mineral deposits. The No Action Alternative would not contribute to cumulative effects on community health.

<u>Alternative 1 – Applicant's Proposed Alternative</u>

Pebble Mine Expanded Development Scenario – The Pebble Project expanded development scenario would extend the life of the project to 78 years to recover more of the estimated reserves. The scenario would increase the geographic area affected by the project by combining project elements of Alternatives 1 and 3. Under Alternative 1, project expansion would continue to use the existing natural gas pipeline; and would construct an access road and concentrate/diesel pipelines to a new port at Iniskin Bay.This has the potential to impact the cumulative impacts to subsistence resource availability, and access to resources, competition, and sociocultural dimensions of subsistence, as discussed in Section 4.9, Subsistence. It would also have the potential to result in increased health impacts over this larger geographic area, especially from increased duration of impacts, and possibly increased releases and affected community exposure to potentially hazardous materials. The health impacts of the expanded development would likely affect not only the four HECs considered most relevant to Alternative 1 (SDH, Accidents and Injuries, Exposure to Hazardous Materials, Diet/Nutrition/Subsistence), but could also result in impacts to the remaining HECs (Water and Sanitation, Infectious Diseases, Noncommunicable Diseases, and Healthcare Infrastructure).

The expansion would continue, and likely increase, the beneficial and adverse socioeconomic impacts that would be realized from the project through the 78-year expansion period. Pedro Bay would experience greater socioeconomic impacts under the expanded development scenario than if just the proposed project were implemented alone (see Section 4.3, Needs and Welfare of the People—Socioeconomics). Health benefits related to a longer period of increased income and employment for the local communities may result in multi-generational improvements in educational attainment, and increase access to affordable healthcare, as well as possible expansion of healthcare facilities, due to increased public revenues. However, psychosocial stress related to further mineral development and anxiety regarding the health of the salmon runs and environmental degradation may be intensified. Maintaining cultural ties within families and to the land could be more difficult, depending access accommodation to areas of traditional subsistence use and flexibility of employment.

The potential for additional surface and water-related accidents and injuries would increase, because the expansion would also create additional annual vessel and truck traffic over an extended period of time, particularly in Iniskin Bay and Cook Inlet. The access road to Diamond Point, if open to non-mining traffic, could be beneficial for business, but would increase traffic overall through the Williamsport-Pile Bay Road corridor, and could be permanent. Construction of the diesel and concentrate pipelines and access road to a deep-water port in Iniskin Bay would increase the magnitude, duration, and extent of transportation impacts (see Section 4.12, Transportation and Navigation). These additional infrastructure elements have the potential to have positive impacts for the affected communities (e.g., road improvement and increased safety), as well as negative impacts related to accidents and injuries based on the level of public access and interaction. The ferry would cease operations at year 20, and the concentrate pipeline would reduce truck traffic associated with shipment of copper/gold concentrate, reducing transportation and subsistence impacts associated with those project components.

Subsistence activities and associated diet and nutrition trends, including exposure of wild foods to hazardous materials, would also likely be impacted by the expansion alternative. The road additions and improvements would increase both the area of disturbance and availability of local access for subsistence resources (see Section 4.9, Subsistence). However, continued exposure of wild foods that might be exposed to project-related bioaccumulative metals in dusts and discharges (plants, wildlife consuming plants, fish, water fowl in ponds and impoundments) could increase human exposure to hazardous chemicals in the long term, and may benefit from surveys and monitoring efforts to confirm that exposures are limited.

Direct exposure of the affected communities to hazardous materials may not be noticeably altered by the expansion scenario as long as the cumulative magnitude of all emissions and releases to air, soil, and water continue to be less than the appropriate screening levels for human health. Project area communities with pre-existing industrial pollutants and contaminated sites have the potential to add to the cumulative health impacts from exposure to potentially hazardous materials in communities where PLP proposes construction and operations support activities. It would be expected that mitigation measures would be used to minimize or mitigate exposure. The cumulative impacts would be long term over extended operations, and decrease in magnitude as closure is implemented.

No major cumulative impacts would be expected for health-related impacts in the area of Water and Sanitation, Infectious Diseases, and Healthcare Infrastructure and Access as long as the expansion continued to ensure self-sufficient, on-site water supplies, worker housing, infectious disease education, treatment, training, and monitoring programs; and operated their own health clinics and healthcare facilities. Cumulative impacts on non-communicable diseases such as incidence of morbidity and mortality due to cancer, lifestyle behavioral factors, and non-infectious non-cancer diseases might decrease further in those segments of the local population that enjoy long-term increases in income and quality of life, but may increase among those who may be excluded from project benefits, or whose lifestyles are altered in the direction of less activity or less nutritious diets.

Overall, the health impacts of the expanded project may be summarized as extending spatially to a larger affected population, with both positive and negative effects lasting for longer duration in comparison to Alternative 1.

Road Improvement and Community Development Projects – Anticipated road improvement projects in the region include new transportation corridors currently being studied in the LPB, such as the Williamsport-Pile Bay Road upgrade and the Nondalton-Iliamna River Road Corridor and Bridge, which would improve overland routes in the region (access to Nondalton) and inter-regionally from Cook Inlet to Iliamna Lake. These in turn could reduce the cost of living through reduced transportation costs of goods.

Impacts on health would be affected by impacts on other contributing factors such as transportation, socioeconomics, and subsistence. These improvements could have positive cumulative effects on ease of transportation with Alternative 1 (e.g., road improvement and overall increased safety), but may also result in increased traffic in certain areas. This may result in increases in accidents and injuries related to surface transportation. Cumulative impacts would also occur associated with surface transportation between the communities for subsistence and recreational uses, in addition to the ongoing LPB, rural Alaska Village Grant Program, and other village projects. These transportation projects would increase access to the area, which could improve access to subsistence resources, but also introduce additional disturbance to and competition for resources, affecting all communities in the cumulative effects analysis area. The projects could also create small-scale construction and operations employment opportunities, improve services, and potentially lower the cost of living. Community construction projects are a particularly important source of seasonal employment and income for small communities. One of the net effects of increased access and interaction among these communities is that the smaller, more rural and remote communities may become more socially and culturally connected with other communities, with consequent positive and negative impacts on SDH.

The scheduling of the project implementation could affect the magnitude of impacts to health and other factors. If these projects were implemented during the construction phase of Alternative 1, the magnitude of adverse effects on transportation and navigation would be temporary but high, and could increase the rates of accidents and injuries; however, if the project improvements occurred before or after the construction phase of Alternative 1, the magnitude would be far less and duration would be unchanged. The socioeconomic impacts would be anticipated to be greater if the project is implemented, which could increase development as support-related businesses take advantage of the additional opportunities provided by the mine. Subsistence impacts from these other projects would have similar effects to the proposed project, but would be of lesser magnitude and geographic extent. The impacts to health and safety would be similar to Alternative 1, with a similar mix of positive and negative impacts, but of lower magnitude and spatial extent.

Alternative 2 – North Road and Ferry with Downstream Dams

Pebble Mine Expanded Development Scenario – Expanded mine site development and associated contributions to cumulative health, and contributing factors such as socioeconomics, subsistence, and transportation and navigation impacts to the region, would be similar to but less than Alternative 1 in magnitude and geographic extent, because the Amakdedori port and connecting transportation infrastructure would not be built. Under Alternative 2, project expansion would continue to use the existing Diamond Point port facility; would use the same natural gas pipeline; and would connect the access road between ferry terminals, and build the concentrate and diesel pipelines to a new port in Iniskin Bay. Cumulative impacts from Alternative 2, combined with the Pebble mine expanded development scenario, would result in lower employment opportunities; but negative impacts to subsistence resource availability, access to resources, and competition for resources would be of lesser magnitude and geographic extent than Alternative 1 (see Section 4.3, Needs and Welfare of the People–Socioeconomics; Section 4.9, Subsistence; and Section 4.12, Transportation and Navigation).

Road Improvement and Community Development Projects – Cumulative effects of these activities would be similar to those discussed under Alternative 1, except that the road to Nondalton could connect with the pipeline corridor, creating an overland access route for Iliamna, Newhalen, and Nondalton to Pedro Bay and Cook Inlet. The magnitude, geographic extent, and duration of cumulative impacts in Alternative 2 would be greater than in Alternative 1, as discussed in Section 4.12, Transportation and Navigation.

Alternative 3 – North Road Only

Pebble Mine Expanded Development Scenario – Expanded mine site development and associated contributions to cumulative health, and contributing factors such as socioeconomics, subsistence, and transportation and navigation impacts would be similar to Alternatives 1 and 2. Under Alternative 3, project expansion would continue to use the existing Diamond Point port facility; would use the same natural gas pipeline; and would use the same north access road and Concentrate Pipeline Variant infrastructure, but extend the concentrate pipeline to Iniskin Bay. Because the Pebble mine expanded development scenario would use the north access road system that would already be built under Alternative 3 and not include any ferry operations, cumulative impacts from Alternative 3, combined with the Pebble mine expanded development scenario to subsistence resource availability and access to resources, would be less than Alternatives 1 or 2 (see Section 4.9, Subsistence). Cumulative tax generation and cost-of-living benefits would be similar to Alternative 2, because employment opportunities associated with truck traffic would be lower, and the facilities would not generate additional taxable income (Section 4.3, Needs and Welfare of the People–Socioeconomics). Impacts to health would be similar to Alternatives 1 and 2.

Road Improvement and Community Development Projects – Overall, cumulative health effects of these activities would be similar to those discussed under Alternative 1. In addition, the Williamsport-Pile Bay Road upgrade and the Nondalton-Iliamna River Road Corridor and Bridge construction would have cumulative effects similar to those under Alternative 2.

4.11 AESTHETICS

Aesthetic impacts include those that could result from changes in the visual landscape (including night sky), soundscape, or olfactory attributes. For this analysis, visual impacts are defined as changes to the scenic attributes of the landscape resulting from the introduction of visual contrasts (e.g., development), and the associated changes in the human visual experience of the landscape (NPS 2014b). Impacts to soundscape are defined by changes in A-weighted decibels (dBA) levels that alter soundscape from a “wilderness ambient” character (see Section 3.19, Noise). Potential impacts to traditional and cultural use of areas are discussed in Section 4.6, Cultural Resources, and Section 4.9, Subsistence.

The Environmental Impact Statement (EIS) analysis area for aesthetic resources extends westward from Happy Valley on the Kenai Peninsula and the Bristol Bay and Cook Inlet drainages to the eastern side of the Iniskin Peninsula, encompassing Iliamna Lake and the surrounding communities. For each alternative, the EIS analysis area includes a 50-mile radius from the mine site; a 10-mile radius from the ferry terminals, a 20-mile buffer from the transportation corridor and natural gas pipeline, and a 25-mile radius around the port. For night-lighting impacts, the EIS analysis area includes a 70-mile radius around the mine site and a 25-mile radius around ferry terminals and port locations. A discussion of potential visual and auditory impacts from overflights is provided in the discussion of the mine site.

Scoping comments expressed concern that the project would have permanent and significant impacts on the appearance of the landscape as viewed from key observation points, and that this would impact use and enjoyment of the area. Comments also requested that visual impacts of the mine, roads, and Amakdedori port include recreation; and secondary industries like flightseeing and wildlife viewing.

Mitigation measures and Best Management Practices (BMPs) to be followed to reduce impacts to visual resources and aesthetics are described in Chapter 5, Mitigation.

4.11.1 Visual Impacts

Visual impacts were assessed by determining 1) the magnitude and geographic extent of visual contrast caused by the proposed project; 2) the change in landscape character attributes; 3) the potential effects of visual contrasts on the viewer experience based on the context of the impact and how it is perceived; and 4) the duration of impacts. Because the area is remote, the impact assessment does not take into account frequency of views (or potential for views) of the project.

4.11.1.1 Magnitude and Geographic Extent of Impacts

The magnitude of impacts on aesthetics and visual resources was assessed by determining the overall change in landscape character based on an assessment of visual contrast and scale dominance. The geographic extent of the effects was measured by the range of moderate to strong visual contrast, and was summarized as localized, extended, or regional.

- **Visual Contrast:** The Bureau of Land Management (BLM) Contrast Rating Procedure was used to determine visual contrast that could result from construction and operation of the project (BLM 1986). The project would not directly affect federal land; however, the BLM Contrast Rating Procedure is an established and developed methodology commonly used to assess visual impacts. This method assumes that the extent to which a project results in adverse effects on visual resources is a function of the visual contrast between the project components and the existing landscape character. Levels of contrast are defined as follows:

  - None – The element contrast is not visible or perceived.
  - Weak – The element contrast can be seen but does not attract attention.
  - Moderate – The element contrast begins to attract attention and to dominate the characteristic landscape.
  - Strong – The element contrast demands attention, would not be overlooked, and is dominant in the landscape.
- **Scale Dominance:** The contrast created by a project is directly related to its size and scale, as compared to the surroundings in which it is placed. Scale dominance refers to the scale of an object relative to the visible expanse of the landscape that forms its setting (BLM 1986). A dominant feature of a landscape tends to attract attention and becomes the focal point of the view. Where two or more features both attract attention and have generally equal visual influence over the landscape, they are considered co-dominant. An object or feature that is easily overlooked or absorbed by the surrounding landscape is considered subordinate. Scale dominance was classified using the following metrics:
  - Not Visually Evident (NVE), where "evident" refers to that which is noticeable, apparent, conspicuous, or obvious.
  - Visually Subordinate (VS), where "subordinate" refers to landscape features that are inferior to, or placed below, another in size, importance, brightness, and other relevant factors.
  - Visually Evident (VE), where "evident" refers to that defined above.
  - Dominant (D), where "dominant" refers to that defined above.

Visual Impacts: Potential visual impacts perceived by viewers was assessed at each Key Observation Point (KOP) based on the level of exposure to moderate or high-magnitude impacts, viewer sensitivity to change, the potential for those effects to alter the human experience of the landscape, and the context of the impact. Exposure was measured based on viewer duration, viewer geometry, and distance from the project component. These metrics were assessed as follows:

- **Viewer Duration:** Viewer duration or exposure refers to the length of time project features may be in view. This description discloses whether expected viewer exposure would be limited to a short duration and/or small number of viewpoints, or would be of a prolonged duration and/or experienced from multiple viewpoints.
- **Viewer Geometry:** Viewer geometry refers to the spatial relationship of the observer to the viewed object (i.e., the project), including both the vertical and horizontal angles of view (BLM 2013). The vertical angle of view refers to the observer's elevation relative to the viewed object. The horizontal angle of view refers to the compass direction of the view from the observer to the object. Visibility is typically greater for observers whose viewing angle is directed toward a project feature than for those with a lateral view.
- **Distance:** The degree of perceived visual contrast and scale dominance of an object is influenced by the object's distance from the viewer. As viewing distance increases, the project appears smaller and less dominant. Likewise, as distance increases, the apparent contrast of color decreases (BLM 1986). Distance from project components is classified as follows:
  - Immediate foreground (less than 3 miles)
  - Foreground–middleground (3 to 5 miles)
  - Background (5 to 15 miles)

- Seldom seen (beyond 15 miles).

Wetlands and Other Waters: For impacts to wetlands and other waters, impacts to aesthetic attributes that could result from discharge of dredged or fill material were assessed. The analysis was based on conclusions presented in Section 4.22, Wetlands and Other Waters/Special Aquatic Sites, including permanent impacts to wetlands, open waters, and streams.

Night Sky: Night lighting associated with project components could result in light pollution, which is defined as the change to natural night-lighting levels from human-caused sources (Falchi et al. 2016a). Light pollution effectively reduces visibility of natural sources of light at night, such as moonlight, starlight from individual stars and planets, the Milky Way, the zodiacal light, the aurora borealis, and meteors. Project components would result in light pollution in the form of glare when viewed from short distances and over water, but would have further-reaching effects from skyglow, which is defined as the brightening of the night sky over areas with artificial lighting (NPS 2016g). Because a lighting plan is not yet available for the project, impacts are evaluated qualitatively, and the magnitude and geographic extent of impacts are estimated using existing data in the New World Atlas of Artificial Night Sky Brightness (Falchi et al. 2016a, 2016b). To estimate the distance that skyglow would be observed from the mine site, data from Anchorage were used. To estimate the distance that skyglow would impact the night sky from the ferry terminals and ports, data from Valdez were used, because these facilities would be smaller in scale, with less extensive night-lighting than the mine site. The Municipality of Anchorage and the City of Valdez are larger than the mine site, ferry terminals, and ports; and includes more nighttime lighting than would be expected for the project components. Therefore; night-sky impacts from the mine site, ferry terminals, and ports are considered conservative, and would likely be of lesser magnitude than those estimated using the available data. However; based on data from the New World Atlas of Artificial Night Sky Brightness, data from the Municipality of Anchorage and the City of Valdez were the best available to represent similar geographic conditions without underestimating impacts. These data are summarized in Table 4.11-1 below.

Table 4.11-1: Estimated Night Sky Effects by Distance from Artificial Lighting

Distance from Mine Site[1,2]	Distance from Ferry Terminals and Ports[1,3]	Ratio to Natural Brightness[4]	Description of Effects
70 miles	25 miles	1%	Values of solitude and the absence of visual intrusion of human development begin to occur. Attention should be given to protect the site from future increase in light pollution.
40 miles	12 miles	8%	Area is considered polluted from an astronomical point of view. Visibility of stars and other astronomical observations are affected.
15 miles	3.5 miles	128%	Visibility of the Milky Way during winter months is affected.
<8 miles	<1.5 miles	>512%	Sky has same luminosity as a natural sky at twilight; true night conditions are never experienced.

Notes:
[1] Data estimated from Falchi et al. 2016a, b
[2] Distance based on data for Anchorage, Alaska
[3] Distance based on data for Valdez, Alaska
[4] Ratio (in percent) between the artificial brightness and the natural background sky brightness
Source: Falchi et al. 2016a, 2016b

In addition, the National Park Service (NPS 2013b) monitoring report includes photographs that depict artificial night glow; as well as monitoring data and narrative, including the Bortle Class based on the Bortle Dark-Sky Scale as reported by NPS observers. The Bortle Dark-Sky Scale is a nine-step scale used to rate sky conditions at an observation site; with Class 1 indicating an excellent dark-sky site, and Class 9 indicating an inner-city sky (Bortle 2001). Data from these two sources were used to estimate existing night-sky quality in the EIS analysis area.

Soundscape: The soundscape was analyzed using the information and methods described in Sections 3.19 and 4.19, Noise. Impacts to soundscape included potential noise generation from the mine and ground, based transportation corridors and overflights.

Olfactory: Because changes in olfactory attributes are subjective, this aesthetic attribute is not analyzed in detail. It is assumed that localized changes to smells could result from project-related activities that alter the natural smells that exist under current conditions.

4.11.2 No Action Alternative

Under the No Action Alternative, the Pebble Project would not be undertaken. No construction, operations, or closure activities would occur. Therefore, no additional future direct or indirect effects on aesthetics would be expected. Although no resource development would occur under the No Action Alternative, permitted resource exploration activities currently associated with the project may continue (ADNR 2018-RFI 073). In addition, there are many valid mining claims in the area, and these lands would remain open to mineral entry and exploration. Pebble Limited Partnership (PLP) would have the same options for exploration activities that currently exist.

PLP would be required to reclaim any remaining sites at the conclusion of their exploration program. If reclamation approval is not granted immediately after the cessation of reclamation activities, the State may require continued authorization for ongoing monitoring and reclamation work as deemed necessary by the State of Alaska. Reclamation would benefit the aesthetics of the setting.

4.11.3 Alternative 1 – Applicant’s Proposed Alternative

Due to the remoteness of the project and the distribution of components across a large geographic area, many of the components are geographically isolated; therefore, visual impacts of the project may be limited to that caused by one component. For example, viewers situated on Cook Inlet may only be exposed to potential impacts from Amakdedori port, but would not experience potential impacts from activities at the mine site. However, some viewers’ locations may be characterized by broader or expansive views (i.e., higher elevations, aircraft), and therefore have the potential for exposure to more than one project component. To address this, potential visual and aesthetic impacts are provided below by project component, and collectively for all project components.

Note that because views of the EIS analysis area from aircraft would include all project components, potential impacts from this viewer position are described under a separate heading below, “All Project Components.”

4.11.3.1 Mine Site

Visual Impacts

Specific mine site components would result in variable levels of visual contrast and scale dominance. In terms of magnitude and extent, the open pit mine, tailings storage facility overburden stockpiles, material sites, and quarries would create strong visual contrast in form, line, color, and texture due to alterations in the existing natural contours of the landscape and removal of vegetation. Smooth texture and the reflective surface of water management ponds would result in strong contrast against the coarse textures and natural matte colors of the landscape. Milling and processing facilities, along with supporting infrastructure such as the power plant, water treatment plants, camp facilities, and storage facilities, would appear industrial. These industrial straight lines and geometric forms would contrast against the softer, less angular lines of the landscape. Collectively, these features would be visually evident and appear dominant on the landscape when viewed from within background distance zones.

Collectively, and where visible in the background distance zone (5 to 15 miles), the mine site would appear dominant in the landscape, and would alter scenic quality. Viewshed models indicate that visibility of mine components from ground-based locations would be limited by topography and vegetation screening (see Appendix K4.11 for figures of the viewshed). Visibility would generally be limited to high-elevation areas on Sharp Mountain and Groundhog Mountain, and the upper Stuyahok River Valley. The mine site could also be visible from higher elevations west of Lake Clark (but outside of Lake Clark National Park and Preserve); however, visual contrast is expected to attenuate to a weak level at this distance (approximately 20 miles away). See Appendix K4.11 for visual simulations of the project at defined KOPs. At Iliamna Lake, views of the mine site would largely be screened by vegetation and topography.

In terms of magnitude and extent, impacts of the mine site perceived by residents, recreationists, or subsistence users in the EIS analysis area for the mine site would be of moderate to strong visual contrast, have VE or D scale dominance, and occur in the immediate foreground, due the remoteness of the site and the existing topographic and vegetation screening. Viewer duration would be intermittent to prolonged, depending on the activity of the viewer. If remote recreation or subsistence use should occur within the background distance zone of the mine site and in the seen area, the magnitude of impacts would be an increased visual contrast perceived from this distance. The duration of impacts would be long term, extending beyond the life of the project. The likelihood of impacts would be certain.

Night Sky

Mine site facility lighting would have a strong contrast level against the existing night sky. Lighting could be visible at distances from high-elevation locations due to the lack of existing night-lighting and high quality of night sky. During periods of snow cover, lighting at the mine site would reflect against the snow, thereby creating a halo effect that could extend outward to background distance zones and contribute to skyglow.

Due to the lack of viewing locations in the foreground or middleground distance zones, the mine site would not produce glare visible from any KOPs; however, glare could be observed by overhead flights. Mine lighting could be directly visible from locations in the modeled viewshed, such as high-elevation areas on Sharp Mountain and Groundhog Mountain, the upper Stuyahok River Valley, and higher elevations west of Lake Clark.

Skyglow from the mine site would brighten the night sky, affecting the human eye from fully adapting to the dark; and reduce visibility of stars and other astronomical observations at some distances. The magnitude and extent of the impact would be that areas 40 to 70 miles from the mine site could begin to experience skyglow from artificial lighting (Table 4.11-2). Impacts may not be readily apparent; however, the introduction of this visual intrusion into an otherwise pristine night sky would begin to put the integrity of the night sky at risk. In terms of magnitude and extent, about 27 percent of the Lake Clark National Park and Preserve and 17 percent of the Katmai National Park and Preserve would experience these types of effects. All of the McNeil River State Game Refuge and a small portion of the Alaska Maritime National Wildlife

Refuge (less than 1 percent) would also be impacted, as shown in Table 4.11-2. The communities of Pedro Bay and Kokhanok, and commercial lodges in the vicinity, would experience these types of effects. One commercial lodge along the Kvichak River and one along the Alagnak River would also be affected. No change to Bortle Class is expected at these distances from the mine site lighting alone and the magnitude of impacts would be low.

The magnitude of additional effects would be that nighttime views in areas 15 to 40 miles from the mine site would begin to experience reduced visibility of stars and other astronomical observations, and could become affected (degraded) in these areas. About 9 percent of the Lake Clark National Park and Preserve would experience these types of effects (Table 4.11-2). The communities of Port Alsworth, Iliamna, and Newhalen, and commercial lodges in the vicinity, would experience these types of effects.

In areas located 8 to 15 miles from the mine site, effects to the night sky would become apparent to casual observers; the magnitude of impacts would increase; and the Bortle Class would be affected. Less than 1 percent of the Lake Clark National Park and Preserve would experience these types of effects (Table 4.11-2). The number of viewers experiencing these effects would be low.

In terms of extent, areas less than 8 miles from the mine site would experience a sky that would never appear darker than twilight, and true night conditions would never be experienced. In terms of magnitude, this would be considered strong visual contrast. The Bortle Class would be degraded; however, the number of viewers experiencing these effects would be low, and no areas in national parks and preserves, state game refuges, or national wildlife refuges would experience impacts of this magnitude. The duration of impacts to the night sky would be long term, lasting through the life of the mine; and they would be certain to occur under Alternative 1.

Table 4.11-2: Estimated Night Sky Effects from the Mine Site

Distance from Mine Site[1]	Total Acres Affected	Acres in Lake Clark National Park and PreserveAffected	Acres in Katmai National Park and PreserveAffected	Acres in the McNeil River State Game Refuge	Acres in the Alaska Maritime National Wildlife Refuge
40 to 70 miles	7,048,784	1,080,429	696,439	131,081	1,742
15 to 40 miles	3,109,797	370,739	0	0	0
8 to 15 miles	420,788	5,732	0	0	0
<8 miles	258,071	0	0	0	0

Notes:
[1] Data estimated from Falchi et al. 2016a, 2016b. The ratio of natural brightness as a function of distance was assumed to be the same as data measured from the artificial light produced from the City of Anchorage, Alaska.
Source: Falchi et al. 2016 a, 2016b

Soundscape

Operations at the mine site would involve noise-producing activities (including those related to discharge of fill) and processes that include blasting and extracting rock at the pit, and transporting rock material to milling facilities or the pyritic tailings storage facility/potentially acid generating storage facility. Section 4.19, Noise, describes anticipated noise-related impacts that could result from construction, operation, and closure of the mine. Based on the results of the noise analysis, it was determined that—in terms of magnitude and extent—the existing "wilderness ambient" soundscape would be unaffected beyond a distance of 10 miles from the mine site. Within approximately 18,450 feet, the estimated operational noise level would be at least 30 dBA equivalent continuous sound level (L_{eq}), and therefore would risk causing sleep disturbance for recreationists and subsistence hunters sleeping outdoors during any seasonal activities on lands considered "wilderness ambient." Within approximately 12,900 feet, the estimated operational noise level would be at least 45 times day-night sound level (dBA L_{dn}) at a building exterior. These impacts to the soundscape would last for the duration of project operations, and would be certain to occur under Alternative 1. See Section 4.19, Noise, for more information.

During construction, impacts to soundscape could also result from increases in project-related flights that could occur between Anchorage and Iliamna to transport material and personnel. The magnitude of the impact would be seven low-elevation flightpaths (lower than 14,000 feet) between these two locations that cross sensitive receptors at Lake Clark National Park and Preserve and communities. If these routes are used frequently for the project, there could be additional impacts to the soundscape from these flights. Project-related flights into and out of Iliamna and Kokhanok would increase noise levels in those communities and surrounding areas for the life of the project, and would be expected to occur.

Reclamation

Following reclamation, the magnitude and extent of visual contrast and scale dominance of the mine site is expected to decrease due to removal of mine components, and regrading and replanting of vegetation. However, the mine site would still be visually evident in the foreground-middleground, resulting in high-magnitude impacts when viewed from this distance zone. Magnitude of impacts would decrease with distance to medium in background distance zones. Night sky and soundscape-related impacts would be reduced, because operation of the mine would cease.

4.11.3.2 Transportation Corridor

Visual Impacts

Specific components of the transportation corridor would result in variable levels of visual contrast and scale dominance. In terms of magnitude, access roads could result in strong visual contrast in form, line, color, and texture against the surrounding landscape, as linear/curvilinear line and gray-brown color and coarse texture of road would contrast surrounding natural color, textures, and lines of the landscape. Mine-related traffic on the roadway could be visually evident due to movement and associated dust plumes. Movement of vehicles would be more apparent during dark sky conditions, because vehicle lighting would be evident. The port and mine access roads and mine traffic are expected to result in the strongest contrast when viewed from higher elevation or superior viewer positions, because roads would not be screened by vegetation.

The magnitude of impacts resulting from both north and south ferry terminals would be a moderate to strong visual contrast when viewed in the foreground-middleground distance zone from Iliamna Lake or higher-elevation locations (see Appendix K4.11 for visual simulations from defined KOPs). The ferry terminals would appear distinct against the shoreline, because the form and line of the structures would contrast with the natural character of the surrounding landscape. Visual contrast would primarily result from the angular lines, varied colors, and smooth texture of cargo containers where they would be stockpiled at the terminals. Strong visual contrast would result from night-lighting where direct views of artificial lighting for the north and south ferry terminals would be experienced. Reflection and glare off Iliamna Lake would further increase the visual contrast from the artificial lighting at the ferry terminals. In terms of geographic extent, reflections off the lake could potentially be viewed by individuals living and recreating in/near Newhalen, Iliamna, and Kokhanok. There are commercial lodges in/near each of these communities that would also experience effects from night-lighting.

Skyglow from the north and south ferry terminals would brighten the night sky, affecting the human eye from fully adapting to the dark; and would reduce visibility of stars and other astronomical observations at some distances. In terms of geographical extent, areas 12 to 25 miles from the north or south ferry terminal could begin to experience effects to skyglow from artificial lighting (Table 4.11-3). Impacts may not be readily apparent; however, the introduction of this visual intrusion into an otherwise pristine night sky would begin to put the integrity of the night sky at risk. The magnitude and extent of impacts from skyglow would be less than 1 percent of the Lake Clark National Park and Preserve; and about 5 percent of the Katmai National Park and Preserve would experience these types of effects from the north and south ferry terminals. The majority of the McNeil River State Game Refuge would also be impacted. However, no change to night-sky quality or Bortle Class is expected at these distances from the ferry terminals' lighting alone.

Areas 3.5 to 12 miles from the ferry terminals, in terms of magnitude and extent, would begin to experience reduced visibility of stars and other astronomical observations. The night-sky quality could become affected (degraded) in these areas. The following communities and commercial lodges in the vicinity of those communities could experience these types of effects: Port Alsworth, Iliamna, Newhalen, and Kokhanok. No areas in national parks and preserves, state game refuges, or national wildlife refuges would experience impacts of this magnitude.

Also in terms of magnitude and extent, effects to the night sky would become apparent to casual observers, with reduced visibility in areas less than 3.5 miles from either ferry terminal. The night-sky quality would be degraded. No areas in the Lake Clark National Park and Preserve, communities, or commercial lodges would experience these types of effects; and less than 1 percent of the Katmai National Park and Preserve would be affected (Table 4.11-3). Therefore, the number of individuals experiencing impacts of this magnitude would be low.

The magnitude and extent of impacts to areas less than 1.5 miles from either ferry terminal would be that the night sky would never appear darker than twilight; true night conditions would never be experienced; and the Bortle Class night-sky quality would be degraded. In terms of magnitude, this would be considered strong visual contrast. No areas in the Lake Clark or Katmai National Park and Preserve, communities, or commercial lodges would experience these types of effects. Therefore, the number of individuals experiencing these effects would be low. These impacts on the night sky would be long term, lasting through the life of the project, and their likelihood of occurrence would be certain. Terminal facilities would be NVE or VS from villages on the shoreline of Iliamna Lake, because the communities are either outside of the seen area, or are situated greater than 25 miles away.

Ferry traffic would appear dominant from Kokhanok, because this community is within 5 miles of the ferry route. Other communities are more than 10 miles from the route; given the size and low stature of the ferries, the magnitude of visual contrast is expected to be weak, and ferries would appear visually subordinate.

Season-specific operational impacts to aesthetic resources during winter months primarily pertain to lighting, the visual contrast created from ice break on the lake where the ferry would cross, and ferry noise associated with icebreaking. The magnitude and extent would be visual impacts experienced by residents of Kokhanok due to the proximity of this village to the ferry terminal and crossing route. Individuals engaged in winter subsistence activity may also experience impacts from vehicle lighting on access roads and facility lighting at the ferry terminals.

Table 4.11-3: Estimated Night Sky Effects from North and South Ferry Terminals

Distance from Ferry Terminal[1]	North Ferry Terminal[2]		South Ferry Terminal[3]		
	Total Acres Affected	Acres in Lake Clark National Park and PreserveAffected	Total Acres Affected	Acres in Katmai National Park and PreserveAffected	Acres in McNeil River State Game Refuge Affected
12 to 25 miles	970,944	18,404	975,283	195,074	86,444
3.5 to 12 miles	267,650	0	270,493	4,009	0
1.5 to 3.5 miles	20,782	0	21,450	0	0
<1.5 miles	5,045	0	5,584	0	0

Notes:
[1] Data estimated from Falchi et al. 2016a, 2016b. The ratio of natural brightness as a function of distance was assumed to be the same as data measured from the artificial light produced from Valdez, Alaska.
[2] The north ferry terminal would have no night-sky impacts to the Katmai National Park and Preserve, McNeil River State Game Refuge, or the Alaska Maritime National Wildlife Refuge.
[3] The south ferry terminal would have no night-sky impacts to the Lake Clark National Park and Preserve or Alaska Maritime National Wildlife Refuge.
Source: Falchi et al. 2016a, 2016b

The magnitude of impacts of the mine and port access roads perceived from residents, recreationists, or subsistence users in the EIS analysis area would be of weak to strong visual contrast and NVE to D dominance); the geographic extent would be foreground-middleground, due to screening of the road corridor by vegetation and the low stature of the ferry terminals (see Appendix K4.11 for project viewshed models). The visual contrast would be greater under dark sky conditions due to the contrast of night-lighting described below. Viewer exposure to the transportation corridor and associated uses would be intermittent to prolonged, depending on the activity of the viewer. The duration of impacts would be long term, extending beyond the life of the project. Visual impacts would not impact viewers in areas identified as special management areas (e.g., national parks or wildlife management areas). The likelihood of impacts would be certain under Alternative 1.

Night Sky

The magnitude of impacts on the night sky would be strong visual contrast resulting from night lighting where direct views of artificial lighting for the north and south ferry terminals would be experienced. Reflection and glare off Iliamna Lake would further increase the visual contrast from the artificial lighting at the ferry terminals. In terms of geographic extent, reflections off the lake could potentially be viewed by individuals living and recreating in/near Newhalen, Iliamna, and Kokhanok. There are commercial lodges located in/near each of these communities that would also experience effects from night lighting.

Skyglow from the north and south ferry terminals would brighten the night sky affecting the human eye from fully adapting to the dark and would reduce visibility of stars and other astronomical observations at some distances. In terms of geographical extent, areas located 12 to 25 miles from the north or south ferry terminal could begin to experience effects to skyglow from artificial lighting (Table 4.11-3). Impacts may not be readily apparent; however, the introduction of this visual intrusion into an otherwise pristine night sky would begin to put the integrity of the night sky at risk. The magnitude and extent of impacts from skyglow would be such, that less than 1 percent of the Lake Clark National Park and Preserve and about 5 percent of the Katmai National Park and Preserve would experience these types of effects from the north and south ferry terminals. The majority of the McNeil River State Game Refuge would also be impacted. However, no change to night sky quality is expected at these distances from the ferry terminals' lighting alone.

In terms of magnitude and extent, areas located 3.5 to 12 miles from the ferry terminals would begin to experience reduced visibility of stars and other astronomical observations. The night sky quality could become degraded in these areas. The following communities and commercial lodges in the vicinity of those communities could experience these types of effects: Port Alsworth, Iliamna, Newhalen, and Kokhanok. No areas within national parks and preserves, state game refuges, or national wildlife refuges would experience impacts of this magnitude.

Also in terms of magnitude and extent, effects to the night sky would become apparent to casual observers with reduced visibility in areas located less than 3.5 miles from either ferry terminal. The night sky quality would be degraded. No areas in Lake Clark National Park and Preserve, communities, or commercial lodges would experience these types of effects and less than 1 percent of the Katmai National Park and Preserve would be affected (Table 4.11-3). Therefore, the number of individuals experiencing impacts of this magnitude would be low.

The magnitude and extent of impacts to areas less than 1.5 miles from either ferry terminal would be such that the night sky would never appear darker than twilight, true night conditions would never be experienced, and the night sky quality would be degraded. In terms of magnitude this would be considered strong visual contrast No areas in Lake Clark or Katmai National Park and Preserve, communities, or commercial lodges would experience these types of effects. Therefore, the number of individuals experiencing these effects would be low. These impacts on the night sky would be long term, lasting through the life of the project. Their likelihood of occurrence would be certain under Alternative 1.

Soundscape

During operations, truck traffic, light vehicles, and maintenance along the mine access road (including those related to construction, dredge, or fill material) could result in impacts to soundscape that extend up to 0.5 mile from the road corridor, as measured by the potential for a 45 dBA L_{max} value, assuming a 15-mile-per-hour (mph) speed limit for large diesel-engine vehicles, and a 30-mph speed limit for passenger vehicles (maximum value level; see Section 4.19, Noise, for more information). The presence of dense vegetation or terrain features like ridgelines or hills could narrow this distance. Impacts to soundscape from the access route would endure for as long as the project is in the operations phase, and would be expected to occur in terms of likelihood.

Primary impacts to soundscape from operation of the ferry terminals would result from continuous (day and night) operation of the power supply (generator) at each ferry terminal. The magnitude of impacts from this feature would be the production of a reference sound level no greater than 70 dBA L_{eq} at 50 feet (see Section 4.19, Noise, for more information). In terms of extent, within approximately 2,250 feet from the ferry terminal, the estimated operational noise level would be at least 30 dBA L_{eq}, and therefore, would risk causing sleep disturbance for any recreationists and subsistence hunters sleeping outdoors during their seasonal activities on lands considered "wilderness ambient." Also in terms of extent, within approximately 1,000 feet, the estimated operational noise level would be at least 45 dBA L_{dn} at a building exterior. Other indirect impacts to soundscape may result from icebreaking as the ferry crosses the lake during winter operations. Anticipated impacts to soundscape would persist through operations, and would be expected to occur under Alternative 1.

Following reclamation, visual contrast and scale dominance of the transportation corridor would persist, because roads would remain operational. Visual impacts associated with ferry terminals and ferry transportation would cease, because these facilities would be removed. Ferry terminals would be replaced with contoured gravel landings. Although landings would appear distinct from the natural shoreline, they would not be visually evident beyond the foreground-middleground. Night sky–related impacts would be reduced, because landings would not be outfitted with night-lighting. Soundscape-related impacts would also be reduced due to the limited and intermittent use of barge operations.

4.11.3.3 Amakdedori Port

Visual Impacts

The magnitude and visual contrast of the Amakdedori port would be similar to those described for the north and south ferry terminals. The port facility would be larger in size, and involve different types and frequencies of vessel operations. Visual contrast may be stronger when viewed from close proximity due to the larger stature of this facility, because vertical lines and geometric shape of the facility would contrast against the low marshlands, with the backdrop of the rolling hills and mountains. As a result of the unobstructed horizon of Cook Inlet, the geographic extent of impacts would continue until moderate to strong contrast attenuated to a weak level (anticipated beyond 10 miles). See Appendix K4.11 for project viewshed models. Development of the port would result in direct effects to aesthetics by changing the configuration of the shoreline and creating an industrial feature in an otherwise natural landscape in Kamishak Bay. The geographical impact of indirect effects would be that increased project-related boat traffic on Kamishak Bay in Cook Inlet would be visually evident from the foreground, middleground, and background distance zones. The port would not be visible from the mouth of McNeil River at the edge of McNeil State Game Refuge; however, vessel traffic (including lighting) at the southern location would be evident, and could be a dominant part of the viewers' experience when vessels are present. Visual impacts could affect viewers in areas identified by special designations; namely, the McNeil River State Game Refuge (including Chenik Lagoon) and Alaska Maritime National Wildlife Refuge. These impacts would primarily affect visitors during the summer season. Peak visitation and viewing is from early summer into fall, and would be extremely low during the winter. Such impacts could indirectly affect the naturalness of the recreation experience at this destination. Although seasonal, the duration would be considered long term, because impacts would occur throughout the life of the project. Visual impacts would be certain to occur under Alternative 1.

Night Sky

The magnitude and extent of impacts from glare and skyglow would be similar to those described for the north and south ferry terminals. As discussed for ferry terminals, strong visual contrast would be expected to result from night-lighting and the potential for haloing during winter months, when lighting is reflected off the snow's surface. Reflection off of Cook Inlet would occur, although it would only be visible to a small number of viewers.

The magnitude and geographical extent of impacts on the night sky would be such that areas 12 to 25 miles from Amakdedori port could begin to experience effects to skyglow from artificial lighting that would begin to put the integrity of the existing pristine night sky at risk. In terms of magnitude, about 4 percent of the Katmai National Park and Preserve, over half of the McNeil River State Game Refuge, and less than 1 percent of the Alaska Maritime National Wildlife

Refuge would experience moderate to strong visual contrast from night-lighting. No specific communities or commercial lodges were identified that would be impacted.

In terms of magnitude and geographical extent, areas 3.5 to 12 miles from Amakdedori port would begin to experience reduced visibility of stars and other astronomical observations, and the night-sky quality could become degraded in these areas. No national parks and preserves, communities, or commercial lodges would experience these impacts. About 40 percent of the McNeil River State Game Refuge and less than 1 percent of the Alaska Maritime National Wildlife Refuge would experience impacts of the same magnitude (Table 4.11-4).

In terms of magnitude and extent of impacts, effects to the night sky would become apparent to casual observers in areas 1.5 to 3.5 miles from Amakdedori port, and the Bortle Class night-sky quality would be degraded. No national parks and preserves, national wildlife refuges, communities, or commercial lodges would experience effects of this magnitude, and about 2 percent of the McNeil River State Game Refuge would be affected (Table 4.11-4). Therefore; the number of individuals experiencing impacts of this magnitude would be low.

The magnitude and extent of impacts to areas less than 1.5 miles from Amakdedori port would be that the sky would never appear darker than twilight; true night conditions would never be experienced; and the night-sky quality would be degraded. No areas in the Lake Clark or Katmai National Parks and Preserves, McNeil River State Game Refuge, Alaska Maritime National Wildlife Refuge, communities, or commercial lodges would experience these types of effects. Therefore; the number of individuals experiencing these effects would be low. However, these impacts from the Amakdedori port on the night sky would be long term, lasting through the life of the project, and their likelihood of occurrence would be certain.

Table 4.11-4: Estimated Night Sky Effects from Amakdedori Port[1]

Distance from Port[2]	Total Acres Affected	Acres in Katmai National Park and Preserve[3] Affected	Acres in McNeil River State Game Refuge Affected	Acres in Alaska Maritime National Wildlife Refuge Affected
12 to 25 miles	990,658	144,766	76,471	14,148
3.5 to 12 miles	280,559	0	51,700	390
1.5 to 3.5 miles	23,834	0	2,493	0
<1.5 miles	7,566	0	0	0

Notes:
[1] Amakdedori port would have no night-sky impacts to the Lake Clark National Park and Preserve.
[2] Data estimated from Falchi et al. 2016a, 2016b. The ratio of natural brightness as a function of distance was assumed to be the same as data measured from the artificial light produced from Valdez, Alaska.
Source: Falchi et al. 2016a, 2016b

Soundscape

Although the equipment and types of vehicles used are different, the technique used for estimating noise exposure attributable to Amakdedori port operations is similar to and uses the same conservative assumptions as the technique used for estimating aggregate noise emissions from mine site operations. In addition, noise from vessel operations, whether during lightering or transit of ore concentrate vessels, could also be audible to people in coastal areas of McNeil River State Game Refuge and the Alaska Maritime National Wildlife Refuge. The magnitude and extent of impacts determined from the predictive analysis, and considering sound attenuation with distance and other factors, would be:

- Within approximately 9,750 feet, the estimated operations-attributed noise level would be at least 30 dBA L_{eq}, and therefore would risk causing sleep disturbance for any recreationists and subsistence hunters sleeping outdoors during their seasonal activities on lands considered "wilderness ambient."

- Within approximately 5,800 feet, the estimated operational noise level would be at least 45 dBA L_{dn} at a building exterior, and therefore would be 10 dBA greater than the existing outdoor ambient sound level.

The duration of impacts in the two latter above-stated distance buffers would be long term throughout port operations. See Section 4.19, Noise, for more detailed analysis.

Reclamation

Following reclamation, the magnitude and extent of visual contrast and scale dominance of the Amakdedori port would be considered not visually evident, because most port facilities would be removed. Because the remaining terminal would no longer operate with the same frequency of vessel traffic, soundscape-related impacts would also be reduced. Likewise, because the terminal would no longer be outfitted with night-lighting, night-sky impacts would be eliminated.

4.11.3.4 Natural Gas Pipeline Corridor

Because the natural gas pipeline corridor would follow the transportation corridor, it would not introduce additional visual contrast in form, line, color, or texture that is distinct from the port and mine access roads. In terms of magnitude, the compressor station, located on the Kenai Peninsula, would result in weak visual contrast against the surrounding landscape, and would be visually subordinate against the natural landscape. In terms of geographical extent, the compressor station would not be seen from Anchor Point State Recreation Area or Stariski Campground. The impacts on visual contrast would be long term, lasting though the life of the project, and would be unlikely to occur.

Although pipeline construction activities would create noise in conjunction with road construction, the duration would be limited to 2 years. No noise-producing sources would be located along the pipeline corridor during pipeline operation. Gas traveling through the buried pipeline would not emit audible noise. The compressor station on the Kenai Peninsula would produce some noise, but would not be expected to impact sensitive receptors; therefore, no noise impacts associated with pipeline operations would occur under Alternative 1.

4.11.3.5 All Components

Due to the scale of the project, many of the components are geographically isolated from each other and from population centers or areas of frequent visitation; and as a result, opportunity to experience visual contrast of more than one component is limited. An exception to this limitation applies to those experiencing views of the project from recreational or local low-altitude aircraft, as well as skyglow effects. There are 14 low-elevation flightpaths that cross the EIS analysis area that could experience views of the project (FAA 2018). In terms of magnitude when viewed from the air, the project would result in moderate to strong visual contrast due to vegetation removal and ground disturbance in access roads and the mine site. For air-based viewers flying to recreation destinations such as the McNeil River State Game Refuge, the transportation corridor and Amakdedori port would be visually evident. Additionally, skyglow effects from different project components could also be visible from one location, which together could increase the magnitude of effects to night sky. The magnitude and duration of visual impacts would be moderate to strong visual contrast that would last for the life of the project. The extent of impacts would decrease with distance from the facilities. These impacts would be certain to occur.

During construction, impacts to the visual environment and soundscape could also result from increased project-related air traffic. As described in Section 4.12, Transportation and Navigation, in terms of magnitude and extent, a Twin Otter or similar aircraft would make 20 to 40 flights per month (average of 5 to 10 flights per week) to Amakdedori port, before the Kokhanok airstrip could be accessed by road. Once the Kokhanok spur road were established, there would be up to 10 flights per month by Twin Otters to Kokhanok. The duration of impacts would be intermittent, but long term, and could affect important scenic resources at the Lake Clark or Katmai National Parks and Preserves, McNeil River State Game Refuge, Alaska Maritime National Wildlife Refuge, communities, or commercial lodges.

During operations, the magnitude of project flights would include those transporting employees on 2-week rotations, as well as cargo flights. Section 4.12, Transportation and Navigation, includes details on the number and location of project flights. In terms of extent, increases of air traffic have the potential to be observed by visitors to Lake Clark National Park and Preserve, where small aircraft are the primary transportation for park visitors. The potential for impacts would be reduced, however, because flights from Anchorage to Bristol Bay generally fly over Iliamna Lake or the project area (FAA 2018) (see Section 3.12, Transportation and Navigation), rather than the preserve. Additionally, the Pebble-related air traffic would not conflict with small planes, which fly at lower altitudes, and use narrow passes such as Lake Clark Pass. The duration of impacts from helicopter traffic would remain throughout operations, because helicopters would be used to perform ongoing environmental monitoring (variable by frequency and season) and aerial inspections of the transportation corridor (weekly or monthly) (PLP 2018-RFI 027b). These effects would be long term, occurring through the life of the project, and would be unlikely under Alternative 1.

The magnitude, extent, and duration of impacts from air traffic would be intermittent, but lasting though the life of the project, and could affect important scenic resources at the Lake Clark or Katmai National Parks and Preserves, McNeil River State Game Refuge, Alaska Maritime National Wildlife Refuge, communities, or commercial lodges.

Following reclamation, visual contrast and scale dominance of the project would be reduced; however, the remaining roadway, airstrips, and mine site infrastructure would remain visually evident. When viewed from the air, the project would result in moderate visual contrast due to ground disturbance in access roads and the mine site. Night-sky impacts are expected to be reduced to a low-medium level, largely due to removal of lighting from ferry terminals and the port. During project closure, impacts from overflights would decline, because fewer personnel would travel to and from the project area.

4.11.3.6 Alternative 1 – Kokhanok East Ferry Terminal Variant

The magnitude, extent, and duration of potential impacts to visual resources and soundscapes would be similar to those described for the south ferry terminal; however, the perception of impacts would be greater due to the close proximity of residential viewers and noise-receptors in Kokhanok. Port Alsworth and commercial lodges in the vicinity would be approximately 20 miles from the Kokhanok east ferry terminal, and therefore, views of the night sky in these areas could begin to experience effects to skyglow from artificial lighting. Kokhanok and commercial lodges in the vicinity would be approximately 5 miles from the Kokhanok east ferry terminal, and therefore, visibility of stars and other astronomical observations from these areas would be affected. All these impacts would be long term, occurring through the life of the project, and would be certain to occur under this variant.

Impacts following reclamation would be similar to those described above for ferry terminals, because similar reduction of visual contrast and scale dominance would occur. Likewise, similar reduction in impacts to night-lighting and soundscape would be expected.

4.11.3.7 Alternative 1 – Summer-Only Ferry Operations Variant

Under the Summer-Only Ferry Operations Variant, in terms of magnitude and extent, visual and soundscape impacts from ferry operations would not occur during the winter, but would be more intense during the summer, with twice the number of ferry trips. Impacts to night sky would be substantially less than other alternatives due to the use of less lighting from extended daylight hours. The duration of impacts, although seasonal, would be long term, lasting for the life of the project, and they would be certain to occur under this variant.

Under the Summer-Only Ferry Operations Variant, the magnitude of impacts from the transportation corridor would be less due to the decrease in lighting-related impacts, the reduction of truck traffic in the winter, and the lack of ice breaks from the ferry operations. This would be offset to some degree by the doubling of truck traffic during the summer, with accompanying visual and noise impacts. The reduction in impacts would be primarily experienced under the Kokhanok East Ferry Variant, because residents of this community would experience the greatest visual and soundscape-related impacts during winter months when the transportation corridor was operational, due to proximity of these receptors to the port, and increased number of trips.

Impacts following reclamation would be similar to those described above for ferry terminals, because similar reduction of visual contrast and scale dominance would occur. Likewise, similar reduction in impacts to night-lighting and soundscape would be expected.

4.11.3.8 Alternative 1 – Pile-Supported Dock Variant

In terms of magnitude, extent duration, and likelihood, the Pile-Supported Dock Variant would result in similar impacts to those described above for visual impact, night-sky, and soundscape for the Amakdedori port.

Also, impacts following reclamation would be similar to those described above for ferry terminals, because similar reduction of visual contrast and scale dominance would occur. Likewise, similar reduction in impacts to night-lighting and soundscape would be expected.

4.11.4 Alternative 2 – North Road and Ferry with Downstream Dams

4.11.4.1 Mine Site

The magnitude, extent, duration, and likelihood of impacts to aesthetic resources (visual, soundscape, and night sky) under Alternative 2 would be the same as or similar to those described for Alternative 1.

Impacts following reclamation would be similar to those described for the mine site under Alternative 1.

4.11.4.2 Transportation Corridor

<u>Visual Impacts</u>

The transportation corridor under Alternative 2 would result in variable levels of visual contrast and scale dominance, as described under Alternative 1. The magnitude and extent of these impacts would be greatest when viewed from higher elevation or superior viewer positons in the western end of Lake Clark National Park and Preserve, because roads would not be screened by vegetation, and visual contrast of the cleared vegetation of the roadway would contrast to the surrounding landscape. When viewed from Nondalton, the mine access road would be expected to result in weak visual contrast, because viewers would be primarily situated at a similar grade to the road, and visibility would be minimized by vegetation screening. In terms of geographical extent, the mine access road would be greater than 5 miles from this village, thereby further minimizing the potential for visual contrast or scale dominance. The magnitude of impacts from the mine access road would be strong visual contrast when viewed from higher elevations on Roadhouse Mountain. Located approximately 3 miles from the Roadhouse Mountain, the road would appear as a discrete curvilinear line that resulted in strong visual contrast against the landscape that would appear visually evident.

Between Pile Bay and Diamond Point port, the magnitude and extent of impacts of operation of the port access road would be weak visual contrast, particularly in areas where the new access road would lie in the same location as the existing roads.

As was described for the north and south ferry terminals, in terms of magnitude and extent, the ferry terminals at Eagle Bay and Pile Bay would result in moderate to strong visual contrast when viewed in close proximity (i.e., 3 to 5 miles) from Iliamna Lake or higher-elevation locations. From this distance zone, the ferry terminals would appear distinct against the shoreline, because the form and line of the structures would contrast with the natural character of the surrounding landscape.

The communities of Newhalen and Iliamna are the only residential areas within approximately 10 miles of the ferry terminals. From these locations, the magnitude and extent of visual contrast would be weak, and the facilities would not be visually evident under daylight conditions. Noise from ferry icebreaking activities could be apparent to these communities.

Other villages on Iliamna Lake are greater than 15 miles from the ferry terminals and route. Given the size and low stature of the ferries, the magnitude and extent of visual contrast would be weak, and ferries would appear visually subordinate. There is one small research camp on the peninsula of Pedro Bay. From this location, passing ferry traffic would be considered visually evident.

As described in Alternative 1, the magnitude and extent of season-specific impacts to aesthetic resources during winter months primarily pertain to those that would result from lighting, and the visual contrast created from ice break on the lake where the ferry crosses. The extent of visual impacts would be primarily experienced by residents of Iliamna, Newhalen, Pedro Bay, and Pile Bay due to the proximity of these communities to the ferry terminals and crossing route. Individuals engaged in winter subsistence activity would also experience impacts from vehicle lighting on access roads and facility lighting at the ferry terminals.

The duration of viewer exposure to visual impacts would be intermittent to prolonged at any given time depending on the activity of the viewer, but would be long term, extending beyond the life of the project. Visual impacts would not impact viewers in areas identified by special designations (see the project viewshed models in Appendix K4.11). The likelihood of impacts would be certain under Alternative 2.

Night Sky

The magnitude, geographical extent, and duration of impacts to the night sky from the Eagle Bay and Pile Bay ferry terminals would be similar those described for the north and south ferry terminals in Alternative 1. There would be no impacts to night sky from the land-based transportation corridor. Reflection off of Iliamna Lake would occur, but it would only be visible to a small number of viewers.

Areas 12 to 25 miles from Eagle Bay or Pile Bay ferry terminals, in terms of magnitude and extent, could begin to experience effects to skyglow from artificial lighting that would begin to put the integrity of the existing pristine night sky at risk. About 5 percent and 7 percent of the Lake Clark National Park and Preserve would be affected by the Eagle Bay and Pile Bay ferry terminals, respectively; as well as a small portion (less than 1 percent) of the Alaska Maritime National Wildlife Refuge (Table 4.11-5). Kokhanok and commercial lodges in the vicinity would also experience these impacts.

The magnitude and extent of impacts to areas 3.5 to 12 miles from Eagle Bay or Pile Bay ferry terminals would be the beginning of reduced visibility of stars and other astronomical observations, and the Bortle Class night-sky quality could become degraded. The Katmai National Park and Preserve, McNeil River State Game Refuge, and Alaska Maritime National Wildlife Refuge would not experience impacts of this magnitude, and only about 1 percent of Lake Clark National Park and Preserve would be impacted (Table 4.11-5). Pedro Bay, as well as the commercial lodges in the vicinity, would experience impacts of this magnitude; Port Alsworth could be affected to a lesser degree, being further away from the ferry terminal and shielded by topography.

Also in terms of magnitude and extent, effects to the night sky would become apparent to casual observers, because visibility of the night sky would be reduced in areas 1.5 to 3.5 miles from Eagle Bay or Pile Bay ferry terminals. Areas less than 1.5 miles from the ferry terminals would experience strong visual contrast, because the sky would never appear darker than twilight, and true night conditions would never be experienced. The night-sky quality would be degraded at distances 3.5 miles or less from the ferry terminals. No areas in the Lake Clark or Katmai National Parks and Preserves, McNeil River State Game Refuge, Alaska Maritime National Wildlife Refuge, communities, or commercial lodges are 3.5 miles or closer to either ferry terminal; therefore, the number of individuals experiencing these effects would be low. These impacts on the night sky would be long term, lasting through the life of the project. Their likelihood of occurrence would be certain under Alternative 2.

Table 4.11-5: Estimated Night Sky Effects from Eagle Bay and Pile Bay Ferry Terminals

Distance from Ferry Terminal[1]	Eagle Bay Ferry Terminal[2]		Pile Bay Ferry Terminal[3]		
	Total Acres Affected	Acres in Lake Clark National Park and Preserve Affected	Total Acres Affected	Acres in Lake Clark National Park and Preserve Affected	Acres in Alaska Maritime National Wildlife Refuge Affected
12 to 25 miles	973,309	183,838	973,346	275,861	107
3.5 to 12 miles	269,197	21,455	269,194	2,930	0
1.5 to 3.5 miles	21,146	0	21,143	0	0
<1.5 miles	5,327	0	5,336	0	0

Notes:
[1] Data estimated from Falchi et al. 2016a, 2016b. The ratio of natural brightness as a function of distance was assumed to be the same as data measured from the artificial light produced from Valdez, Alaska.
[2] Eagle Bay ferry terminal would have no night-sky impacts to Katmai National Park and Preserve, McNeil River State Game Refuge, or Alaska Maritime National Wildlife Refuge.
[3] Pile Bay ferry terminal would have no night-sky impacts to Katmai National Park and Preserve or McNeil River State Game Refuge.
Source: Falchi et al. 2016a, 2016b

Soundscape

The magnitude, extent, and duration and likelihood of impacts to soundscape would be similar to those described for Alternative 1; however, noise-related impacts would not be expected to affect local communities, because communities are more than 0.5 mile from the transportation corridor.

Reclamation: The magnitude, extent, duration, and likelihood of impacts following reclamation would be similar to those described for the Transportation Corridor under Alternative 1.

4.11.4.3 Diamond Point Port

Visual Impacts

The magnitude of impacts from the Diamond Point port would be less than that described for the Amakdedori port under Alternative 1 because of the level of existing development. Visual contrast would appear strong when viewed from the foreground distance zone due to the larger stature of this facility; the vertical lines and geometric shape of the facility would contrast against the natural backdrop of Iliamna Bay. The geographic extent of impacts would be more limited than Amakdedori port due to the steep landforms and enclosure of views created by topography surrounding the bay (see Appendix K4.11 for project viewshed models). For viewers situated in the bay, the port would appear dominant and focal due to the enclosure of the landscape in the bay.

Increased project-related boat traffic in Cook Inlet would be visually evident from the foreground, middleground, and background distance zones. The port would be visible from the Alaska Maritime National Wildlife Refuge, and vessel traffic would be evident and could dominate the viewers' experience. The duration of impacts would be long term, extending beyond the life of the project if the port remains in operation. Visual impacts could impact viewers in areas identified by special designations, including the Alaska Maritime National Wildlife Refuge. In terms of likelihood, the impacts would be expected to occur under Alternative 2.

Night Sky

The magnitude, extent, and duration of impacts to the night sky from the Diamond Point port would be similar those described for Amakdedori port. There would be no impacts to night sky from the land-based transportation corridor.

In terms of magnitude and extent, areas 12 to 25 miles from Diamond Point port could begin to experience effects to skyglow from artificial lighting that would begin to put the integrity of the existing pristine night sky at risk. About 2 percent of the Lake Clark National Park and Preserve, less than 1 percent of the Alaska Maritime National Wildlife Refuge, and the community of Pedro Bay and commercial lodges in the vicinity would have impacts of this magnitude.

The Lake Clark and Katmai National Parks and Preserves, and McNeil River State Game Refuge and all identified communities and commercial lodges are further than 12 miles from Diamond Point port; less than one-tenth of 1 percent of the Alaska Maritime National Wildlife Refuge falls within that distance.

These impacts on the night sky from the Diamond Point port would be long term, lasting through the life of the project (see Table 4.11-6). Their likelihood of occurrence would be certain under Alternative 2.

Table 4.11-6: Estimated Night Sky Effects from Diamond Point Port

Distance from Port[1]	Total Acres Affected	Acres in Lake Clark National Park and Preserve Affected	Acres in Alaska Maritime National Wildlife Refuge Affected
12 to 25 miles	1,001,777	87,678	22,793
3.5 to 12 miles	287,814	0	92
1.5 to 3.5 miles	25,537	0	8
<1.5 miles	8,855	0	7

Notes:
[1] Data estimated from Falchi et al. 2016a, 2016b. The ratio of natural brightness as a function of distance was assumed to be the same as data measured from the artificial light produced from Valdez, Alaska.
Source: Falchi et al. 2016a, 2016b

Soundscape

The magnitude, extent, duration, and likelihood of impacts to the soundscape would be similar to those described for Amakdedori port (see Section 4.19, Noise, for more information). Noise-related impacts would be largely contained in Iliamna Bay due to the steep topography of the surrounding landforms.

Reclamation

The magnitude, extent, duration, and likelihood of impacts following reclamation would be similar to that described for the Amakdedori port under Alternative 1.

4.11.4.4 Natural Gas Pipeline Corridor

Visual Impacts

The magnitude of impacts from the pipeline would be greatest between the junction with the Eagle Bay ferry terminal access road and the Pile Bay ferry terminal access road because visual moderate-strong contrast of the cleared right-of-way would contrast the existing natural landscape. As described in the transportation corridor, visual contrast would be perceived by viewers situated in close proximity to the pipeline, or in elevated viewer positions (i.e. Roadhouse Mountain). Visual contrast of the segment between Diamond Port and Ursus Cove would be weak-moderate because of the rugged topography of the Chigmit. Individuals traveling between Dutton and Meadow Lake would be exposed to visual contrast where the pipeline crossed the access trail. Air-based viewers would perceive moderate contrast of this feature when viewed form low-elevation aircraft. Where aligned with the exiting Williamsport-Pile Bay Road, the pipeline would result in weak to moderate visual contrast resulting primarily from roadway upgrades.

Night Sky

The natural gas pipeline corridor is not expected to have any impacts on the night sky.

Soundscape

As described in Alternative 1, pipeline construction activities would create noise in conjunction with road construction, the duration of which would be limited to 2 years. No noise-producing sources would be located along the pipeline corridor during pipeline operation. Gas traveling through the buried pipeline would not emit audible noise, and the compressor station on the

Kenai Peninsula would not be expected to impact sensitive receptors; therefore, no noise impacts associated with pipeline operations would occur under Alternative 2.

4.11.4.5 All Components

The magnitude, extent, duration, and likelihood of visual impacts from all components would be similar to those described for Alternative 1; however, the proximity of the port and mine access roads to popular recreation destinations could result in increased viewer exposure to those features. For example, the transportation corridor, pipeline corridor (including between Diamond Port and Ursus Cove), and Diamond Point port would be visually evident for air-based viewers flying to recreation destinations such as the Lake Clark National Park and Preserve, McNeil River State Game Refuge, Katmai National Park and Preserve, and area sport fishing lodges, although not as visually evident as the Amakdedori port under Alternative 1. The magnitude of visual impacts would be expected to be of moderate to strong visual contrast, and would decrease with distance from the facilities.

Frequency and impacts of flights to and from Iliamna would be the same as Alternative 1. Construction cargo and passenger flight frequencies to the airstrip in Pile Bay would be similar to flight frequencies to Kokhanok in Alternative 1. Impacts to Pedro Bay and Pile Bay would be similar to those discussed for Kokhanok in Alternative 1, including the use of the airport at Pedro Bay during construction. The Pebble Limited Partnership would not construct a new airstrip at Diamond Point, but would improve the existing airstrip near Pile Bay for limited use during construction. In terms of likelihood, these impacts would be expected to occur under Alternative 2.

Reclamation

The magnitude, duration, extent, and likelihood of impacts following reclamation would be similar to that described for all components under Alternative 1.

4.11.4.6 Alternative 2 – Summer-Only Ferry Operations Variant

Under the Summer-Only Ferry Operations Variant, visual and soundscape impacts from ferry operations would not occur during the winter, but would be more intense during the summer with twice the number of ferry trips. The magnitude of impacts to night sky would be substantially less than other alternatives due to the extended daylight hours. The duration of impacts would be long term.

The magnitude, duration, extent and likelihood of impacts following reclamation would be similar to that described for Summer-Only Ferry Operations Variant under Alternative 1.

4.11.4.7 Alternative 2 – Pile-Supported Dock Variant

The Pile-Supported Dock Variant would result in similar impacts in terms of magnitude, extent, duration, and likelihood to those described above for visual resources, soundscape, and night sky.

Also, impacts following reclamation would be similar to those described for the Pile-Supported Dock Variant under Alternative 1.

4.11.5 Alternative 3 – North Road Only

4.11.5.1 Mine Site

The magnitude, duration, extent, and likelihood of impacts to aesthetic resources (visual, night sky, and soundscape) under Alternative 3 would be the same as those described for Alternative 1.

Also, impacts following reclamation would be similar to those described for the mine site under Alternative 1.

4.11.5.2 Transportation Corridor

The magnitude, duration, extent, and likelihood of impacts from the transportation corridor under Alternative 3 would be similar to Alternative 2 in portions of the network that are the same under both alternatives (mine site to junction leading to Eagle Bay ferry terminal; Pile Bay to Diamond Point port). However, because the access road would extend along the northern shore of Iliamna Lake, impacts would be of greater magnitude and larger geographic extent (see Appendix K4.11 for project viewshed models). Visual contrast would be strong, and the road would appear dominant when viewed from the foreground-middleground of the community of Pedro Bay; from areas within 3 miles of the shoreline of Iliamna Lake; and from high points in Lake Clark National Park and Preserve. The magnitude, duration, extent, and likelihood of impacts to night sky would be the same as Alternative 2.

Given the proximity of the access road to Pedro Bay, noise from construction activities and operational truck traffic could be heard in the community up to 3,000 feet from the activity.

<u>Reclamation</u>

Impacts following reclamation would be similar to those described for the transportation corridor under Alternative 1.

4.11.5.3 Diamond Point Port

The magnitude, duration, extent, and likelihood of impacts under Alternative 3 would be the same as those described for Alternative 2. Impacts following reclamation would be similar to those described for the Amakdedori port under Alternative 1.

4.11.5.4 Natural Gas Pipeline Corridor

The magnitude, duration, extent, and likelihood of impacts under Alternative 3 would be the same as those described for the transportation corridor, above, because these components would be co-located. The magnitude, duration, extent, and likelihood of impacts expected to result from the portion of the pipeline located between Diamond Port and Ursus Cove would be the same as described in Alternative 2.

Impacts following reclamation would be similar to those described for the Amakdedori port under Alternative 1.

4.11.5.5 All Components

The magnitude, duration, extent, and likelihood of visual impacts from all components would be similar to those described for Alternative 2; however, the magnitude of visual impacts would be greater due to operation of the north access road (Alternative 3). The road would be visually evident, appearing as a curvilinear line with contrasting color and texture against the surrounding landscape.

Frequency of flights, and associated magnitude of effects, to and from Iliamna would be the same as Alternative 1. Flight frequencies to Pedro Bay, and associated magnitude of effects, would be similar to Alternative 2; but the connecting of Pedro Bay by road to the Cook Inlet would affect frequency of flights after construction, if the road leads to more traffic through Pedro Bay. Potential effects on Kokhanok would be limited to resident crew change flights. These impacts would last for the life of the project, and would be expected to occur under Alternative 3.

Impacts following reclamation would be similar to those described for all components under Alternative 1.

4.11.5.6 Alternative 3 – Concentrate Pipeline Variant

The Concentrate Pipeline Variant would result in impacts similar in magnitude, extent, duration, and likelihood as those described above for visual impacts, soundscape, night sky, and reclamation.

4.11.6 Summary of Key Issues

See Table 4.11-7 for a summary of key issues.

Table 4.11-7: Summary of Key Issues for Aesthetic Resources

Project component	Alternative 1 and Variants	Alternative 2 and Variants	Alterantive 3 and Variants
Mine Site	Aesthetic resources would be affected by moderate to strong visual contrast that would appear dominant in the landscape. Impacts would be limited in geographic extent by rugged topography. Impacts from lighting would be visually evident, particularly during winter months. Night sky could be affected as far as 70 miles from the mine site. Impacts to soundscape would be limited to within 10 miles of the mine site.	Same as Alternative 1.	Same as Alternative 1.
Transportation Corridor	Aesthetic resources would be affected by weak to moderate visual contrast impacts that would be visually evident in the landscape. Movement of vehicles and ferries could be more apparent during dark sky conditions,	Impacts would be similar to Alternative 1; however, the northern route would affect residents of Iliamna, Newhalen, and Pile Bay due to proximity to the access route and ferry terminals. Impacts would include those that result from movement and lighting.	Impacts would be the same as described in Alternative 2, with the exception of those pertaining to ferry terminals -magnitude impacts would occur in the community of Pedro Bay due to the proximity to the transportation route.

Table 4.11-7: Summary of Key Issues for Aesthetic Resources

Project component	Alternative 1 and Variants	Alternative 2 and Variants	Alterantive 3 and Variants
	because lighting would be evident. Impacts to soundscape would be limited to within 0.5 mile of the transportation corridor. Night sky could be affected as far as 25 miles from the ferry terminals. Kokhanok—and to a lesser extent Iliamna and Newhalen—would be affected by transportation corridor and ferry activities. Under the Kokhanok East Ferry Terminal Variant, potential impacts to aesthetic resources would be similar to those described for the south ferry terminal; however, the perception of impacts would be higher due to the close proximity of viewer- and noise-receptors. Under the Summer-Only Ferry Operations Variant, the visual contrast would not be created from ice break on the lake where the ferry crosses. The reduction in impacts would be primarily experienced under the Kokhanok East Ferry Terminal Variant. Impacts to night sky would also be much less.	Under the Summer-Only Ferry Operations Variant, reduction of season-specific impacts to aesthetic resources during winter months would be similar to Alternative 1; however, reduction in impacts would be experienced by residents in the communities along the northern shore of Iliamna Lake.	
Amakdedori Port and Diamond Point Port	Aesthetic resources would be affected by weak to moderate visual contrast that would be visually evident when viewed within 5 miles. Scale dominance of the port facility would decrease with distance. Night sky could be affected as far as 25 miles from the ports. Soundscape-related	Impacts would be similar to those described for Alternative 1; however, the port site would be in Iliamna Bay, where steep topography would limit geographic extent of visual and soundscape-related impacts.	Same as Alternative 2.

Table 4.11-7: Summary of Key Issues for Aesthetic Resources

Project component	Alternative 1 and Variants	Alternative 2 and Variants	Alterantive 3 and Variants
	impacts could extend to almost 2 miles from port.		
Natural Gas Pipeline	Because the natural gas pipeline corridor would follow the transportation corridor, it would not introduce additional visual contrast in form, line, color, or texture that is distinct from the roadway access road.	The magnitude of impacts from the pipeline would be greatest between the junction with the Eagle Bay ferry terminal access road, because visual contrast of the cleared right-of-way (ROW) would contrast the existing natural landscape.	Same as Alternative 1.
All Components	Visual impacts would appear dominant to viewers located in recreational or local low-altitude aircraft. When viewed from the air, the project would result in moderate to strong visual contrast due to vegetation removal and ground disturbance in access roads and the mine site. For air-based viewers flying to recreation destinations such as the McNeil River State Game Refuge, the transportation corridor would be visually evident. Visual impacts are expected to be of medium to high magnitude, and would decrease with distance from the facilities.	Visual impacts from all components would be similar to those described for Alternative 1; however, the proximity of the access road to recreation destinations in the west end of Lake Clark National Park and Preserve could result in increased viewer exposure to those features.	Visual impacts from all components would be similar to those described for Alternative 2, with the exception of ferry terminals and operations; however, the magnitude of impacts would be greater due to operation of the north access road. The road would be visually evident, appearing as a curvilinear line with contrasting color and texture against the surrounding landscape.

4.11.7 Cumulative Effects

The cumulative effects analysis area for aesthetics encompasses Iliamna Lake and the surrounding communities and west to Cook Inlet. For night-sky impacts, the cumulative effects analysis area would be 140 miles from the mine site and 50 miles from the ferry terminals and ports. Potential cumulative impacts to aesthetics and soundscape include visual impacts from the air, ground, and water transport and activities. Visual impacts at nighttime would be different than during the day, because development often includes lighting features.

Past, present, and reasonably foreseeable future actions (RFFAs) in the cumulative impact analysis area identified in Section 4.1, Introduction to Environmental Consequences, have the potential to contribute cumulatively to impacts on aesthetics that are carried forward in this analysis. These include contiguous mining claims located roughly between Iliamna Lake and the Chuitna River, as well as more geographically isolated claims in the watershed, oil, and gas development in Cook Inlet, and smaller-scale onshore oil and gas, as summarized below. Other RFFAs removed from further consideration include those outside the EIS analysis area.

- Pebble Project buildout – develop 55 percent of the resource over a 78-year period
- Pebble South/PEB*
- Big Chunk South*
- Big Chunk North*
- Fog Lake*
- Groundhog*
- Shotgun
- Johnson Tract*
- Diamond Point Rock Quarry
- Alaska LNG
- Alaska Stand Alone Pipeline
- Cook Inlet Lease Sales
- Onshore Hydrocarbon Exploration*
- Lake and Peninsula Transportation, Infrastructure and Energy Project

**Indicates exploration activities only.*

4.11.7.1 Past and Present Actions

Currently, in the EIS analysis area, there is little development outside of communities. Other activities in the region that impact aesthetics include subsistence, recreation, and mining exploration activities. Mining exploration activities have been supported by aircraft, which generate temporary but regular noise that has been noticeable to local residents, as documented in scoping comments. Temporary mining exploration camps in support of drilling programs have also generated visual and noise impacts in their immediate area. Support of commercial recreation by guides, lodges, and air taxis have generated aircraft and small boat noise in the vicinity of their activities. Transport of fishing vessels and cargo over the Williamsport-Pile Bay Road has historically generated summer truck traffic and increased vessel traffic on Iliamna Lake during the summer, which is noticeable to local residents and non-resident recreation users. These would be expected to continue to contribute to the cumulative impacts of aesthetics, although impacts are low in intensity and generally seasonal in duration. The Iliamna Airport has introduced skyglow to the night sky, extending approximately 6 miles from the airport.

4.11.7.2 Reasonably Foreseeable Future Actions

<u>No Action Alternative</u>

The No Action alternative would not contribute to cumulative effects on Aesthetics.

<u>Alternative 1 – Applicant's Proposed Alternative</u>

Pebble Mine Expanded Development Scenario – An expanded development scenario for this project would extend the impacts to aesthetics for a longer duration (78 total years of mining, with another 20 years of processing). Expansion of the Pebble Project could include the impacts from both Alternatives 1 and 3, which would contribute to the cumulative impacts of aesthetics in the region. Expansion of the open pit and tailings/waste rock storage facilities would increase the visual and noise impacts that could be experienced by local subsistence hunters in the area, and by recreation users that are dropped off and float the Koktuli and Stuyahok rivers. The transportation corridors between the mine site/Amakdedori port and the mine access road would operate concurrently, affecting those communities in the vicinity of both routes, although truck traffic to Amakdedori would decrease because concentrate would be shipped to the Iniskin deepwater port by pipeline. Concentrate and diesel pipelines from the mine site to the Iniskin port facility would be located in the access road corridor, and would not noticeably increase the visual impact of that corridor. There would be additive effects to the viewshed for visitors flying over the region, because the landscape as a whole is more visible from a higher elevation, and the mine site would be more noticeable as it expands. With increased production, the frequency of vessel traffic to the Iniskin port facility would also increase. Similarly, impacts to night sky would have a longer duration. The magnitude of impacts would be greater due to the larger mine site footprint, however; the direct and indirect analysis conservatively assumed skyglow effects similar to Anchorage. The Pebble mine expanded development scenario is not expected to exceed the magnitude and geographic extent of those effects.

The prolonged use of the Amakdedori port facility and transportation corridor would continue to contribute adverse effects to the cumulative impacts in the region, and the development of a port in Iniskin Bay would have additive effects that alter landscape character from naturally evolving to industrial across a large geographic extent during the day and at night. Such impacts could be experienced by recreationists in Cook Inlet, and would be of high magnitude and dominant when viewed from high elevations, flightpaths, and vessels. Operations would be audibly apparent. There would be further impacts to the region from the pipeline right-of-way (ROW) from the mine site to Iniskin Bay, and the development of a road to Diamond Point. Impacts to the night sky from the Iniskin Bay port would be similar to impacts from the Diamond Point port in magnitude and geographic extent.

Other Mineral Exploration Projects – Reasonably foreseeable locatable mineral exploration in the project area of Iliamna Lake and the Chuitna River, and east to Lake Clark, could contribute cumulatively to visual and audible impacts across a large geographic extent. Such impacts could be experienced by communities close to mineral deposits, and recreationists in Lake Clark National Park and Preserve and surrounding areas. However, impacts to night sky would be of low magnitude, because activity for most mineral exploration projects would occur during summer months, and work is anticipated to be sporadic and of low intensity.

Oil and Gas Exploration and Development – Oil and gas development in Cook Inlet would contribute cumulatively to impacts in Cook Inlet, with the magnitude dependent on the level of on- and offshore oil and gas development. Marine support vessel and helicopter traffic may be visible and audible to marine and coastal recreation users. Lighting required would create reflection and glare on the surface of Cook Inlet, which—in combination with impacts from the Amakdedori port—would increase nighttime glare in the inlet. Night-lighting from the proposed alternative and oil and gas exploration and development could also increase overall skyglow in the vicinity. Construction of the Alaska Liquefied Natural Gas (LNG) or the Alaska Stand Alone Pipeline (ASAP) projects would increase ship traffic in the vicinity of Cook Inlet during the period of construction. Operation of the LNG project would generate monthly LNG carrier traffic for the duration of operations. Combined with concentrate shipment from expanded development, increased ship traffic would be noticeable to local residents and visitors using coastal areas in the vicinity of the project.

Road Improvement and Community Development Projects – Transportation and infrastructure development in communities would contribute to cumulative impacts at a lesser extent; however, when combined with other RFFAs, these actions would contribute to overall change in character in the region from one that is more remote and undeveloped to one that is more industrial. The project would contribute to cumulative impacts, and there would be no difference across alternatives. Impacts to night sky would be minimal, because the majority of projects would be upgrades or improvements, and increase in night-lighting would be minimal. Night-lighting associated with new road corridors is also anticipated to be minimal.

Alternative 2 – North Road and Ferry with Downstream Dams

Pebble Mine Expanded Development Scenario – Expanded mine site development and associated contributions to cumulative impacts would be the same as Alternative 1. Under Alternative 2, there would be a road constructed between the ferry terminals, adversely impacting aesthetics by introducing development and use in a natural area. Impacts from the Diamond Point port would also continue, and development in Iniskin Bay would impact aesthetics in the same ways as Alternative 1. The addition of a service road would add to the adverse impacts for the region's aesthetics. Cumulative effects of construction disturbance would be similar to those discussed under Alternative 1. Overall, cumulative impacts to aesthetics from Alternative 2, combined with the Pebble mine expanded development scenario, would be of lesser magnitude and geographic extent than Alternative 1, because the north ferry operation would be discontinued, and the south transportation system/ferry would not be in place.

Other Mineral Exploration Projects, Oil and Gas Development, and Road Improvement and Community Development Projects – Cumulative effects of these activities would be similar to those discussed under Alternative 1.

Alternative 3 – North Road Only

Pebble Mine Expanded Development Scenario – Expanded mine site development and associated contributions to cumulative impacts would be the same as Alternative 1. Under Alternative 3, project expansion would continue to use the existing Diamond Point port facility; would use the same natural gas pipeline; and would use the same north access road and Concentrate Pipeline Variant infrastructure, but extend the concentrate pipeline to Iniskin Bay. The port site and associated facilities would be constructed at Iniskin Bay, as discussed under Alternative 1 above. A diesel pipeline from the mine site to Iniskin Bay would be constructed, as discussed under cumulative effects for Alternative 1. Because the Pebble mine expanded development scenario would use the north access road system that would already be built under Alternative 3 and not include any ferry operation, cumulative impacts to aesthetics from Alternative 3, combined with the Pebble mine expanded development scenario, would be less than Alternatives 1 or 2.

Other Mineral Exploration Projects, Oil and Gas Development, Road Improvement and Community Development Projects – Cumulative effects of these activities would be similar to those discussed under Alternative 1.

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4.12 TRANSPORTATION AND NAVIGATION

The Environmental Impact Statement (EIS) analysis area for this section includes the transportation and navigation resources that could be affected by the proposed mine site, port, transportation corridor, material sites and natural gas pipeline corridor for each alternative. This includes surface transportation from the mine site to Cook Inlet and a small section of the Sterling Highway, air transportation from airports across the region (Dillingham to Anchorage), and water transportation on Cook Inlet, Iliamna Lake, and navigable rivers from the mine site to Cook Inlet. Navigation also includes deep water port construction and usage from local to global users and is part of the EIS analysis area. Local and regional land, air, and water transportation systems and activities in the EIS analysis area are included. Potential impacts include:

- Additional vehicle traffic in the road-connected communities of Iliamna, Newhalen, Kokhanok, Nondalton, and Pedro Bay.
- Off-road transportation access to subsistence areas.
- Beneficial alternative routes for transporting goods.
- Increased flight frequency to affected airports and communities.
- Additional vessel traffic on Cook Inlet, with a higher volume during construction, and increased marine traffic in the port area.
- Additional vessel traffic on Iliamna Lake.
- Impediment of navigation along navigable rivers.
- Re-routes of winter over-ice traffic on Iliamna Lake due to creation of open water.

The magnitude of impacts from the project is determined by the amount of surface, air, and water traffic that would be interrupted or displaced. The duration and geographic extent of impacts depends on the location and season in which the disturbance occurs during construction, operations, or closure. For example, long-term impacts would last throughout the life of the project, on the order of years to decades. Short-term effects would be temporary, lasting only through the construction phase, or months to years. The potential or likelihood of impacts is related to how likely the project would be to impact surface, air, and water transportation.

4.12.1 No Action Alternative

Under the No Action Alternative, the Pebble Project would not be undertaken. No construction, operations, or closure activities would occur. Therefore, no additional future direct or indirect effects on recreation would be expected. Though no resource development would occur under the No Action Alternative, permitted resource exploration activities currently associated with the project may continue (ADNR 2018-RFI 073). The Pebble Limited Partnership (PLP) would have the same options for exploration activities that currently exist. In addition, there are many valid mining claims in the area and these lands would remain open to mineral entry and exploration. The level of activity and use of transportation systems in the region would be assumed to remain the same as the past 10 years.

Scoping comments expressed concerns about increased use and user conflicts at Iliamna Lake, Kamishak Bay, and Cook Inlet. Concerns were also expressed regarding how the ferry crossing and vessel traffic could impact local boaters and access, and whether snowmachine travel on Iliamna Lake would be impacted. High winds on Iliamna Lake and the potential for them to impact he proposed ferry crossing were also noted. The following sections address these and other issues.

4.12.2 Alternative 1 – Applicant's Proposed Alternative

4.12.2.1 Surface Transportation

Mine Site

Alternative 1 would involve the construction and use of roads in the mine site, and connection of mining areas with the locations of facilities and material sites.

During project construction, operations, and closure, public access to or through the mine site would be restricted for safety reasons. Such a restriction to public access would be long term, lasting though the life of the project. The area is not commonly used by the public. However, subsistence overland travel that occurs in the area of the mine site would require adjustments to traditional routes (PLP 2018-RFI 088). See Section 4.9, Subsistence, for impacts on access to subsistence resources. The likelihood of impacts related to travel restrictions would be certain under Alternative 1.

Project construction, operations, and closure activities would introduce additional vehicles and road use patterns in the mine site area. The magnitude and extent of this adverse effect would be in the displacement of existing surface transportation modes (primarily all-terrain vehicle and snowmachine trails). The impact in the analysis area would be long term for the life of the project, and would be certain to occur. Impacts would include the need to take alternate overland routes around the mine site; they would be most apparent during construction and operations. Use of the mine and port access roads, and the spur roads by the local communities and businesses would most likely be scheduled and coordinated with PLP. The magnitude of impact would decrease after mine closure because mine traffic would decrease (but would not be eliminated) and the road system would be retained as long as required for the transport of bulk supplies needed for post-closure water treatment and monitoring, possibly lasting for years or decades. The adverse effects would be noticed by the nearby community members who travel through the area.

Transportation Corridor

During construction, the port access road would be constructed from the Amakdedori port site to the southern shore of Iliamna Lake and the mine access road would be constructed from the northern shore of Iliamna Lake to the mine site. Construction would involve using heavy equipment (for construction, excavation, and pipeline installation) and vehicles to transport personnel, fuel, and supplies during construction activities. Crews would live at the work sites in camps. A temporary airstrip would be built at the proposed Amakdedori port to facilitate the construction phase, and Amakdedori port would be used for offloading construction equipment and supplies from air and water deliveries. The magnitude and extent of impacts due to these actions would be in the number of vehicles using the roads. Road traffic in Kokhanok would increase during construction as project vehicles travel from the airstrip to the south access road. Similarly, road traffic in Iliamna and Newhalen would increase during construction as project vehicles travel from the airstrip to the mine access road, associated with delivering goods and services, and from local employees travelling to construction work sites. In terms of magnitude, this volume of traffic would likely decrease with the transition from construction to operations, but would still be higher than before construction. The impacts would be long term, lasting through the life of the project.

Until Iliamna Lake is connected to Cook Inlet through the transportation corridor at the southern ferry terminal, Williamsport-Pile Bay Road (which connects the two waterbodies at the northern end of Iliamna Lake over land) would be used to transport supplies to the beachheads on

Iliamna Lake during construction (PLP 2018-RFI 037). The magnitude and extent of the impact would be an increase in the volume of vehicles on the Williamsport-Pile Bay Road during construction. The road is currently used infrequently (i.e., an average 38 trips per day in the summer only; see Section 3.12, Transportation and Navigation) to transport commercial fishing vessels and general supplies, (Kevin Waring & Associates 2010b). The impact would last throughout the life of the project, and would be certain to occur under Alternative 1.

Spur roads proposed for the transportation corridor would connect the proposed mine access road to the existing roads in the communities of Iliamna, Newhalen, and Nondalton via the Iliamna spur road. The Kokhanok spur road would connect the Kokhanok community roads to the port access road, which would run from the southern ferry terminal to Amakdedori port. Spur roads would be gated to prevent vehicles from using the mine access road and port access road. Additional access would be coordinated between the State of Alaska, the Lake and Peninsula Borough (LPB), PLP, and landowners. Known trail crossings would be marked, and traffic controls would be implemented for safety (PLP 2018-RFI 027).

The current public roadway network in the EIS analysis area is limited to the vicinity of existing communities, and is used by local residents. Local roads provide important routes for overland travel, because there are no alternative roads. The airports in Iliamna and Kokhanok are outside of each town center. The magnitude of impacts on local roads would be an increase in the number of vehicles on roads connecting the towns of Iliamna and Kokhanok to the airports, with fewer additional vehicles in town. The duration of the impact would be long term, and it would be certain to occur under Alternative 1.

During winter, once snow cover on land and ice formation on Iliamna Lake are adequate, surface transportation occurs over land and Iliamna Lake for subsistence activities and inter-village travel. The new port and mine access roads could act as obstacles for overland inter-village and subsistence travel, although there would be marked crossing points for known trail crossings (PLP 2018-RFI 027). This impact would be long term.

During project operations, daily transportation of materials (concentrate, fuel, reagents, and consumables) would require up to 39 truck round trips per day on each leg of the road, including three loads of fuel per day. Personnel would be transported to the mine site via the spur road from Iliamna, and would remain at the mine site during their 2-week work shifts, which would minimize traffic on the mine and port access roads. Gates limiting unauthorized traffic would be installed on the spur roads. The communities of Iliamna, Newhalen, and Nondalton could see altered traffic patterns and a higher volume of vehicles on the roads as employees are transported from the Iliamna Airport to the mine site.

Impacts on surface transportation would last through the life of the mine, and through post-closure, until the roads are no longer deemed necessary for post-closure monitoring activities. These impacts would be certain to occur under Alternative 1.

Amakdedori Port

The temporary beachhead and workforce camps set up during construction, Amakdedori port facilities lasting for the life of the project, and post-closure facilities would be located in the same general area. Currently, no existing/developed surface transportation facilities exist in the vicinity of the port site. The magnitude and extent of impacts from port construction and operation would be the disruption of surface transportation activities associated with the area's subsistence uses. Figures in Section 3.9, Subsistence, and Appendix K3.9, show some subsistence use in the areas in the vicinity of Amakdedori, but not at the port site itself. While subsistence use in the area of the port appears to be infrequent, construction and operations activities at Amakdedori site could require that some traditional overland routes be altered. The port also could provide a beneficial alternative route for goods to be shipped to Iliamna Lake communities, which could be less expensive than current methods. These impacts would last through the life of the project, through closure and would be certain to occur under Alternative 1.

Natural Gas Pipeline Corridor

During construction of the pipeline on the Kenai Peninsula and connection to the compressor station near Anchor Point, traffic on the Sterling Highway would be affected by vehicles transporting materials to the site. The magnitude and extent of the effect would be delays and disruption of traffic due to construction of the project components. However these traffic delays are expected to be less than the usual delays experienced on Sterling Highway during the summer months when tourist traffic at its highest and road construction is most active (PLP 2018-RFI 037). Disruption of traffic may include lane closures and slow vehicles in the immediate vicinity of the construction site. This disruption would be short-term, only occurring during pipeline construction, but the likelihood of occurrence is certain under Alternative 1.

Because construction of the pipeline would be in the main transportation corridor from Amakdedori port to the mine site and would not cross existing roads, there would be no additional disruption of community roads systems associated with pipeline installation.

During operations and closure, inspections and maintenance of the pipeline would not be expected to have adverse effects on over-land traffic.

4.12.2.2 Air Transportation

Existing airports in Iliamna and Kokhanok would be used to transport personnel and some supplies to and from the project area for construction and operations activities. Iliamna Airport has the capacity to facilitate the planned aircraft traffic for the project, and would not require improvements. Kokhanok Airport has a runway capable of handling the anticipated commuter flights for workers, but would require improvements to lighting and navigation, and potentially air radio service. It is assumed that the improvements would take place on the existing airport footprint and therefore would not affect surface waters, including wetlands. Additional maintenance of the Kokhanok Airport would be required with an increase in traffic and would not be anticipated to have an effect on surface waters, including wetlands (PLP 2018-RFI 027b). Transportation infrastructure improvements would remain in place after closure providing a potential beneficial impact for regional travel. Helipads would also be built at Amakdedori port and at the mine site. In the event that emergency evacuation of mine personnel is required, any these air travel facilities may be used.

During construction, work crews would access sites by helicopter or boat until the mine access road is complete. An airstrip would be built at Amakdedori port to facilitate construction. The magnitude of impacts during construction would be the number of flights required. A Twin Otter or similar aircraft would make 20 to 40 flights per month (average of 5 to 10 flights per week) to Amakdedori port, before Kokhanok could be accessed by road. Once the Kokhanok spur road is established, the magnitude would change to up to 10 flights per week by Twin Otters to Kokhanok (PLP 2018-RFI 027a).

During operations, an estimated 600 employees would fly to Iliamna Airport from the Anchorage or Kenai airport, approximately 200 employees would fly to Iliamna and Kokhanok from surrounding community airports, and about 50 employees would travel by road to project locations. Employee flights would be on a 2-week rotation. The magnitude of impacts would be the additional weekly employee flights to Iliamna including one Twin Otter from King Salmon, one from outlying villages, two from Dillingham, four from Kenai, and two Q400 flights from Anchorage (10 total). If these airplanes are commercial carriers and not private charters, a beneficial effect of more frequent commercial flights, providing for more flight options for local residents could be realized. Kokhanok would also receive 5 to 10 employee flights per week during operations (PLP 2018-RFI 027a). Iliamna and Kokhanok airports would also receive an estimated one cargo flight per week, and six unscheduled cargo flights per year, in addition to the above passenger flights (PLP 2018-RFI 027). This would increase air traffic from the current annual operations (see Section 3.12, Transportation and Navigation). Increases of air traffic at these magnitudes have the potential to be observed by visitors to Lake Clark National Park and Preserve, where small aircraft are the primary transportation for park visitors. The potential would be reduced, however, because flight paths from Anchorage to Bristol Bay generally go over Iliamna Lake or the project area (FAA 2018) (see Section 3.12, Transportation and Navigation), rather than the preserve. Additionally, the Pebble-related air traffic would not conflict with small planes which fly at a lower altitude and use narrow passes such as Lake Clark Pass. Helicopter traffic would remain throughout operations to perform ongoing environmental monitoring (variable of frequency and season) and aerial inspections of the transportation corridor (weekly or monthly) (PLP 2018-RFI 027b). These effects would be long term, occurring throughout the life of the project, and would be certain to occur under Alternative 1.

In terms of magnitude, during project closure, impacts on air traffic would decline because fewer personnel would travel to and from the project area; aerial environmental monitoring and transportation inspections would continue by helicopter (PLP 2018-RFI 027b). Additionally, instead of private charters, project personnel would most likely use commercial airlines and cargo flights (PLP 2018-RFP 027a).

4.12.2.3 Navigation

Mine Site

No new water access would be constructed at the mine site. No navigation impacts would occur from the proposed project to the Kvichak and Nushagak rivers, which are navigable waters hydrologically connected to the mine site.

Transportation Corridor

The transportation corridor would cross waterbodies, including the Newhalen River, Gibraltar River, Iliamna Lake, and Cook Inlet, which are considered navigable by the US Army Corps of Engineers (USACE), the US Coast Guard (USCG), or the State of Alaska, or by a combination of these entities. Of these crossings, seven would utilize bridges. The lower Newhalen River Bridge would have a minimum of 32 feet of vertical clearance in the navigation channel, with 96 feet between each piling. The Newhalen River is approximately 596 feet wide at the proposed crossing. The Gibraltar River Bridge would be built where the river is approximately 100 feet wide, but the bridge would extend to 515 feet, with pilings 100 feet apart. The minimum vertical clearance would be 43 feet above the river (PLP 2018i). Existing structures on the Newhalen River include one small-boat launch and a beach landing, indicating that traffic on this river does not include larger vessels. The Gibraltar River is much smaller than the Newhalen River, so it is not likely that it supports larger vessels. The magnitude of impacts due to the structures would be to increase the likelihood of a vessel being impeded by either bridge, as the instream pilings would represent a risk of allision[1] to vessels. Navigation at the crossings on these two rivers would be directly affected during construction of the crossings and the associated increase in traffic crossing the river. Direct effects of the river crossings after construction would consist of

[1] Allision is a nautical term for when a vessel strikes a fixed object.

the presence of bridge pilings and the height of the bridges as obstacles. The risk of impacts would be reduced over the long term (during operations and after mine closure), as compared to over the short term (during construction). These impacts to navigation would be certain to occur under Alternative 1.

To support construction of the north and south ferry terminals and the ferry itself, small temporary barges would cross Iliamna Lake until completion of the ferry terminals. Barges may also move freight and equipment transported during construction on the Williamsport-Pile Bay Road, increasing Iliamna Lake traffic. Construction of the north ferry terminal may use facilities in Iliamna and Newhalen, possibly increasing road traffic and barge traffic to Iliamna creating an additional impact on lake navigation. Employees may be transported to work via boat during this phase. The magnitude of these impacts would be that construction traffic could temporarily impede inter-village and subsistence travel along the shorelines and across the lake via watercraft, and commercial traffic in Iliamna, Newhalen, and Kokhanok. Structures added to the lake would include a 115 foot by 155 foot ramp at the south ferry terminal and an 85 foot by 105 foot ramp at the north ferry terminal. A 200 foot by 160 foot ferry construction ramp at the south ferry terminal would extend 36 feet out into the lake. Two mooring buoys would be installed at each ferry terminal, attached to the lake substrate or to anchors 2 feet in diameter. During construction of these project components, direct adverse impacts on water navigation on Iliamna Lake would be realized. These adverse impacts would be reduced during operations. During operations, the ferry terminal structures would create an allision risk to vessels travelling along the shore. The structures have the potential to impact navigation, but the magnitude of impacts would be reduced since the terminals would be visible, and lighted, and the lake is large enough to provide routes around the structures.

During mine operations, the ferry would cross Iliamna Lake year-round along an 18-mile route that would take an estimated 1.5 hours in open water, or 3 hours in ice conditions. The magnitude of impacts to other lake traffic and navigation would be one round-trip per day in open water by the ferry; this trip would not disrupt lake traffic because it would be infrequent and alternate routes across the lake would be available. The effects would last through operations and post-closure and would be expected to occur under Alternative 1.

Scoping comments noted hurricane-force winds on Iliamna Lake, which could be hazardous for the ferry crossing in open water. Eagle Bluff, west of Kokhanok, would be downwind of the ferry route and could pose a hazard to the ferry in high winds if it lost power or steering. In addition, there are small islands in the lake within approximately 5 miles of the ferry route that could potentially be hazardous in a high wind situation. The proposed ferry would be constructed with multiple engines, propellers, and steering to minimize the potential for loss of control (PLP 2018-RFI 052), to minimize impacts.

When the lake is frozen and ice cover is sufficient, it is used as a passageway for people on snowmachines (PLP 2018-RFI 088). The magnitude of project impacts on winter lake transportation would be in the disruption of cross-lake snowmachine routes and potential safety hazards due to open water created by the ice-breaking ferry. PLP would work with communities (and supply funding) to provide for the marking and maintenance of snowmachine trails between communities across Iliamna Lake, when lake ice is thick enough to support such traffic (PLP 2018-RFI 071a). The impacts would be long term, throughout the use of the ferry and would be realized. After mine closure, the ferry facilities would be removed and supplies would be transported across the lake using a summer barging operation, so there would be no impacts from ice-breaking ferries.

Amakdedori Port

During construction and operation, supply barges would transport materials, supplies, and equipment to Amakdedori port, creating an increase in barge traffic on Cook Inlet. The magnitude would be the increase in barge traffic during operations, approximately 27 concentrate vessels and 33 supply barges per year (an average of one vessel per week). Each concentrate vessel would require 10 lightering barge trips between the port site and lightering location to fill the bulk carrier, which would be anchored for 4 to 5 days. Diesel delivery to the port would be by tank barges with an expected maximum load of 4 million gallons to allow fewer shipments during the winter. The additional vessel traffic on Cook Inlet would add approximately 110 transits or port calls (an average of about two per week) to the 2010 count of 480 (an average of about nine per week). Barge speeds would be between 5 and 7 knots and wake heights would not be expected to exceed natural waves at the shore (PLP 2018-RFI 039). The geographical extent of the impacts would be across Cook Inlet and the impacts would be long term, lasting throughout the life of the project.

Amakdedori port infrastructure in Cook Inlet would include an earthen causeway that would extend to 15 feet of natural water depth (1,900 feet long by up to 500 feet wide), two navigation buoys (anchored by 3 foot concrete blocks or anchors), and two lightering locations (2,300 foot by 1,700 foot, with buoys marking the corners and anchored in 80 feet of water). The magnitude and extent of impacts to navigation is that these structures would pose an allision risk for the infrequent traffic that occurs on the west side of the Cook Inlet, and would likely be most noticeable when unfavorable sea conditions force vessels to moor in the safe harbor of Iniskin Bay. These structures would be recorded on navigation charts and would not restrict navigation. The impacts would be realized during construction due to increased vessel activity, would decrease slightly during operations, and even more so post-closure, after the dock structures have been removed.

Amakdedori port would be located in Kamishak Bay, which has several identified reefs, as well as strong winds that create a funnel effect off of the surrounding mountains. Winds can be accompanied by short, choppy sea on flood currents, and can cause heavy swells. From Tignagvik Point to Cape Douglas, vessels are warned to proceed with caution (NOAA 2017). Project vessels may encounter these winds and swells during barging and lightering activities; vessels could drift onto reefs, mud flats, or otherwise run aground at the southern end of Kamishak Bay or near Amakdedori should they lose power or steering. The duration of impact would be long term and would be expected to occur under Alternative 1. Two lighted navigation buoys (3 feet in diameter) would be located on the reefs framing the entrance to the Amakdedori port. The nearby Augustine volcano has potential to cause a tsunami at the port site, as it has in the past (PLP 2018-RFI 039).

Natural Gas Pipeline Corridor

Construction of the entire pipeline would take place during the second and third years of construction. The magnitude and extent of impacts on navigation due to pipeline construction would be 94 miles of pipeline crossing the Cook Inlet seabed and 18-miles crossing on the Iliamna Lake bed. This construction phase would involve working in and crossing a high-traffic area of Cook Inlet, and would represent collision hazards for vessels transiting Cook Inlet and Iliamna Lake (Eley 2012). The construction of the Cook Inlet crossing of the pipeline would be expected to take 30 to 40 days, and would include approximately 10 construction, support, and survey vessels. These vessels would stay in Cook Inlet for the duration of this effort, some of which would travel to shore daily to resupply. In Iliamna Lake, pipeline construction would require one barge (PLP 2018-RFI 027b). Impacts on navigation would be short term and certain to occur. However, these waterbodies are large and non-project related navigation would be maintained.

In terms of magnitude, once the pipeline is fully operational, effects on vessel traffic and anchoring in Cook Inlet or in Iliamna Lake would be reduced. The 12-inch diameter pipe would be placed in a trench deeper than the height of the installation, or HDD would be used to install pipe segments. If the depth of water is greater than 200 feet, the pipeline would be placed atop the seabed. This pipeline would add to the multiple pipelines and other structures already installed and located in Cook Inlet. In Iliamna Lake and Cook Inlet, vessel operators would be notified (via a USCG-approved method) of the pipeline location. Mitigation measures would be included as permit conditions for the protection of navigation and the general public's right of navigation on the water surface, and those can include requirements to report Notice to Mariners, or to install and maintain lights or signals as prescribed by the USCG (see Chapter 5, Mitigation). In terms of duration, effects of post-operational activities would be short term.

4.12.2.4 Alternative 1 – Variant: Kokhanok East Ferry Terminal

The Kokhanok East Ferry Terminal Variant would have the same magnitude, extent, duration and likelihood of impacts to air and surface transportation as the proposed alternative.

For the Kokhanok East Ferry Terminal Lake Variant, there would be little change to navigation of Iliamna Lake other than relocation of the ferry terminal (in-water structures would be nearly identical). Operation of the proposed ice-breaking ferry on Iliamna Lake at the Kokhanok east ferry terminal would be more sheltered from wind and waves, but the route would contain more navigational hazards, such as shallow water, and is 33 percent longer, for a total impact magnitude of 27 miles (PLP 2018-RFI 078). Snowmachine access to Iliamna Lake would be provided to the east of the terminal to enable access to the Sid Larson Bay area without crossing the ferry route (PLP 2018-RFI 078). Alternate, marked safe routes would help avoid the ferry path, but would have the potential to add to travel time, distance, and fuel costs. The duration of these impacts would be long term and they would be certain to occur under this variant.

The Kokhanok East Ferry Terminal Variant has thicker ice for a longer duration than the proposed south ferry terminal. There is a substantial amount of winter traffic between Kokhanok and Sid Larson Bay (to the east of the community), and winter travel routes would cross the Kokhanok east ferry route. However, the creation of an alternate winter travel route along the Kokhanok east spur road with an access point to the lake east of the terminal would mitigate this impact by creating a route that would not cross ferry traffic. However, traffic in the town of Kokhanok would see an increase between the airport and the ferry terminal site. These impacts would also be long term and certain to occur under this variant.

4.12.2.5 Alternative 1 – Summer-Only Ferry Operations Variant

The magnitude of impacts due to the Summer-Only Ferry Operations Variant would be a doubling of truck traffic in the summer to 78 round trips per day on each access road. Surface transportation over ice on Iliamna Lake would not be disrupted during the winter under this variant. This variant would have the same impacts to air transportation as the proposed alternative.

Under the Summer-Only Ferry Operations Variant, the number of in-water structures would be the same but there would be two ferry trips per day during open water, and no trips when there is ice cover. The risk of allision with ferry terminal components would be the same as described above, but in terms of magnitude, increased ferry traffic would increase the risk of vessel collisions, especially if two ferry vessels are needed. These impacts would be long term and certain to occur under this variant.

4.12.2.6 Alternative 1 – Pile-Supported Dock Variant

The Pile-Supported Dock Variant would construct similar structures in navigable waters and would not change vessel traffic compared to the proposed alternative. The magnitude, extent, duration and likelihood of impacts of a pile-supported dock to navigation and air and surface transportation would not differ from those associated with a solid fill type dock.

4.12.3 Alternative 2 – North Road and Ferry with Downstream Dams

At the mine site, Alternative 2 would be very similar to Alternative 1, except that a different dam design would be used to construct the bulk tailings storage facility north embankment. The effects to air and surface transportation would generally be the same as Alternative 1. No effects on navigation would exist for this alternative at the mine site.

4.12.3.1 Surface Transportation

<u>Transportation Corridor</u>

Effects on the Kenai Peninsula would be the same as in Alternative 1. The port location at Diamond Point would require a new mine access road to be constructed to Pile Bay through Williamsport, in the vicinity of and replacing the current Williamsport-Pile Bay Road. Construction would create an increase of traffic on the road during the busy summer months. Once constructed, project-related haul trucks would share the road with privately operated trucks and vessels being portaged. The magnitude of impacts would be an increase in the volume and density of traffic. Because the Williamsport-Pile Bay Road is steep and narrow, it is difficult to traverse, especially with wide loads. An improved road would make the corridor more economically and logistically appealing for portaging vessels and shipping supplies to villages, as the mine access road would be built to withstand the full capacity of current and potential future traffic. This would have the potential of increasing private vehicle traffic further, if the proposed or existing Williamsport port could accommodate the increase. These impacts would occur every season during construction and operations, and would require coordination between Pebble Project and private users.

There are no existing roads in the vicinity of the road proposed to be constructed from Eagle Bay to the mine site, and potential adverse effects on current surface transportation would be similar to Alternative 1 with regard to Iliamna, Newhalen, and Nondalton. This proposed road would cross the existing Newhalen River Road; therefore, building a spur road to Iliamna would not be necessary under this alternative. The magnitude of impacts from this alternative would be that a section of the Newhalen River Road between the crossing and Iliamna would see increased traffic; this road is maintained by the State of Alaska. The duration of impacts would be long term, lasting for the life of the project and the likelihood of impacts would be certain to occur. Under this alternative Kokhanok would not be connected to the road system and would therefore not experience surface transportation effects.

<u>Diamond Point Port</u>

The need for a temporary beachhead during construction may be eliminated at the Diamond Point port site, but a construction camp may be necessary. The magnitude of adverse impacts on surface transportation due to port improvements and operation would be additional mine traffic to the quarry area, and the creation of a connection of the quarry with Williamsport and the road to Pile Bay. The duration and likelihood of these impacts would be long term and they would be certain to occur under Alternative 2.

Natural Gas Pipeline Corridor

Effects of construction of the natural gas pipeline on the Kenai Peninsula would be the same as in Alternative 1. The crossing from Ursus Cove to Cottonwood Bay over land would not affect surface transportation because there are no roads there, and little to no subsistence travel. Construction along the road to Pile Bay would occur simultaneously with road construction and improvements, and impacts to surface transportation would be the same as discussed above. Installation of the pipeline from where it would depart from the road near Pile Bay to where it would realign north of Eagle Bay would run through Pedro Bay. The magnitude of impacts would be in the increase of the number of vehicles in the village as construction vehicles work their way through and near town. This impact would be short term, occurring only during the construction phase. During operations, the pipeline right-of-way (ROW) between the two ferry terminals may create a route for all-terrain vehicle (ATV) or snowmachine traffic. The most likely users of this new route along the ROW would be the residents in the communities of Pedro Bay, Nondalton, Iliamna, and Newhalen. The duration of this impact would be long term lasting though the life of the project. In terms of likelihood, all impacts would be certain to occur under Alternative 2. Impacts of the new ROW on access to subsistence resources are discussed in Section 4.9, Subsistence.

4.12.3.2 Air Transportation

Frequency and impacts of flights to and from Iliamna would be the same as Alternative 1. Construction cargo and passenger flight frequencies to the airstrip in Pile Bay would be similar to flight frequencies to Kokhanok in Alternative 1. The magnitude, extent, duration, and likelihood of impacts to Pedro Bay and Pile Bay would be similar to those discussed for Kokhanok in Alternative 1, including the use of the airport at Pedro Bay during construction. PLP would not construct a new airstrip at Diamond Point, but would improve the existing airstrip near Pile Bay for limited use during construction. It is assumed that improvements would take place on the existing airport footprint and therefore would not affect wetlands and other waters.

4.12.3.3 Navigation

The effects of the transportation corridor on water transportation and navigation would be similar to Alternative 1, except for the location of the ferry terminals, ferry traffic, and bridge locations. The Newhalen River would be crossed by a bridge in a location upriver from that in Alternative 1, and the Iliamna River, considered navigable by the State of Alaska, would be crossed by a bridge along the Williamsport-Pile Bay Road. The Iliamna River Bridge would be built alongside an existing bridge built by the Alaska Department of Transportation and Public Facilities (ADOT&PF) in 2018 to replace a historic trestle bridge on Williamsport-Pile Bay Road. The new bridge would have a vertical clearance of approximately 21 feet, and two sets of pilings set 67 feet apart, and would have potential to replace the ADOT&PF bridge. The upper Newhalen River Bridge would be built with a minimum vertical clearance of 25 feet, and four sets of pilings set at approximately 124 feet apart. Navigation would not be impeded by these bridges, but the instream pilings would represent an increased risk of allision to vessels. As discussed in Alternative 1, the Newhalen River is bigger than other navigable river with crossings. At the proposed crossings, the magnitude of adverse impacts on navigation would be the construction activities occurring in the river at the crossings and the associated increase in traffic crossing the river. The magnitude of effects on navigation at river crossings after construction would consist of bridge pilings and the height of the bridges, lasting through operations and into closure. These short- and long-term effects would be certain to occur under Alternative 2.

Under Alternative 2, the ferry terminals would be relocated to the east but would be similar in design to Alternative 1 and would not be expected to restrict navigation. The community of Pedro Bay would be affected by year-round and summer-only ferry operations in the way that Kokhanok would be as described under Alternative 1. The northeastern portion of Iliamna Lake has a lower median number of days of ice than the southwestern portion, meaning that the ferry route and terminals in this alternative would have less of an adverse effect on winter cross-lake transportation than Alternative 1. See Section 4.9, Subsistence, for impacts of access to subsistence resource use areas.

The Diamond Point port under Alternative 2 would be similar in design and scale to the proposed Amakdedori port and would pose a similar allision risk to vessels transiting the area. However, the port would not block the route that vessels calling on Williamsport would use and existing navigation of the waterway would be maintained. Unlike Alternative 1, dredging would be required at Diamond Point and would require USACE authorization. The magnitude of impacts due to dredging and lightering activities would be in the increase in the number of vessels in the area, especially during inclement weather when vessels take refuge in Iniskin Bay. Project-related vessel activity would be similar to that discussed under Alternative 1, and would be long term, occurring during operations. The likelihood of the impact would be certain under Alternative 2 is selected as the preferred alternative and the project is constructed and built.

The magnitude, duration and likelihood of adverse effects on water transportation from the construction and operation of the natural gas pipeline in Cook Inlet would be the same as Alternative 1, but in terms of extent would be in an area somewhat further north. Under Alternative 2, there would be no pipeline in Iliamna Lake.

4.12.3.4 Alternative 2 – Summer-Only Ferry Operations Variant

Under the Summer-Only Ferry Operations Variant, the magnitude, duration and likelihood of adverse effects on surface transportation traffic would be similar to those discussed under the Alternative 1 variant, but, in terms of extent, would affect the area around Pedro Bay. The magnitude of impacts would be in the increased activities and traffic along the improved Williamsport-Pile Bay Road and disruption from increased truck traffic in the summer, as the volume of mine traffic would double in intensity. Truck traffic would be absent in the winter. The impacts to the Williamsport-Pile Bay Road would be long term and definite.

Under the Summer-Only Ferry Operations Variant, the in-water ferry terminal structures would be the same as described for Alternative 2, but there would be two ferry trips per day during open water and no trips when there is ice cover. The risk of allision with ferry terminal components would be the same as the proposed project, but, in terms of magnitude, increased ferry traffic would increase the risk of vessel collisions, especially if two ferry vessels are needed.

4.12.3.5 Alternative 2 – Pile-Supported Dock Variant

The Pile-Supported Dock Variant would construct similar structures in navigable waters and would not change vessel traffic compared to the Alternative 2 solid fill dock. The magnitude, extent, duration and extent of impacts of a pile-supported dock to navigation and air and surface transportation would not differ from a solid fill type dock.

4.12.4 Alternative 3 – North Road Only

Alternative 3 would be the same as Alternative 1 at the mine site. No effects on navigation would occur for this alternative at the mine site.

4.12.4.1 Surface Transportation

Effects on the Kenai Peninsula would be the same as in Alternative 1. The magnitude, extent, duration and extent of adverse effects of the road from Diamond Point through Williamsport to Pile Bay would be the same as in Alternative 2.

In this alternative, a road would be built from Diamond Point and routed around the north side of Iliamna Lake, through Pedro Bay and to the mine site to eliminate the need for the ferry. The route would be the same as the natural gas pipeline corridor from Alternative 2, and have similar surface transportation effects during construction. The magnitude of effects of this road during operations and closure would be an average of 39 heavy truck round trips per day through Pedro Bay; there would also be some additional vehicle traffic because the road would connect the communities on the northern side of Iliamna Lake over land to each other and to Cook Inlet. Access would be controlled the same as in Alternative 1, although private traffic would be allowed on the Williamsport-Pile Bay portion of the road. The impacts during construction would be short term, and those during operations and closure would be long term. They would be expected to occur under Alternative 3.

The road would have similar effect on traffic in Iliamna, Newhalen, and Nondalton, as described in Alternative 2.

Effects on surface transportation at the Diamond Point port site would be the same as Alternative 2.

Installation of the natural gas pipeline along the road from the Pile Bay spur to the mine site would occur simultaneously with road construction and improvements, and have similar effects as Alternative 2.

4.12.4.2 Air Transportation

Frequency of flights to and from Iliamna would be the same as Alternative 1. Flight frequencies to Pedro Bay would be similar to Alternative 2, but the connecting of Pedro Bay by road to the Cook Inlet would affect frequency of flights after construction, if the road leads to more traffic through Pedro Bay. In terms of magnitude and extent, potential effects on Kokhanok would be limited to resident crew change flights.

4.12.4.3 Navigation

The magnitude, extent, duration and extent of effects of Alternative 3 would be the same as Alternative 2 on navigation and water transportation at the Diamond Point port site and similar to Alternative 2 waterbody crossings along the transportation corridor. This alternative would eliminate the ferry and all impacts to transportation or navigation on Iliamna Lake.

Bridges for Alternative 3 would include Iliamna River (discussed under Alternative 2) and Pile River, considered navigable by the State of Alaska. The Pile River Bridge would have a 26 foot minimum vertical clearance and two sets of pilings set approximately 80 feet apart in the center of the channel. The navigation is not likely to be impeded by these bridges, but the instream pilings would represent an increased risk of allision to vessels. Impacts from the bridges would be long term and certain to occur under Alternative 3.

As discussed under Alternative 2, navigation at the proposed crossings on these rivers would be directly affected during construction of the crossings due to the associated increase in vessel traffic crossing the river. Direct effects of the river crossings after construction would consist of bridge pilings and the height of the bridges being a risk to navigation. The impacts during construction would be short term, and those during operations and closure would be long term. They would be expected to occur under Alternative 3.

4.12.4.4 Alternative 3 – Concentrate Pipeline Variant

The Concentrate Pipeline Variant would result in impacts with similar magnitude, extent, duration and extent as those described above under surface transportation, except that truck traffic would be reduced, reducing the magnitude of effects on overland traffic. This variant would not change the Alternative 3 impacts to navigation or air transportation.

4.12.5 Summary of Key Issues

See Table 4.12-1 for a summary of key issues.

Table 4.12-1: Summary of Key Issues for Transportation and Navigation

Transportation Mode	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
Surface Transportation	Kokhanok, Iliamna, and Newhalen would experience an increase in volume of road traffic due to new road connections with the project area through operations. There would be 39 truck round trips per day on the mine access road and the port access road. The Kokhanok East Ferry Terminal Variant would change the terminus of the port access road but would not change traffic volume. The Summer-Only Ferry Operations Variant would double truck traffic in the summer and eliminate it in winter. The Pile-Supported Dock Variant would not affect surface transportation.	Same as Alternative 1, except impacts from traffic at Kokhanok would occur at Pedro Bay instead. During operations, the pipeline ROW may create a route for ATV or snowmachine traffic between ferry terminals. The Williamsport-Pile Bay Road would experience a high-volume increase in traffic that would last the life of the project. The Summer-Only Ferry Operations Variant and Pile-Supported Dock Variant would have similar effects to surface transportation as these variants under Alternative 1.	Same as Alternative 2 except that the road from Diamond Point to the mine site would be routed through Pedro Bay. During operations and closure, this road would increase traffic in Pedro Bay from mine operations and also from the public, because this road would connect the communities on the northern side of Iliamna Lake over land to each other and to Cook Inlet. The Concentrate Pipeline Variant would reduce truck traffic on the transportation corridor from 39 round trips per day to 21; a controlled access service road would be constructed along the extension of the pipeline to Iniskin Bay.
Air Transportation	During construction 10 flights per week would land at the Kokhanok airport. During operations increased air traffic of up to 10 employee flights and one scheduled cargo flight per week would affect Iliamna and Kokhanok airports, plus additional	Iliamna air traffic would be the same as Alternative 1. This alternative would use the Pile Bay Airstrip instead of the Kokhanok Airport, and the construction cargo and passenger flight frequencies to Pile Bay would be similar to flight	Same as Alternative 2.

Table 4.12-1: Summary of Key Issues for Transportation and Navigation

Transportation Mode	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
	unscheduled cargo flights. Kokhanok Airport would need improved navigation systems and lighting. The variants would not affect air transportation.	frequencies to Kokhanok in Alternative 1. Impacts to Pedro Bay and Pile Bay would be similar to those discussed for Kokhanok in Alternative 1, including the use of the airport at Pedro Bay during construction.	
Navigation	The proposed Amakdedori port / lightering system would add new structures to Cook Inlet that would increase the risk of vessel allision. There would be a noticeable increase in barge and vessel traffic during operations. The new structures and additional marine traffic would not be expected to restrict navigation and would be similar for the supported dock variant. Bridges over the Newhalen and Gibraltar rivers would introduce pilings and the height of the bridges as obstacles, which would increase the risk of allusion. The bridges are not expected to limit navigation. The proposed ferry terminals would add new structures to Iliamna Lake that could increase the risk of vessel allision and there would be additional traffic. The new structures and additional traffic would not be expected to restrict navigation. Impacts from the Kokhanok East Ferry Terminal Variant would be similar but in a different location. The Summer-Only Ferry Operations Variant would have the same in-water structures but would increase ferry trips from one to two round trips per day in the summer, and zero in the winter. This variant would	A new port at Diamond Point would add similar structures in Cook Inlet and also dredging that would increase the risk of vessel allision. These new structures and existing vessel traffic in Iliamna Bay would not be expected to restrict navigation. Bridges over the Newhalen River, Pile River, and Iliamna River would introduce pilings and bridges that would increase the risk of vessel allision, although they are not expected to restrict navigation. The Summer-Only Ferry Operations Variant would have similar impacts as this variant under Alternative 1. Winter travel over frozen Iliamna Lake would be impacted, but this ferry route experiences fewer average days of ice than the route in Alternative 1. This effect would not take place with the Summer-Only Ferry Operations Variant.	Effects on Cook Inlet and rivers would be the same as Alternative 2. This alternative would not require a ferry and would eliminate the impacts to Iliamna Lake navigation that would occur under Alternatives 1 and 2. Alternative 3 would not require a ferry and would eliminate effects on winter traffic on Iliamna Lake that would occur under Alternatives 1 and 2. The Concentrate Pipeline Variant would not change the impacts to navigation for this alternative.

Table 4.12-1: Summary of Key Issues for Transportation and Navigation

Transportation Mode	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variant
	not be expected to restrict navigation. Winter travel over Iliamna Lake would be impacted from open water caused by the ice-breaking ferry. This effect would not take place with the Summer-Only Ferry Operations Variant.		

4.12.6 Cumulative Effects

Past, present, and reasonably foreseeable future activities in the cumulative impact study area have the potential to contribute cumulatively to impacts on transportation and navigation. The potential future actions are similar to the proposed project in how they impact surface, air, and water transportation and navigation during construction, operation, and closure.

The following Reasonably Foreseeable Future Actions (RFFAs) identified in Section 4.1, Introduction to Environmental Consequences, were carried forward in this analysis based on their potential to impact transportation and navigation in the EIS analysis area:

- Pebble Project buildout – develop 55 percent of the resource over 78-year period
- Pebble South/PEB*
- Big Chunk South*
- Big Chunk North*
- Fog Lake*
- Groundhog*
- Shotgun
- Johnson Tract*
- Diamond Point Rock Quarry
- Alaska Stand Alone Pipeline Project
- Alaska Liquefied Natural Gas (LNG)
- Drift River Oil Pipeline
- Cook Inlet Oil and Gas Lease Sales
- Hydrocarbon Exploration Licensing and Leasing Program*
- LPB Transportation Projects
- LPB Community Development and Capital Improvement Projects
- Rural Alaska Village Grant Program Projects
- LPB and other regional Renewable Energy Initiatives
- Nushagak Electric Cooperative Village Intertie Project
- Villages of Iliamna, Newhalen, Pedro Bay, Port Alsworth, Nondalton, Igiugig, Kokhanok, Koliganek, Levelock, New Stuyahok, King Salmon, Naknek, Aleknagik, Clarks Point, Manokotak, Dillingham, Nikiski, and Seldovia

**Indicates exploration activities only.*

The future actions included in this analysis are those that would contribute to the cumulative increase in land, sea, and air traffic in the EIS analysis area.

Furthermore, RFFAs in the immediate project vicinity could potentially extend the operation of the port facilities for an additional 78 years.

4.12.6.1 Past and Present Actions

Actions that have effected transportation and navigation in the past or present in the EIS analysis area include mining exploration, non-mining related projects, community development, oil and gas development, and subsistence activity. These actions have resulted in development of transportation infrastructure and have altered traffic patterns and increased traffic over land, in the air, and on waterways. In particular, the construction of the Williamsport-Pile Bay Road allows transportation of fishing vessels and some cargo from Cook Inlet to Iliamna Lake during the summer season, generating road, marine and Iliamna Lake vessel traffic. Communities and roads already exist in the EIS analysis area, and activities at the mine site and other nearby mineral deposits currently include exploration drilling, which has resulted in a summer season increase in air traffic in support of exploration activities. Oil and gas activity, docks, ports, and marine vessel traffic have impacted navigation in Cook Inlet although there has been little development in Iliamna Lake and the navigable rivers.

4.12.6.2 Reasonably Foreseeable Future Actions

No Action Alternative

The No Action Alternative would not contribute to cumulative effects on transportation and navigation.

Alternative 1 – Applicants Proposed Alternative

Pebble Mine Expanded Development Scenario – The Pebble project buildout RFFA would add additional annual vessel and truck traffic, and would continue operation of the port facilities at a higher production rate over an extended period of time. There is also the possibility of additional infrastructure. Therefore, this scenario would have a larger contribution to cumulative effects in the area.

A larger mine site and infrastructure footprint would be more noticeable to those travelling over land for inter-village trips, and would continue to impede non-mine related access through the mine site. The extended timeframe of mining would have a longer duration of effects on transportation, lasting 78 years. The additional concentrate and diesel pipelines to Iniskin Bay would impact the transportation characteristics of the region similar to those discussed for the natural gas pipeline under Alternatives 2 and 3 above, primarily associated with construction activities and the development of access roads along the pipelines.

The construction and operation of a deep-water loading facility would impact traffic in Iniskin Bay, especially during bad weather, when vessels take refuge there. An additional 58 years of mining and processing would extend the impacts on Cook Inlet traffic. Increased production and transport of concentrate through a pipeline would further increase vessel traffic on Cook Inlet, therefore increasing magnitude, duration, and extent of impacts.

The Amakdedori port facility and applicant's proposed transportation corridor (including ferry) would continue to be used for general cargo and concentrate shipment, and would extend the duration of truck and vessel traffic effects in the port area and transportation corridor, although at a reduced level. The access road to Diamond Point, if open to non-mining traffic, could be beneficial for business, but would increase traffic overall through the Williamsport-Pile Bay Road corridor, and could be permanent.

Other Mineral Exploration Projects – Mineral exploration is likely to continue for the mining projects listed above. Exploration activities would result in disturbance of overland inter-village traffic related to core sampling and temporary exploration facilities.

There would be an accumulating demand for regional and helicopter air transportation and logistical support, particularly if mining exploration activities or construction schedules of the proposed alternative, and RFFAs were to overlap. It is likely that any increased demand for air transport could be met by adding supply, because the RFFA sites are distributed, rather than clustered with different airstrips or staging sites.

The further development of the Diamond Point Rock Quarry could have some effects on transportation if it is developed or operational during the construction phase of Alternative 1, while the Williamsport-Pile Bay Road is used for transport. If issued, the quarry's permit to dredge could either be beneficial to transportation in the area, creating easier navigation in Iliamna Bay, or it could hinder transportation, depending on timing and location of the dredging. Overall, the magnitude of effects and geographic extent of cumulative effects would increase while the duration would remain the same.

Oil and Gas Exploration and Development – Oil and gas projects in Cook Inlet could contribute cumulatively to adverse impacts to boat traffic and navigation on the inlet if construction periods overlapped.

From June to October, vessel traffic in the Cook Inlet typically includes large deep-draft vessels, tugs, barges, and small commercial vessels. Project-generated vessel traffic in Cook Inlet would include deep-draft vessels such as concentrate transport vessels, vessels for fuel, and barges for delivery and transport of materials and supplies. The proposed alternative vessel and barge delivery traffic would contribute to the disturbance of transportation access and traffic levels in Cook Inlet. Magnitude and geographic extent of effects would increase, while duration would remain the same.

Road Improvement and Community Development Projects – Anticipated road improvement projects in the region include new transportation corridors currently being studied in the LPB, such as the Williamsport-Pile Bay Road upgrade and the Nondalton-Iliamna River Road Corridor and Bridge, which would improve overland routes in the region (access to Nondalton) and inter-regionally from Cook Inlet to Iliamna Lake. These improvements could have positive cumulative effects on transportation with Alternative 1. The timing of the improvements to the Williamsport-Pile Bay Road would be critical as to whether the improvements would be positive or adverse to traffic on the road. If implemented during the construction phase of Alternative 1, the magnitude of adverse effects would be temporary but high, and affect the progress of road improvement, portaging ships, and PLP's construction schedule, and could increase duration of all three elements. If the improvements occurred before or after the construction phase of Alternative 1, the magnitude would be far less and duration would be unchanged from the original scenario.

Surface transportation disruption would occur along roads leading to the communities of Iliamna, Newhalen, and Nondalton via the proposed Iliamna spur road, and Kokhanok community roads would be connected to the proposed south access road, which would run from the proposed south ferry terminal to Amakdedori port. Cumulative impacts would occur associated with surface transportation between the communities for subsistence and recreational uses, in addition to the ongoing LPB, rural Alaska Village Grant Program, and other village projects.

An additional RFFA that has the potential to affect transportation and navigation in the region is subsistence activities, as they can increase the number of people using over-land routes and boat traffic in certain areas.

Alternative 2 – North Road and Ferry with Downstream Dams

Pebble Mine Expanded Development Scenario – Cumulative effects of construction disturbance, traffic, and navigation impacts would be similar to those discussed under Alternative 1, except the magnitude and geographic extent of impacts would be reduced (Alternative 2 would not develop both Amakdedori and Diamond Point transportation corridors, the corridor for the diesel and concentrate pipelines would have been disturbed for the natural gas pipeline, and the transportation and natural gas pipeline corridors would already have some impacts on transportation and navigation in Iliamna and Iniskin bays.) An access road would be constructed along the concentrate pipeline and year-round ferry operations would be discontinued.

Other Mineral Exploration Projects – Cumulative effects of these activities would be similar to those discussed under Alternative 1.

The development of the Diamond Point Rock Quarry would have similar impacts on transportation and navigation as during the construction phase of Alternative 1, because the Williamsport-Pile Bay Road and Iliamna Bay would be used for transport. The development and operation of the Diamond Point Rock Quarry was considered above; the magnitude of effects, geographic extent, and duration of cumulative effects would be the same as discussed.

Oil and Gas Exploration and Development – Cumulative effects of these activities would be similar to those discussed under Alternative 1.

Road Improvement and Community Development Projects – The Williamsport-Pile Bay Road upgrade and the Nondalton-Iliamna River Road Corridor and Bridge construction would have similar cumulative effects as in Alternative 1, except that the road to Nondalton could connect with the pipeline corridor, creating an over-land access route for Iliamna, Newhalen, and Nondalton to Pedro Bay and the Cook Inlet. The magnitude, geographic extent, and duration of cumulative impacts in Alternative 2 would be greater than in Alternative 1 as the project infrastructure and logistical operations would be more concentrated in this area through all phases, having a larger compounded impact over the life of the project and beyond.

Alternative 3 – North Road Only

Pebble Mine Expanded Development Scenario – Expanded mine site development and associated contributions to cumulative impacts would be similar to Alternative 2. Under Alternative 3, project expansion would continue to use the existing Diamond Point port facility, would use the same natural gas pipeline, and would use the same north access road and Concentrate Pipeline Variant infrastructure, but would extend the concentrate pipeline to Iniskin Bay. The port site and associated facilities would be constructed at Iniskin Bay as discussed under Alternative 1 above. A diesel pipeline from the mine site to Iniskin Bay would be constructed as discussed under cumulative effects for Alternative 1.

Other Mineral Exploration Projects – Cumulative effects of these activities would be similar to those discussed under Alternative 1.

The development of the Diamond Point Rock Quarry would have similar impacts on transportation and navigation as Alternative 2. The development and operation of the Diamond Point Rock Quarry was considered above; the magnitude of effects, geographic extent, and duration of cumulative effects would remain the same.

Oil and Gas Exploration and Development – Cumulative effects of these activities would be similar to those discussed under Alternative 1.

Road Improvement and Community Development Projects – The Williamsport-Pile Bay Road upgrade and the Nondalton-Iliamna River Road Corridor and Bridge construction would have similar cumulative effects as under Alternative 2.

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4.13 GEOLOGY

This section describes project-related impacts on the geologic resources discussed in Section 3.13, Geology, for all project alternatives and variants. The impacts include removal and relocation of rock, soil, and sediment. Appendix K4.13 presents an analysis of potential impacts on paleontological resources. The impacts of the project on other aspects of the geologic environment are described in the following sections: Section 4.14, Soils; Section 4.15, Geohazards; Section 4.17, Groundwater Hydrogeology; Section 4.18, Water and Sediment Quality; and Section 4.22, Wetlands/Special Aquatic Sites, which also describes the affected footprint of project features, and facilities of the components, for all phases of the project.

The Environmental Impact Statement (EIS) analysis area for geology includes the footprints for the mine (including material sites), port and ferry terminals, and transportation and pipeline corridors.

The impact analysis considered the following factors: magnitude, duration, geographic extent, and potential:

- Magnitude – impacts are assessed based on the magnitude of the impact as indicated by the quantified amount of geologic resources expected to be affected (e.g., cubic feet or tons affected).
- Duration – impacts are assessed based on the duration of effects on geologic resources (e.g., short-term, long-term, or permanent). Short-term effects are considered to be those impacts occurring only during the construction and operations phases; long-term effects are considered to be those impacts extending into closure; and permanent effects are considered to be those impacts extending indefinitely into post-closure, with no restorative actions planned.
- Geographic extent – impacts are assessed on the location and distribution of occurrence of the expected effects on geologic resources (e.g., mine site footprint).
- Potential – impacts are assessed based on the potential likelihood of an effect to geologic resources occurring as a result of the proposed action or alternatives.

All three action alternatives would result in a similar magnitude and potential for impacts related to geology. The primary difference between the alternatives would be the areas and volumes of associated geologic resources that would be affected.

Geotechnical investigations and studies have been completed to support engineering design (see Appendix K4.13). Additional investigations and studies are ongoing, and will continue as needed to support detailed design and ensure project compliance with all relevant regulations that are protective of the environment. Mitigation measures that would reduce project impacts to geologic resources are discussed in Chapter 5, Mitigation.

4.13.1 No Action Alternative

Under the No Action Alternative, the Pebble Project would not be undertaken. No construction, operations, or closure activities would occur. Therefore, no additional future direct or indirect effects on recreation would be expected. Though no resource development would occur under the No Action Alternative, permitted resource exploration activities currently associated with the project may continue (ADNR 2018-RFI 073). Pebble Limited Partnership (PLP) would have the same options for exploration activities that currently exist. In addition, 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 to continue under this alternative (PLP 2018-RFI 073), which could include borehole drilling and sampling.

Geology along the transportation corridor, natural gas pipeline corridor, and at the port sites would remain in its current state. There would be no effects on existing geology in the areas of these components. In summary, there would be no additional direct or indirect impacts on baseline geology conditions in the EIS analysis area from implementation of the No Action Alternative.

4.13.2 Alternative 1 – Applicant's Proposed Alternative

This section addresses the analysis of impacts from Alternative 1 on geologic resources and materials. Scoping comments related to geology requested that impacts to bedrock, surface geology, material resources, and paleontology be analyzed.

4.13.2.1 Mine Site

Removal/Relocation of Geologic Materials

The magnitude and extent of impacts on geologic materials from construction and operations at the mine site would be the removal and relocation of rock, sediment, and soil within 8,086 acres of land (Chapter 2, Alternatives, Figure 2-4 and Figure 2-5) (PLP 2018d). These impacts would be permanent and would be certain to occur if the project is permitted and constructed. Closure of some facilities and regrading of facility footprints during site closure would minimize some of these impacts (see Section 4.16, Surface Water Hydrology, Figure 4.16-2 through Figure 4.16-6).

Open Pit

Removing and relocating overburden and rock at the open pit would result in direct impacts on geologic resources, which would be permanent, unavoidable consequences of the action alternatives.

The magnitude and extent of impacts from excavating the open pit during construction and operation would be the removal and relocation approximately 1.44 billion tons (approximately 2.9 trillion pounds) of material that would include overburden, mineralized process material, and waste rock. The open pit would be approximately 8 percent of the total mine site surface area (Chapter 2, Alternatives, Figure 2-4).

The majority of rock removed from the open pit would remain at the mine site in perpetuity in the form of tailings. Bulk tailings would remain in the bulk tailings storage facility (TSF) in perpetuity. Pyritic tailings would be stored in the pyritic TSF during operations and relocated to the open pit during closure.

A relatively small fraction of the excavated rock from the open pit would make up the economic minerals that would be processed (concentrated) then exported off site. This economic mineral portion would include 7.4 billion pounds of copper, 398 million pounds of molybdenum, and 12.1 million ounces of gold (PLP 2018d).

Approximately 89.5 million tons of overburden would be removed from the open pit. Suitable rocky overburden materials would be used for embankment fill, regrading purposes, and other rockfill for the project. Appendix K4.15, Geohazards, addresses the volumes and geotechnical characteristics of the rockfill generated from the open pit and the quarries. Some overburden material would be used for regrading purposes, topsoil would be used as a growth medium during reclamation, and the remainder would be placed in the overburden stockpile.

At the end of mining, the pit would be partially backfilled with pyritic tailings and potentially acid-generating (PAG) waste rock. The partial backfilling would reduce the volume of the open pit, but a permanent void in the landscape would remain. The extent of impacts would be limited to the footprint of the excavated pit and the locations where the materials would be relocated in the mine site. These impacts would be certain to occur if the mine were permitted and built as described for Alternative 1.

Tailings Storage Facilities

A bulk TSF and pyritic TSF would store tailings and waste rock generated from the mined and processed open pit rock (Chapter 2, Alternatives, Figure 2-4). Approximately 88 percent (1,140 million tons) would be bulk tailings, and approximately 12 percent (155 million tons) would be pyritic tailings (PLP 2018d).

The bulk TSF would have the largest footprint of the mine site facilities: about 30 percent of the mine site area. The pyritic TSF would compose about 5 percent of the mine site area.

The magnitude and extent of direct impacts on geologic materials resources would be from the removal and relocation of rock and sediment required for construction of the two TSFs. The impacts would be limited to the footprints of the facilities. During closure, the pyritic tailings would be would be backfilled into the open pit, and the footprint of the pyritic TSF would be regraded to near preexisting topography, so that its impact would be long term. The bulk TSF would be closed, recontoured, and vegetated at closure, and would remain as a new landform. The impact of the bulk TSF on the landscape would be permanent and would be certain to occur if the mine is permitted and the TSF is constructed.

Quarries

Surficial sediments and bedrock would be removed from three quarries in the western portion of the mine site to provide rockfill for the construction of embankments, roads, and other mining-related facilities (Chapter 2, Alternatives, Figure 2-4). The quarries would be developed in granodiorite bedrock, and blasting would be required to remove the rock. The combined areas of the three rock quarries would be an estimated 16 percent of the total mine site area. The magnitude and area of impacts from quarry excavation would be the removal of the following estimated volumes of material and respective dimensions (PLP 2018d) (PLP 2018-RFI 015):

- 1.7 billion cubic feet (ft^3) from Quarry A (approximately 5,000 feet by 2,900 feet)
- 3.2 billion ft^3 from Quarry B (approximately 5,800 feet by 7,000 feet)
- 1.4 billion ft^3 from Quarry C (approximately 5,200 feet by 3,300 feet).

The area of Quarry A would be covered during construction of the bulk TSF; Quarries B and C (west and east of the bulk TSF, respectively) would be backfilled and reclaimed during mine closure (see Section 4.16, Surface Water Hydrology, Figure 4.16-4). Excavation of the quarries would result in direct, long-term to permanent impacts on geologic resources. If the project is permitted and the quarries are mined as described for Alternative 1, these impacts would be certain.

Other Mine Site Facilities

Geologic materials would be removed from and/or relocated to various other facility footprints in the mine site, including water management facilities, milling and processing facilities, the power plant, water treatment plants, camp facilities, storage facilities including laydown areas, and access roads (Chapter 2, Alternatives, Figure 2-4).

The magnitude and extent of the direct impacts on geologic resources at the mine site would be the removal and relocation of geologic materials at these sites, limited to the footprints of the respective facilities. Regrading of some of these facilities at mine closure would minimize impacts on geologic materials (see Section 4.16, Surface Water Hydrology, Figure 4.16-6).

Power generation facilities, some camp and storage facilities, access roads, and the open pit water treatment plant would remain to support post-closure water treatment and site monitoring, which would likely continue beyond post-closure. Therefore, the duration of impacts of these facilities on geologic resources would be permanent. The impacts would be certain to occur if the project were permitted and built.

4.13.2.2 Transportation Corridor

Removal/Relocation of Geologic Materials

Access Roads

The construction of access and spur roads (Chapter 2, Alternatives, Figure 2-13) would require removing and relocating surficial glacial deposits and bedrock (PLP 2018-RFI 032a). The 29-mile-long mine access road from the mine site to the north ferry terminal on Iliamna Lake would be constructed in mostly surficial glacial deposits, with the potential for bedrock presence along approximately 2 miles. The spur road to Iliamna would be approximately 7 miles long and underlain by mostly surficial glacial deposits. Therefore, the road construction right-of-way (ROW) width and associated disturbed geologic resources would be similar to those for the mine access road. The port access road from the south ferry terminal to the Amakdedori port would be approximately 37 miles long and underlain mostly by bedrock.

The width of the construction ROW would vary based on the terrain and underlying geology. The estimated range of disturbed geologic resources to construct the road prism may be roughly 60 to 80 feet (PLP 2018d) (Chapter 2, Alternatives, Figure 2-16). This would include the 30-foot-wide road, embankment slopes, drainage ditches, natural gas pipeline, and cut slopes in surficial glacial deposits and bedrock. Portions of the roadbed underlain by bedrock would likely require blasting (Section 3.13, Geology, Figure 3.13-4).

Under Alternative 1, roads would include a total of 97 stream crossings. These crossing structures would consist of nine bridges and 88 culverts. Crossings designated as fish passage culverts are addressed in Section 4.24, Fish Values. All structures would require rock and riprap consisting of blasted bedrock from the geologic material sites discussed below (PLP 2018d) (Appendix K2, Figure K2-1a and Figure K2-1b).

The magnitude and extent of direct impacts on geologic resources would be the disturbance of these resources within the access road ROW, at stream crossings footprints, and at the material sites (MSs) discussed in the next subsection. The access road would be required for site maintenance and monitoring through post-closure. Therefore, impacts on geologic resources would be permanent, and would be expected to occur if the access roads are permitted and constructed as described for Alternative 1.

Material Sites

The access roads would require rockfill and aggregate for embankments and road surfacing during mine construction, operation, and closure. The rockfill and aggregate would be provided by 18 material sites adjacent to the transportation corridor (Appendix K2, Figure K2-1a and Figure K2-1b).

Footprints of the material sites would vary from 8 to 22 acres, for a total of approximately 241 acres (Appendix K2, Alternatives, Table K2-6). The total volume is estimated to be 7.9 million cubic yards (yd^3).

Two of the seven material sites along the mine access road would be situated in bedrock, and therefore would likely require blasting (Section 3.13, Geology, Figure 3.13-4; Appendix K2, Alternatives, Table K2-6). The remaining five material sites would be in surficial glacial deposits generally consisting of silt- to gravel-sized materials that would not require blasting.

No blasting is anticipated for the three material sites on the spur road to Iliamna that would be situated in surficial glacial deposits (PLP 2018-RFI 035).

All eight material sites along the port access road would be situated in bedrock and would likely require blasting.

The magnitude of direct impacts of the project at materials sites would be the removal of rock and gravel from these sites. The impact would be permanent in terms of geologic resources, but the extent would be limited to the material site footprints. The material sites would eventually be stabilized and progressively reclaimed, but generally would not be backfilled during mine closure and post-closure. These impacts to material sites would be realized if the project is permitted and built.

Ferry Terminals

Constructing the north and south ferry terminals on Iliamna Lake would require excavation of surficial glacial deposits and possibly bedrock on the combined 27 acres of the terminal footprints (Chapter 2, Alternatives, Figure 2-21 through Figure 2-26).

The magnitude of impacts due to ferry terminal construction on geologic features would be the removal and relocation of geologic materials. The extent of direct impacts would be limited to the footprints of the facilities. The ferry terminals would be closed and the sites would be reclaimed during closure. Impacts related to geology would be permanent and certain to occur if the project is permitted and the terminals are constructed.

4.13.2.3 Amakdedori Port

<u>Removal/Relocation of Geologic Materials</u>

The Amakdedori port would be approximately 14 acres, and would require construction of a port terminal, a truck route and causeway, and a barge berth (Chapter 2, Alternatives, Figure 2-28 and Figure 2-29).

Surficial glacial deposits and possible alluvium (mostly of sand and gravel) would be affected during construction of the port terminal.

The truck route and causeway would be constructed of an earthfill embankment. The barge berth would be constructed using an enclosed steel sheet-pile wall wharf structure filled with earthfill. The combined area of the causeway and barge berth would be approximately 13 acres (Chapter 2, Alternatives, Figure 2-28) (PLP 2018-RFI 071). The source of the earthfill would likely be the nearest geologic materials site, MS-A08, and possibly the footprint of the port terminal.

The rockfill access causeway would be constructed in nearshore sediment deposits on the bottom of the bay (see Section 4.16, Surface Water Hydrology, for impacts on marine water; see Section 4.18, Water and Sediment Quality, for impacts on marine water quality). Dredging would not be required.

The magnitude of impacts on geologic features due to Amakdedori port construction would be the removal and relocation of geologic materials. The extent of direct impacts would be limited to the footprints of the port (14 acres) and the cause way and barge berth (13 acres). The port would be closed, and undergo reclamation after completion of the off-site transport of concentrate. Therefore, the duration of impacts would be long-term, and certain to occur if the project is permitted and the Amakdedori port is constructed.

4.13.2.4 Natural Gas Pipeline Corridor

Removal/Relocation of Geologic Materials

Construction of the shoreline component of the pipeline west of the compressor station at Anchor Point would use horizontal directional drilling (HDD) (see Section 4.15, Geohazards, for a more detailed discussion). From the eastern nearshore, portions of the pipeline would be installed beneath the seafloor to a depth determined to avoid navigational hazards, then the pipeline would be laid on the seafloor (PLP 2018-RFI 011). The segment of pipeline placed on the Cook Inlet seafloor would not affect geologic resources.

From the western landfall near Amakdedori port, the magnitude of impacts from pipeline construction on upland geologic features would be the removal of both surficial glacial deposits and bedrock (depending on the location along the corridor) to bury the pipeline. Much of this material would be used to backfill the excavation. Upland pipeline construction would be integrated with access road construction in the ROW where practicable and the extent of impacts would generally be limited to the immediate vicinity of the construction ROW and in established areas used for material laydown and staging of equipment.

Installing the pipeline would likely require drilling and blasting for those segments mapped as underlain by bedrock (Section 3.13, Geology, Figure 3.13-4). Where the pipeline installation is coincident with access road construction, the extent of pipeline-related impacts on geologic resources would be considered part of the impact of the access road ROW (Chapter 2, Alternatives, Figure 2-15).

Where the pipeline installation is not coincident with access road construction, the magnitude and extent of impacts from pipeline installation on geologic resources within the ROW and the related corridor would be approximately 100 feet (Chapter 2, Alternatives, Figure 2-54). However, the disturbed area would be reclaimed after installation of the pipeline. Therefore, the impact on geologic resources beyond the installation trench would be short term, lasting only though the construction phase. However, these impacts would be certain to occur if the project is permitted and the pipeline is constructed as described for Alternative 1.

For the crossing of Iliamna Lake, the pipeline would be buried nearshore in sediments to prevent inadvertent damage, but would then be placed on the floor of the lake (PLP 2018d). The pipeline segment placed on the lake floor would not affect geologic resources.

The natural gas pipeline would be required to support mine site maintenance and monitoring through post-closure. Therefore, the impact on geologic resources would be permanent, because of the displacement of materials required to accommodate the pipeline.

4.13.2.5 Alternative 1 – Summer-Only Ferry Operations Variant

Mine Site Concentrate Storage

During the winter, concentrate would be stored in a 38-acre shipping storage container laydown area constructed of rock and gravel fill northeast of the pyritic TSF (Chapter 2, Alternatives,

Figure 2-56). The magnitude and extent of impacts due to construction of the concentrate storage site on geologic features would be the removal and relocation of geologic materials from these 38 acres. The facility would be removed and the sites would be reclaimed during closure. Therefore, impacts related to geology would be long term and certain to occur if the Summer-Only Ferry Operations Variant is chosen, the project is permitted and the storage area is constructed.

Amakdedori Port

The Summer-Only Ferry Operations Variant would require the Amakdedori port to include an expanded storage yard. The extent of impacts on geologic resources would be limited to the construction footprint. The port would be closed and undergo reclamation after completion of the off-site transport of concentrate for the project. Impacts would therefore be long term and certain to occur if the Summer-Only Ferry Operations Variant is chosen and the project is permitted and built.

4.13.2.6 Alternative 1 – Kokhanok East Ferry Terminal Variant

The Kokhanok east ferry terminal would be constructed east of Kokhanok (Chapter 2, Alternatives, Figure 2-41 and Figure 2-42). Construction of the ferry terminal under this variant would encounter similar geology as construction of the Kokhanok ferry terminal.

The Kokhanok east ferry terminal would require approximately 64 percent more rockfill material than the Kokhanok ferry terminal (PLP 2018d). Also, because the natural gas pipeline alignment would not coincide with the road corridor in the northern portion of the alignment, installing the pipeline would result in additional disturbance of geologic materials in the ROW (Chapter 2, Alternatives, Figure 2-41).

Three of the material sites for the Kokhanok East Ferry Terminal Variant would change from MS-A01 through MS-A0 (totaling approximately 39 acres) to MS-K01 through MS-K03 (totaling approximately 163 acres). This would result in an approximately 70 percent increase in the area of material sites needed to construct the Kokhanok East Ferry Terminal Variant.

The magnitude of impacts on geological features due to construction of the Kokhanok east ferry terminal site would be the removal and relocation of geologic materials in the construction footprints of the ferry terminal site, the natural gas pipeline alignment, and the access road to the ferry terminal. The extent of impacts due to the removal of geologic material would be greater than those estimated for the Kokhanok ferry terminal (Alternative 1 without this variant) because more fill would be required to construct the terminal at the east location.

The closure-related impacts of the Kokhanok East Ferry Terminal Variant would be similar to those for the south ferry terminal site. Both ferry terminal sites would be closed, and reclaimed in closure, so that the duration of impacts would be long term. These impacts on geologic resources would be certain to occur if the Kokhanok East Ferry Terminal Variant were chosen, permitted, and built.

4.13.2.7 Alternative 1 – Pile-Supported Dock Variant

The Pile-Supported Dock Variant (Chapter 2, Alternatives, Figure 2-43) would include approximately 518 piles that would disturb approximately 6,500 square feet of area (less than 2 acres) (PLP 2018-RFI 071). This would compare with an estimated 27 acres for the port without the pile-support design (Chapter 2, Alternatives, Figure 2-28). Therefore, the magnitude of impacts on geologic resources due to construction of the Pile-Supported Dock Variant would be approximately 94 percent less on than the earthfill causeway and sheet pile wall wharf structure described for Alternative 1.

As described above for the earthfill causeway and sheet pile wall wharf, the Pile-Supported Dock Variant would be closed, and undergo reclamation after completion of the off-site transport of concentrate, as described under Alternative 1. Therefore, the duration of impacts would be long term.

Closure of the pile-supported port facility would be similar to closure of the port without pile support. However, instead of removing the earthfill from the footprint of the causeway and from behind the sheet pile wall berth and wharf structure, closure would involve removing the steel piling and disposing of it off site (PLP 2018d). Therefore, closure-related impacts would also be approximately 98 percent less than the closure-related impacts of the earthfill causeway and sheet pile wall wharf design. These impacts would be certain to occur if the Pile-Supported Dock Variant were to be chosen, permitted, and built.

4.13.3 Action Alternative 2 – North Road and Ferry with Downstream Dams

The analysis of impacts from Alternative 2 on geologic resources is presented below.

4.13.3.1 Mine Site

Removal/Relocation of Geologic Materials

Impacts of Alternative 2 on geologic resources at the mine site would be similar to impacts of Alternative 1. The difference is that the bulk TSF main embankment would be developed by downstream construction with downstream buttresses under Alternative 2, compared to centerline construction with downstream buttresses under Alternative 1 (Chapter 2, Alternatives, Figure 2-45 through Figure 2-47). The magnitude and extent of impacts to geologic resources would increase from 78 million yd^3 for Alternative 1 to 124 million yd^3 for Alternative 2 (PLP 2018-RFI 075a). This is because the footprint for the bulk TSF main embankment would increase by approximately 119 acres, requiring additional embankment fill. This would be an increase in direct impacts on geologic resources under Alternative 2 of approximately 5 percent for the bulk TSF main embankment, and approximately 1 percent for the overall mine site (PLP 2018-RFI 075a) as compared to Alternative 1. The impacts would be permanent because the bulk TSF would be closed, and reclaimed in place. The impacts would be expected to occur if the Alternative 2 is chosen as the preferred alternative and the project is permitted and built.

4.13.3.2 Transportation Corridor

Removal/Relocation of Geologic Materials

Access Road

Alternative 2 would involve constructing and operating an access road that would total approximately 54 miles (Chapter 2, Alternatives, Figure 2-48; PLP 2018d). An estimated 5 miles of the Alternative 2 access road would use an existing road; and the remainder would require new road construction, or widening of the existing road.

The mine access road to the ferry terminal at Eagle Bay would be approximately 36 miles long and underlain by geology similar to that of the mine access road under Alternative 1, including possible blasting for approximately 2 miles of the corridor (Chapter 2, Alternatives, Figure 2-49; Figure 3.13-4). A spur road to Iliamna would not be required under Alternative 2.

The access road from the Pile Bay ferry terminal to Williamsport would generally follow the existing road (Chapter 2, Alternatives, Figure 2-50; PLP 2018d). However, the road would need to be expanded and possibly bypassed in places to make the road suitable for use by haul trucks. This would have the potential to result in fewer impacts on geologic resources than constructing a new road. However, material sites would still be needed for both construction and maintenance of the road surface (see “Material Sites,” below).

Portions of the corridor are underlain by surficial glacial deposits where there may be less need for blasting. However, if the existing road were to be bypassed or widened to accommodate the requirements for a haul road, it is possible, and in places likely, that bedrock would be encountered outside the ROW of the existing road. For example, several material sites are likely in bedrock.

A new, approximately 3-mile-long access road from Williamsport to Diamond Point would be constructed. Constructing this road would require removing and relocating mostly bedrock. Blasting would likely be required because of the type of bedrock (competent igneous intrusive rock) (Section 3.13, Geology, Figure 3.13-4).

The magnitude of direct impacts on geologic resources from constructing the access road would be the removal of geologic materials. The extent of impacts would be limited to the access road ROW. The total road distance for Alternative 2 would be approximately 19 percent less than under Alternative 1. If the 5 miles of existing road are considered, the net impact on geologic resources under Alternative 2 would be approximately 26 percent less than the impact under Alternative 1.

As described for Alternative 1, the Alternative 2 road would be required for site maintenance and monitoring through post-closure. Therefore, the impact on geologic resources would be permanent. The impacts would occur if Alternative 2 is chosen and the transportation system associated with it is permitted and built.

Material Sites

Road construction and operational maintenance under Alternative 2 would require material sites to provide required aggregate for road surfacing during mine construction, operation, and closure (Chapter 2, Alternatives, Figure 2-48 through Figure 2-50; and Appendix K2, Table K2-6).

For Alternative 2, 17 material sites (including the existing Diamond Point quarry) would be required versus 15 sites under Alternative 1. The footprints of the Alternative 2 material sites would vary from approximately 8 acres to 54 acres, for a total of approximately 431 acres (Appendix K2, Table K2-12). This would be approximately 179 percent more area than needed under Alternative 1.

Blasting would likely be required to remove bedrock from five of the 17 Alternative 2 material sites (Section 3.13, Geology, Figure 3.13-4). No blasting is anticipated for the 10 material sites associated with the mine access road to the Eagle Bay ferry terminal. Five of the seven material sites between Pile Bay and the port would likely require blasting. This would result in approximately 66 percent less blasting than under Alternative 1.

As under Alternative 1, the magnitude of direct impacts on geologic resources at material sites under Alternative 2 would be the removal and relocation of geologic materials for road surfacing. The extent of direct impacts would be limited to the footprints of the material sites. The material sites would be eventually stabilized and progressively reclaimed, but generally would not be backfilled during mine closure and post-closure. Therefore, impacts would be permanent. They would be certain to occur as described in Alternative 2 was chosen, permitted, and built.

Ferry Terminals

The transportation corridor under Alternative 2 would require ferry terminals at Eagle Bay and Pile Bay, which would be approximately the same size as the ferry terminals described for Alternative 1 (Chapter 2, Alternatives, Figure 2-48 through Figure 2-50). The geology at the ferry terminals under Alternative 2 would be similar to the geology at the ferry terminals under Alternative 1.

The magnitude, extent, duration, and likelihood of impacts of construction of the Alternative 2 ferry terminals on geologic resources would be similar to the impacts of the ferry terminals under Alternative 1.

4.13.3.3 Diamond Point Port

Removal/Relocation of Geologic Materials

The Diamond Point port facility would use the same design concept as the Amakdedori port under Alternative 1. The total footprint of the Diamond Point port would be larger than that of the Amakdedori port. The Diamond Point port would encompass an estimated 102 acres (PLP 2018-RFI 071). The estimated dredged area would be an additional estimated 60 to 70 acres. The entire port area would total roughly 162 to 172 acres of affected geologic resources, compared to the roughly 27 acres at the Amakdedori port under Alternative 1.

Dredging would create approximately 650,000 yd^3 of geologic materials to deepen the channel adjacent to and near the port wharf structure. Most dredged material (615,000 yd^3) would be used as earthfill behind the sheet pile wall. Any remaining material would be placed in the Dredged Materials Storage Area west of the port terminal (Chapter 2, Alternatives, Figure 2-52).

The magnitude of direct impacts on geologic resources would be the removal and relocation of geologic materials to construct the Diamond Point port. Because the Diamond Point port site is much larger than the Amakdedori port site, these impacts would be more than five times the geographic extent of the impacts described under Alternative 1. As described for the Alternative 1 Amakdedori port site, the earthen access causeway would affect the nearshore sediment deposits of Iliamna Bay (see Section 4.16, Surface Water Hydrology, for impacts on marine water; see Section 4.18, Water and Sediment Quality, for impacts on marine water quality).

The Diamond Point port would be closed, and would undergo reclamation after the completion of off-site transport of concentrate, as described for Alternative 1. Therefore, the duration of impacts would be long term, and would be certain to occur if this alternative was chosen and the port was permitted and built.

4.13.3.4 Natural Gas Pipeline Corridor

Removal/Relocation of Geologic Materials

Construction of the natural gas pipeline under Alternative 2 would require disturbing both surficial glacial soils and bedrock for all upland portions of the pipeline (Chapter 2, Alternatives, Figure 2-52), as described for Alternative 1 above. The corridor route, length, and respective geologic resources would differ from those of Alternative 1. See Chapter 2, Alternatives, for the Alternative 2 pipeline corridor route.

Pipeline construction materials and methods for Alternative 2 would be similar to those for Alternative 1. However, the pipeline segment between the Pile Bay road intersection and the mine site would require an installation corridor independent of the transportation system. The pipeline installation equipment would require a corridor or ROW estimated at 100 feet wide; the actual width would vary depending on the terrain and underlying geology (Chapter 2, Alternatives, Figure 2-55).

For the pipeline segment between the Pile Bay road intersection and about Pedro Bay, the corridor is underlain by bedrock with relatively steep topography for portions of the alignment. From Pedro Bay to the western portion of Knutson Bay, the geology would consist mostly of surficial glacial deposits, and then bedrock similar to that found near Pedro Bay. From Knutson Bay to the mine site, the geology would generally consist of surficial glacial deposits, similar to the geology of the Alternative 2 transportation corridor to the Eagle Bay ferry terminal.

The total length of the upland section of the pipeline from Ursus Cove to the mine site would be approximately 88 miles. Blasting would be required during installation of an estimated 20 to 25 miles of the pipeline, an estimated 20 to 40 percent less blasting than Alternative 1.

The magnitude of direct impacts on geologic resources from installation of the natural gas pipeline would be the removal and placement of geologic materials for construction. The extent of impacts would be limited to within the construction ROW for pipeline installation. As described for Alternative 1, the natural gas pipeline would be required for site maintenance and monitoring through post-closure. Therefore, the duration of the impact on geologic resources would be permanent and certain to occur if this pipeline as described for Alternative 2 were permitted and built.

4.13.3.5 Alternative 2 – Summer-Only Ferry Operations Variant

Impacts would be the same as those described above for Alternative 1 during summer-only ferry operations.

4.13.3.6 Alternative 2 – Pile-Supported Dock Variant

A Pile-Supported Dock Variant (Chapter 2, Alternatives, Figure 2-58) with a total of 253 steel piles would replace the earthfill causeway, sheet pile wall, and earthfill wharf structure of Alternative 1. The magnitude of the impact would be the disturbance of about approximately 3,200 square feet of geologic resources (PLP 2018-RFI 072). Impacts on geologic resources would be direct, and the extent of impacts would be limited to the footprint of the piling. As described above for the non-pile-supported dock, the Pile-Supported Dock Variant would be closed, and would undergo reclamation after the completion of off-site transport of concentrate, as described for Alternative 1. Therefore, the duration of the impacts would be long term, and they would be expected to occur if Alternative 2 were chosen as the preferred alternative and the Pile-Supported Dock Variant was permitted and built.

Closure of the pile-supported dock port would be similar to closure of the port without pile support. However, instead of removing the earthfill from the footprint of the causeway and from behind the sheet pile wall berth and wharf structure, the closure would include removing the steel piling and disposing of it off site (PLP 2018d). Therefore, the closure-related impacts would also be less than the closure-related impacts of the earthfill causeway and sheet pile wall wharf design.

4.13.4 Action Alternative 3 – North Road Only

The analysis of impacts from Alternative 3 on geologic resources is presented below.

4.13.4.1 Mine Site

Impacts of Alternative 3 on geologic resources at the mine site would be the same as those described for Alternative 1.

4.13.4.2 Transportation Corridor

Removal/Relocation of Geologic Materials

Access Road

Impacts on geologic resources resulting from the construction and operation of the Alternative 3 access road (Chapter 2, Alternatives, Figure 2-61) would be generally the same as the impacts of the natural gas pipeline corridor described for Alternative 2. The differences in potential related impacts are summarized below.

From the mine site to near Knutson Bay, the geology would consist of surficial glacial deposits, similar to the geology of the Alternative 2 transportation corridor to the Eagle Bay ferry terminal. From the western portion of Knutson Bay to Pedro Bay, the geology would consist mostly of bedrock and surficial glacial deposits. From Pedro Bay to the Pile Bay road intersection, the corridor is mapped as underlain by bedrock and relatively steep topography for portions of the alignment.

The access road from the Pile Bay road intersection to Williamsport would generally follow the existing road (Chapter 2, Alternatives, Figure 2-61), which is underlain by a combination of bedrock and surficial glacial deposits. The last approximately 3 miles of new road from Williamsport to the Diamond Point port would be underlain by bedrock.

The magnitude of direct impacts on geologic resources from constructing the access road would be the placement of geologic materials, and the extent of impacts would be limited to the access road ROW. Alternative 3 would require removing and relocating approximately 25 percent more geologic material for the access road than under Alternative 1, and 54 percent more than under Alternative 2. As with Alternatives 1 and 2, the road would be required for site maintenance and monitoring through post-closure. Therefore, the duration of the impact on geologic resources would be permanent. These impacts would be certain to occur if Alternative 3 is chosen as the preferred alternative and the project is constructed and built.

Material Sites

As with Alternative 1 and Alternative 2, access road construction and operational maintenance under Alternative 3 would require material sites, to provide required aggregate for road surfacing during mine construction, operation, and closure (Appendix K2, Figure K2-3; and Table K2-16).

Twenty-seven material sites (including the existing Diamond Point quarry) would be required for Alternative 3, versus 15 sites under Alternative 1, and 12 sites under Alternative 2. The footprints of the Alternative 3 material sites would vary from 8 acres to 54 acres, for a total of an estimated 808 acres (PLP 2018-RFI 035). This would be 208 percent more than needed under Alternative 1, and 72 percent more than needed under Alternative 2.

Blasting would likely be required to remove bedrock from seven of the Alternative 3 material sites (Section 3.13, Geology, Figure 3.13-4). All other material sites would be in surficial glacial deposits. Therefore, approximately 72 percent less blasting would be required under Alternative 3 than under Alternative 1, and 227 percent more than under Alternative 2.

As under both Alternatives 1 and 2, the magnitude an extent of direct impacts to material sites under Alternative 3 would be the removal of rock and gravel. The extent of the impact would be limited to within the footprints of the material sites; the sites would be eventually stabilized and progressively reclaimed, but not backfilled, during mine closure and post-closure. Therefore, the duration of impacts to the sites would be permanent. These impacts would be expected to occur if Alternative 3 is chosen, permitted and built.

Ferry Terminals

No ferry terminals would be needed under Alternative 3. Therefore, no impacts on geologic resources would occur.

4.13.4.3 Diamond Point Port

Impacts on geologic resources at the Diamond Point port site would be the same as those described above for Alternative 2.

4.13.4.4 Natural Gas Pipeline Corridor

Removal/Relocation of Geologic Materials

As described for Alternative 1 and Alternative 2, construction of the natural gas pipeline under Alternative 3 would require removing and relocating geologic resources to bury the pipeline in an excavated trench for all upland portions of the pipeline.

The Alternative 3 pipeline route would be the same as the route under Alternative 2. However, the Alternative 3 corridor may be an average of approximately 10 to 20 percent narrower, because the access road would be available for staging materials during pipeline installation, instead of needing an estimated 100-foot-wide ROW for pipeline installation when not adjacent to an access road (Chapter 2, Alternatives, Figure 2-54).

Therefore, the magnitude of impacts to geological resources would be less than that for Alternative 2. The extent of impacts would be within the pipeline and access road corridors. As described for both Alternatives 1 and 2, the natural gas pipeline under Alternative 3 would be required for site maintenance and monitoring through post-closure. Therefore, the duration impact on geologic resources would be permanent and expected to occur if Alternative 3 is chosen as the preferred alternative and the project is permitted and built.

4.13.4.5 Alternative 3 – Concentrate Pipeline Variant

The Alternative 3 Concentrate Pipeline Variant would involve installing and operating a concentrate pipeline from the mine site to the Diamond Point port. The pipeline would be installed in the same trench as the natural gas pipeline, and in a ROW estimated to be 100 feet wide (Chapter 2, Alternatives, Figure 2-63). Therefore, impacts would be the same as those for the Alternative 2 natural gas pipeline corridor.

From Williamsport to Diamond Point, the concentrate pipeline would be installed in the transportation corridor, which would still be required for construction and maintenance of the Diamond Point port (Chapter 2, Alternatives, Figure 2-63). The port would be modified to accommodate a concentrate pipeline filter plant and bulk storage building. This would not change the overall footprint of the port. The impact on geologic materials, however, would be similar to that of the port terminal without concentrate-related facilities.

The Concentrate Pipeline Variant would also require a pump house at the mine site. The magnitude and extent of impacts on geologic resources would be limited to a footprint of about 0.7 acre (Chapter 2, Alternatives, Figure 2-62). The concentrate pipeline would be decommissioned in place at mine closure; however, to avoid further ground disturbance, the pipeline would not be removed. Therefore, the duration of impact on geologic materials would be permanent. Impacts would be certain to occur at this magnitude if Alternative 3 was chosen and the pipeline is permitted and built.

4.13.5 Summary of Key Issues

Table 4.13-1 provides a summary of the key issues and impacts from the project on geologic resources.

Table 4.13-1: Summary of Key Issues for Geology

Impact-Causing Project Component	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variants
Mine Site			
Mine Site Construction and Operations	Construction and operation of the mine site would result in removal and/or replacement of geologic resources in conjunction with all facilities. Impacts would occur from blasting of most bedrock in construction areas. All impacts would be direct, and limited to footprints of facilities. No change in impacts for variants.	Impacts similar to those of Alternative 1, except the bulk TSF main embankment, would be downstream; constructed with downstream buttresses, which would result in an ~5% increase in the total mine site footprint, and resulting direct impacts on geologic resources. No change in impacts for variants.	Impacts similar to those of Alternative 1. **Concentrate Pipeline Variant:** Increased project footprint by less than 1 acre, and associated impacts.
Mine Site Closure	All embankments other than those at the bulk TSF would be removed and the areas reclaimed at closure, resulting in direct, long-term impacts. <u>Pyritic TSF</u>: Material would be placed in the open pit, resulting in long-term direct impacts. <u>Open Pit</u>: Would be partially backfilled, resulting in permanent direct impacts. <u>Bulk TSF</u>: Would be closed and reclaimed in place, resulting in permanent direct impacts. No change in impacts for variants.	Impacts would be the same as those for Alternative 1, except with a larger bulk TSF footprint. No change in impacts for variants.	Impacts would be the same as those for Alternative 1. No change in impacts for variants.
Transportation Corridor			
Transportation Corridor Construction and Operations	<u>Access Road:</u> Total 75 miles. <u>Mine Access Road</u>: 27 miles to north ferry terminal, mostly surficial glacial deposits. Bedrock ~2 miles; likely blasting impacts. <u>Iliamna Spur Road</u>: 7 miles, mostly surficial glacial deposits. <u>Port Access Road</u>: 32 miles, mostly bedrock, likely blasting. <u>Geologic MSs:</u> 18 MSs, 241	<u>Access Road:</u> Total 54 miles (~5 miles using existing road). <u>Mine Access Road</u>: 36 miles to Eagle Bay, mostly surficial glacial deposits. Bedrock ~2 miles, likely blasting. <u>Iliamna Spur Road</u>: N/A <u>Port Access Road</u>: 32 miles mostly shallow	<u>Access Road:</u> Total 82 miles. <u>Mine Access to Port Road:</u> Mostly surficial glacial deposits from mine site to Knutson Bay, then a combination of glacial deposits and bedrock to the port. Blasting likely for northwestern Knutson Bay, Pedro Bay to Pile

Table 4.13-1: Summary of Key Issues for Geology

Impact-Causing Project Component	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variants
	acres. Mine Access Road MSs: 7 total and 2 blasting. Iliamna Spur Road MSs: 3 total, and no blasting. Port Access Road MSs: 8 total and all blasting. Ferry Terminals: 27 acres of direct impacts. Kokhanok East Ferry Terminal Variant: Direct impact ~70% more geologic resources to construct than the Alternative 1 terminal, and indirect impact of wider gas pipeline ROW where not adjacent to road.	bedrock blasting. Geologic MSs: 17 MSs, 431 acres. Mine Access Road MSs: 10 total & 0 blasting. Iliamna Spur Road MSs: N/A. Port Access Road MSs: 7 total & 5 blasting. Ferry Terminals: 27 acres, direct impacts. Variants N/A	Bay road intersection, and Williamsport to the port. Geologic MSs: 27 MSs, 808 acres. Mine Access Road to Port MSs: 27 total and 7 blasting. Iliamna Spur Road MSs: N/A. Port Access Road MSs: N/A. Ferry Terminals: N/A. Concentrate Pipeline Variant: Same impacts as those for Alternative 1 for the gas pipeline.
Transportation Corridor Closure	Geologic MSs: Progressively reclaimed but not backfilled, so there would be permanent impacts. Ferry Terminals: Decommissioning and reclamation at mine closure, so long-term impacts. **Kokhanok East Ferry Terminal Variant:** Same as for Alternative 1.	Geologic MSs: Same as for Alternative 1. Ferry Terminals: Same as for Alternative 1. **Variants** N/A	Geologic MSs: Same as for Alternative 1. Ferry Terminals: Same as for Alternative 1. **Concentrate Pipeline Variant:** Same impacts as those of Alternative 2 gas pipeline.
Ports			
Port Construction and Operation	Amakdedori Port: Earthfill embankment causeway and steel sheet pile wall wharf with earthfill design. Port Terminal +Causeway/ Barge Wharf: 27 acres. No dredging. **Pile-Supported Dock Variant:** Reduce causeway/barge wharf to ~0.1 acre **Summer-Only Ferry Variant:** Expanded port terminal by 28 acres.	Diamond Point Port: Earthfill embankment causeway and steel sheet pile wall wharf with earthfill design. Port Terminal Causeway/ Barge Wharf: 101 acres. Dredging: ~60 to 70 acres (most dredged material used as earthfill). **Pile-Supported Dock Variant**: Reduce causeway/barge wharf to ~2 acres.	Same as for Alternative 2. **Concentrate Pipeline Variant:** Modify port terminal, but footprint nearly the same as for Alternative 2.
Port Closure	Amakdedori Port: Structures and earthfill removed after mine closure, so impacts would be long-term. **Pile-Supported Dock Variant**: Same as above, but the impact would be less because of smaller piling footprint and no causeway and wharf earthfill.	Diamond Point Port: Same as for Alternative 1, but with an area about four to five times larger. **Pile-Supported Dock Variant**: Larger area of impact on seafloor. Long-term impacts.	Impacts same as those of Alternative 2. **Concentrate Pipeline Variant**: Minimal impact difference. Long-term impacts.

Table 4.13-1: Summary of Key Issues for Geology

Impact-Causing Project Component	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variants
	Long-term impacts. **Summer-Only Ferry Variant:** Same as for Alternative 1, but larger area and long-term impacts.		
Natural Gas Pipeline Corridor			
Gas Pipeline Construction and Operations	Total Upland Length: 66 miles Kenai Peninsula: HDD at Anchor Point to safe depth in Cook Inlet, then on seafloor. Amakdedori Port to Mine Site: Generally installed within access road alignment, so same geological resources affected. 66 miles upland (plus lake crossing, pipeline on lake floor). Impacts are the same as for Alternative 1 access road. **Variants** N/A	Total Upland Length: 88 miles Kenai Peninsula: Same as for Alternative 1. Ursus Cove to Mine Site: Independent alignment from Ursus Cove to Diamond Point port. Installed in access road to Pile Bay road intersection. Then independent ROW to mine site. Impacts for ROW independent of access road about 10 to 20% more because of design width. Would directly affect geologic resources consisting of surficial glacial deposits for about 63 to 68 miles, and bedrock for the remainder, which would likely require blasting. **Variants** N/A	Same as for Alternative 2 except installed in access road ROW. **Variants** N/A
Gas Pipeline Closure	Required through post-closure, resulting in permanent impacts. **Variants** N/A	Same as for Alternative 1. **Variants** N/A	Same as for Alternative 1. **Variant** N/A

MS = material site N/A = not applicable

4.13.6 Cumulative Effects

The cumulative effects analysis area for geologic resources encompasses the footprint of the proposed project, including alternatives and variants. In this area, a nexus may exist between the project and other past, present, and reasonably foreseeable future actions (RFFAs) that could contribute to cumulative effects on geologic resources. Section 4.1, Introduction to Environmental Consequences, details the comprehensive set of past, present, and RFFAs considered for evaluation as applicable. A number of the actions identified in Section 4.1, Introduction to Environmental Consequences, are considered to have no potential of contributing to cumulative effects on geologic resources in the analysis area. These include offshore-based developments, activities that may occur in the analysis area but are unlikely to result in any appreciable impact on geologic resources (such as tourism, recreation, fishing, and hunting), or actions outside of the cumulative effects analysis area (e.g., Donlin Gold, Shotgun, Johnson Tract).

Past, present, and RFFAs that could contribute cumulatively to geologic resource impacts, and are therefore considered in this analysis, include:

- Pebble Project buildout—develop 55 percent of the resource over a 78-year period
- Pebble South/PEB*
- Big Chunk South*
- Big Chunk North*
- Fog Lake*
- Groundhog*
- Diamond Point Rock Quarry

**Indicates exploration activities only.*

4.13.6.1 Past and Present Actions

Past and present actions that have impacted geologic resources in the analysis area include transportation development where existing roads intersect the project footprint, and mineral exploration in locations where past or current activities have impacted geologic resources (e.g., drill sites). Although these actions affect localized areas, they are additive to other actions that may occur, slightly increasing the total cumulative effect on geologic resources. Past exploration at the Pebble deposit has included drilling of over 1,600 boreholes. Similarly, there have been boreholes drilled associated with exploration at other deposits in the analysis area. However, for approved exploration activities on state lands, there are requirements with regard to stabilizing boreholes and site remediation. Overall, the cumulative effects on geologic resources from past and present actions are minimal in extent and minor in magnitude for all action alternatives.

4.13.6.2 Reasonably Foreseeable Future Actions

No Action Alternative

The No Action Alternative would not contribute to cumulative effects on geologic resources.

Alternative 1 – Applicant's Proposed Alternative

Pebble Mine Expanded Development Scenario – An expanded development scenario for this project, as detailed in Section 4.1, Introduction to Environmental Consequences, Table 4.1-2, would include an additional 58 years of mining (for a total of 78 years) over a larger mine site footprint, and would include increases in port and transportation corridor infrastructure. The mine site footprint would have a larger open pit and new facilities to store tailings and waste rock (Section 4.1, Introduction to Environmental Consequences, Figure 4.1.1), which would contribute to cumulative effects on geologic resources through removal of overburden, waste rock, and ore.

The mine-expanded development scenario project footprint would impact approximately 34,790 acres, compared to 12,371 acres under Alternative 1.

Other Mineral Exploration Projects – Mineral exploration is likely to continue in the analysis area for the mining projects listed previously in this section. Exploration activities, including additional borehole drilling, road and pad construction, and development of temporary camp and other support facilities, would contribute to the cumulative effects on geologic resources, although impacts would be expected to be limited in extent and low in magnitude.

Road Improvement and Community Development Projects – Road improvement projects could have limited impacts on geologic resources, and therefore contribute to cumulative effects in the analysis area. The most likely road improvements in the area would be in the development footprint of existing communities, with only Iliamna and Newhalen being considered to be in the analysis area for geologic resource cumulative effects. Some limited road upgrades could also occur in the vicinity of the natural gas pipeline eastern terminus near Stariski Creek. None of the anticipated transportation development in the geologic resources analysis area would contribute greatly to cumulative effects on those resources.

Additional RFFAs that have the potential to affect geologic resources in the analysis area are limited to the Diamond Point rock quarry. That RFFA would include the excavation of geologic resources, which would represent a direct and cumulative effect. The estimated total rock reserve of the proposed quarry source is approximately 10 to 15 million cubic yards (USFWS 2012g).

Alternative 2 – North Road and Ferry with Downstream Dams

Pebble Mine Expanded Development Scenario – Expanded mine site development and associated contributions to cumulative effects would be the same for all action alternatives. Under Alternative 2, project expansion would use the existing Diamond Point port facility; would use the same natural gas pipeline; and would use the constructed portion of the North Road. A concentrate pipeline and a diesel pipeline from the mine site to Iniskin Bay would be constructed, both having potentially limited impacts on geologic resources due to trenching and burial. Cumulative effects on geologic resources would be similar to those discussed under Alternative 1.

Other Mineral Exploration Projects, Road Improvement and Community Development Projects – Cumulative effects of these activities on geologic resources would be similar to those discussed under Alternative 1.

Alternative 3 – North Road Only

Pebble Mine Expanded Development Scenario – Expanded mine site development and associated contributions to cumulative effects on geologic resources would be very similar for all action alternatives. Under Alternative 3, project expansion would use the Diamond Point port facility; would use the same natural gas pipeline and diesel pipeline; and would use the same north access road and Concentrate Pipeline Variant as described under Alternative 2, but extend the concentrate pipeline with a service road to Iniskin Bay.

Other Mineral Exploration Projects, Road Improvement, and Community Development Projects – Cumulative effects of these activities on geologic resources would be similar to those discussed under Alternative 1.

4.14 SOILS

This section describes potential impacts on soils resulting from each project component for all alternatives and variants. Mitigation and control measures would incorporate structural and non-structural best management practices (BMPs) to address erosion and stormwater runoff. The evaluation also assumes that activities would be performed in accordance with prepared water management and sediment control plans, and necessary Alaska Department of Environmental Conservation (ADEC) permits (if issued) and stormwater pollution prevention plans (SWPPPs). This includes typical or standard practice activities and BMPs when none are specified in project documents (see Chapter 5, Mitigation).

The Environmental Impact Statement (EIS) analysis area for soils includes all areas that would be disturbed as a result of the project, and addresses all alternatives, components, and variants. Disturbed areas would include locations of removal or subsequent placement of soil.

The impact analysis considered the following factors: magnitude, duration, geographic extent, and potential:

- Magnitude – impacts are assessed based on the magnitude of the impact, as indicated by the quantified amount of soil resources expected to be affected (e.g., cubic feet or tons affected).
- Duration – impacts are assessed based on the duration of effects on soil resources (e.g., short-term, long-term, or permanent). Short-term effects are considered to be those impacts occurring only during construction and operations phases; long-term effects are considered to be those impacts extending into closure; and permanent effects are considered to be those impacts extending indefinitely into post-closure, with no restorative actions planned.
- Geographic extent – impacts are assessed on the location and distribution of occurrence of the expected effects on soil resources (e.g., mine site footprint).
- Potential – impacts are assessed based on the potential likelihood of an effect to soil resources occurring as a result of the proposed alternatives.

All three alternatives would result in a similar magnitude and duration of and potential for impacts related to soils. The primary difference between the alternatives would be the amount of soils that would be affected.

There were no scoping comments that addressed specific concerns regarding the impact of the project on soils.

4.14.1 No Action Alternative

Under the No Action Alternative, the Pebble Project would not be undertaken. No construction, operations, or closure activities would occur. Therefore, no additional future direct or indirect effects on soils would be expected. Though no resource development would occur under the No Action Alternative, permitted resource exploration activities currently associated with the project may continue (ADNR 2018-RFI 073). Pebble Limited Partnership (PLP) would have the same options for exploration activities that currently exist. In addition, 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 to continue under this alternative (ADNR 2018-RFI 073), which could include borehole drilling and sampling.

PLP would be required to reclaim any remaining sites at the conclusion of their exploration program. If reclamation approval is not granted immediately after the cessation of reclamation activities, the State may require continued authorization for ongoing monitoring and reclamation work as deemed necessary by the State of Alaska. Soils along the transportation corridor, natural gas pipeline corridor, and at the port sites would remain in the current state. There would be no effects on existing soils in the areas of these components. In summary, there would be no direct or indirect impacts on baseline soil conditions from implementation of the No Action Alternative.

4.14.2 Alternative 1 – Applicant's Proposed Alternative

Impacts to soil resources from Alternative 1 would include those related to soil disturbance and erosion. Soil quality is also evaluated for the mine site due to potential fugitive dust impacts from sources of concern. Factors used to evaluate soil impacts include soil type and area of disturbance; erosion based on BMPs and foreseeable control measures using common industry practices; planned reclamation and objectives; and anticipated effects on soil quality based on planned project activities. Chapter 5 discusses PLP's proposed mitigation measures that have been incorporated into the project.

Evaluation of soil impacts assumes that sediment control measures, BMPs, and adaptive control strategies would be established in a water management and sediment control plan prepared prior to construction and operations; and that proposed earthwork would sufficiently meet necessary conditions required under the Alaska Pollutant Discharge Elimination System program (APDES) for approval of an ADEC Clean Water Act (CWA) Section 402 Stormwater Construction and Operation Permit, and a Stormwater Discharge Pollution Prevention Plan prior to construction. Discharge of pollutants from construction would be addressed under an APDES Construction General Permit (CGP) for disturbances of at least 1 acre of land. The CGP requires establishing authorized stormwater and non-stormwater discharges, including those that are not authorized. A permittee is required to contain runoff from exposed soils to minimize erosion and sediment transport. The CGP also requires established conditions that meet water quality standards through operator control measures. The CGP would be required prior to project start, and would include filing a signed Notice of Intent and SWPPP to ADEC. The SWPPP would be prepared by an ADEC-qualified person, and would establish sources of pollutants and how control measures would be implemented to meet permit standards. The SWPPP also requires establishing inspection-related criteria; how corrective actions are addressed; and permit eligibility related to endangered species. Additional information and reference to applicable requirements are provided in the ADEC APDES CGP-Final, Permit No. AKR100000 (ADEC 2016); Alaska Storm Water Guide (ADEC 2011); and Alaska Department of Transportation and Public Facilities (ADOT&PF) Best Management Practices for Erosion and Sediment Control (ADOT&PF 2016). To be issued, the requirements of all of these permits must be met.

Other agencies that may require additional considerations related to upland soils include the Alaska Department of Natural Resources (ADNR) for an Approved Pipeline Right-of-Way (ROW) Permit; the ADOT&PF for a Utility Permit on ROW; Kenai Peninsula Borough; and US Army Corps of Engineers (USACE) Section 404/10 Permit.

4.14.2.1 Mine Site

This section describes potential effects on soils at the mine site from construction through closure and post-closure management.

Soil Disturbance

The magnitude and extent of impact would be the disturbance of approximately 8,086 acres of soil at the mine site. The majority of the extent of the impact would be soils associated with soil map unit IA9 (5,755 acres), with the remaining disturbance associated with soil map unit IA7. The total acreage of soil disturbances includes major earthworks and the duration of the impact would occur be long term over the 4-year construction period, and mine site operations up to closure. The total acreage estimate does not include reclamation of various mine site infrastructure that would be partially restored, or reduced soil disturbances during the closure period. These impacts to soil at the mine site would be certain to occur if the project is permitted and built as described for Alternative 1.

Mine site facilities not required for post-closure activities would be reclaimed in accordance with an ADNR-approved reclamation plan per Alaska Reclamation Act requirements; and mining reclamation regulations per Alaska Statute (AS) 27.19 and 11 Alaska Administrative Code (AAC) 97. The reclamation performance standard is the adequate reclamation of disturbed areas from mining operations, and to leave the site in a stable condition; or reestablishment of renewable resources on the site within a reasonable period of time by natural processes.

Facilities that would be reclaimed include the pyritic tailings storage facility (TSF), bulk TSF, overburden stockpiles, milling and processing facilities, and non-essential roads. Progressive reclamation of the seepage recovery systems, main water management pond, and water treatment plants would be performed in post-closure. With the exception of overburden stockpiles, all reclamation would occur after operations have ceased. Mine site infrastructure that would not undergo reclamation includes the open pit (approximately 608 acres); mine water treatment plants (approximately 27 acres); power generation facilities (approximately 22 acres); inert monofill (approximately 9 acres) in the disturbed footprint; quarry sites (approximately 873 acres); and limited camp, storage facilities, and access roads. The magnitude and duration of post-closure impacts would be that a total of approximately 1,500 acres would not be reclaimed, and would result in permanent disturbances to existing soil conditions.

Although soil conditions underlying the TSF footprints would result in permanent soil disturbances, each would be reclaimed to conform to designated post-mining land use, as administered by the ADNR. The liner below the pyritic TSF would be removed, and bermed structures would be recontoured. This would be followed by application of salvaged growth media and surface restoration. The bulk TSF would remain in place after controlled dewatering and dry closure, resulting in a permanent landform. The bulk TSF surface would be graded and contoured as needed for drainage control. Growth media would be added for seeding and revegetation, including the embankments.

Summary of Soil Disturbance Impacts

Indirect soil disturbance impacts are most likely to be associated with erosion and stormwater sediment transport processes, and are evaluated under erosion.

Soil Quality

The magnitude and extent of project effects on soil quality would be the wet and dry deposition of fugitive dust derived from mine site sources, including mining operations in the pit (e.g., drilling and blasting); material transport, storage, processing, and handling (including ore, waste rock, concentrate, and aggregate); and wind erosion of exposed bulk tailings. This deposition would be long-term, lasting from construction through the life of the project, and would be certain to occur if the project is permitted and built. The cumulative deposition (i.e., loading) of dust throughout construction and operation were evaluated for the potential to impart an adverse change to surface soil chemistry. Dust deposition effects on water quality are discussed in Section 4.18, Water and Sediment Quality.

Fugitive Dust Constituents of Concern

Total potential criteria pollutant and hazardous air pollutant (HAP) emissions were calculated for the mine site and other project components assuming that each emission unit was operated continuously unless otherwise noted (PLP 2018-RFI 007). Annual fugitive particulate matter (PM) emissions were calculated based on conservative scenarios that assumed worst-case conditions for each activity or source component, such as peak ore crushing capacity, maximum ore hauling distance from final pit, and maximum waste rock hauling.

Of the 189 HAPs listed in the 1990 Clean Air Act Amendment and 40 Code of Federal Regulations (CFR) Part 63, applicable metals from fugitive sources were further evaluated for incremental increase over the 20-year operations period (Table 4.14-1). Hydrocarbons, anions, and cations are not considered compounds of concern from fugitive dust emissions.

Table 4.14-1: Calculated Mine Site Post-Dust Deposition Metal Concentrations in Soil

Analyte	Baseline Mean[1] (mg/kg)	Post-Dust Deposition			Comparative Action Levels	
		Incremental Increase over 20 Years (mg/kg)[2,3]	Baseline + 20 Years of Dust Deposition	Percent Increase after 20 Years	Human Health[4] (mg/kg)	Migration to Groundwater[4] (mg/kg)
Antimony	0.24	0.0075	0.25	3.04%	33	4.6
Arsenic	**10.2**	0.0589	**10.3**	0.57%	7.2 (inorganic)	0.2
Beryllium	0.41	0.00213	0.412	0.52%	170	260
Cadmium	0.24	0.00173	0.242	0.72%	76 (diet)	9.1
Chromium (total)	17.7	0.0733	17.77	0.41%	1.0×10^5 (Cr^3)	1.0×10^5 (Cr^3)
Cobalt	6.55	0.0195	6.57	0.30%	--	--
Lead	8.74	0.0205	8.76	0.23%	400	--
Manganese	388.0	0.693	388.69	0.18%	--	--
Mercury	0.120	0.00013	0.120	0.11%	3.1 (elemental)	0.36
Nickel	9.16	0.0176	9.18	0.19%	1,700 (soluble salts)	340
Selenium	2.76	0.00753	2.77	0.27%	410	6.9

Notes:
[1] 3PPI 2011a
[2] Based on PLP 2018-RFI 009 total HAPs concentration in dust and EPA 2005.
[3] Assumptions include life of mine (20 years) deposition period, soil mixing zone of 2 centimeters, and bulk soil density of 1.5 grams per cubic centimeter based on USGS estimate for silty soils (NRCS 2018; EPA 2005).
[4] ADEC 18 AAC 75, Oil and Other Hazardous Substances Pollution Control, September 29, 2018, Table B1. Method Two – Soil Cleanup levels, Human Health, Over 40 Inch Zone, and Migration to Groundwater (ADEC 2017a).
mg/kg = milligrams per kilogram-- No available reference value per ADEC 18 AAC 75. Additional human health evaluation of all HAP metals is provided in Section 4.10 (Health and Safety) based on published EPA Regional Screening Levels (RSLs).

Dust Deposition on Soils

Figure 4.14-1 depicts result of modeling dust deposition at the mine site during operations.

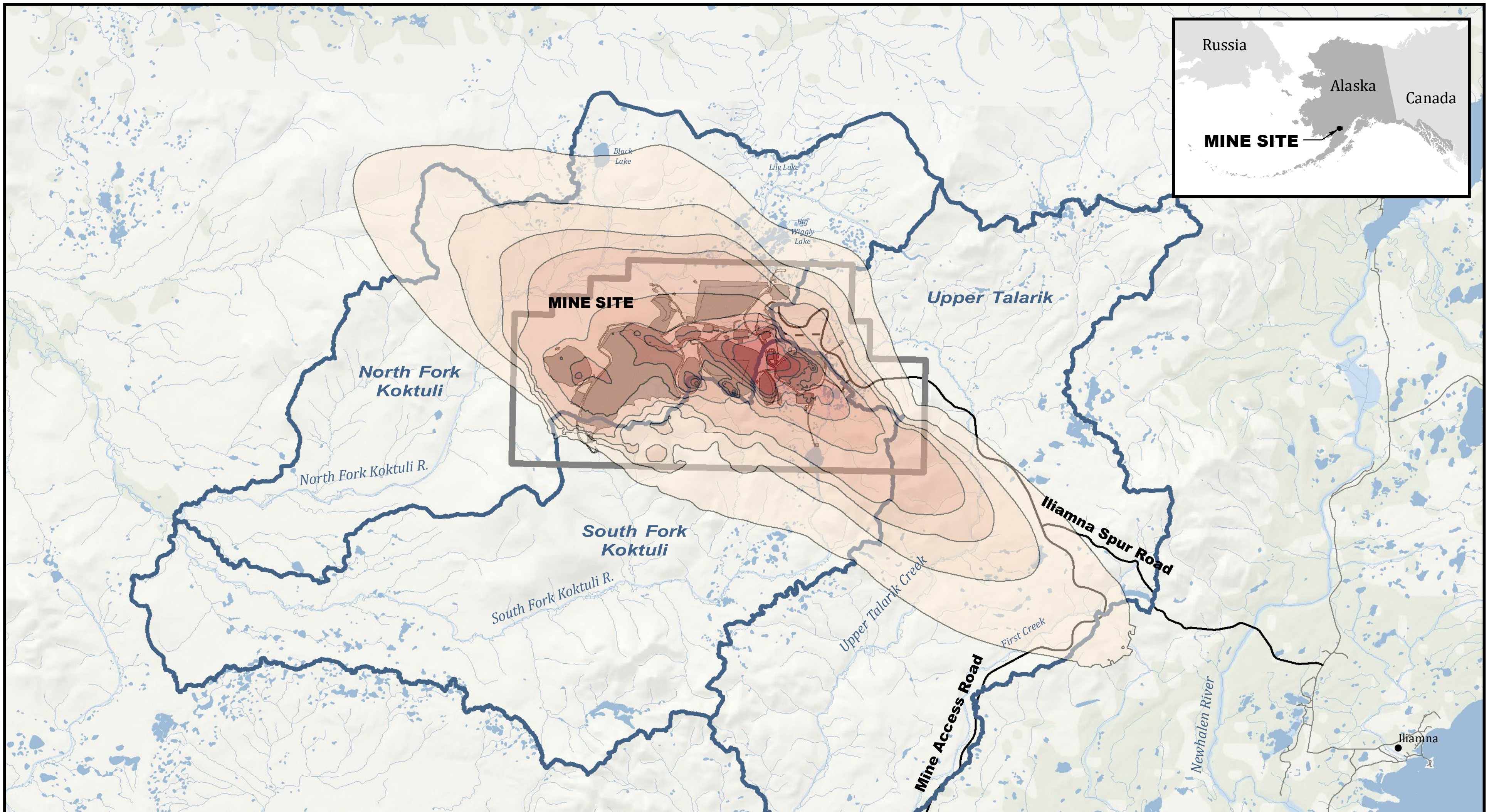
Potential increase in metal concentration in the top 1 inch of soil at the mine site was estimated using AERMOD modeling data for airborne metals concentrations and dust deposition (PLP 2018-RFI 009). The EPA defines ambient air as the portion of the atmosphere, external to buildings, to which the general public has access (40 CFR Part 50.1 [e]). Airborne metal concentration was modeled along the mine site ambient air boundary to determine the maximum cumulative concentration of metals bordering the ambient environment. Extrapolating from the upper-bound airborne concentration, dust deposition was modeled by calculating deposition values for metals (PLP 2018-RFI 009). The incremental increase in metals concentration in mine site soil over the 20-year mine life was calculated using the following formula (EPA 2005):

$$Cs = 100t_D * \left(\frac{D}{Z_S * B_D}\right)$$

Where: C_s is the average soil concentration over the exposure duration (milligrams [mg] constituents of potential concern [COPC] per kilograms [kg] of soil); D is the yearly dry deposition rate (in grams COPC per square meter per year [g COPC/m^2-yr]); t_D is the time period over which deposition occurs (in years); Z_S is the soil mixing zone depth (in centimeters [cm]), B_D is the soil bulk density (grams per cubic meter [g/cm^3]), and 100 is a unit conversion factor. The expected constituent soil concentration after the 20-year mile life due to operational dust deposition was calculated by adding the incremental increase to baseline soil concentrations provided in Appendix K3.14. Calculated results are summarized in Table 4.14-1.

The calculated percent increase in HAP metals from 20 years of dust deposition at the mine site would not be considered of sufficient magnitude to have an adverse impact on surface soils relative to baseline conditions and ADEC action levels used for purposes of comparative evaluation. The greatest percent increase in baseline metals concentration (3.04 percent) is associated with antimony, although the concentrations with dust are still below ADEC levels. All calculated percent increase of other HAP metals were all below 1 percent. With the exception of arsenic, all evaluated metals were well below ADEC levels. The presence of naturally occurring arsenic above the ADEC level is readily apparent, with a reported mean of 10.2 milligrams per kilogram (mg/kg). For these reasons, the incremental arsenic increase of 0.57 percent from fugitive dust in surface soils is considered negligible relative to baseline conditions and documented presence of elevated concentrations in soils throughout the state. The natural occurrence of elevated chromium and arsenic concentrations in soil is acknowledged in ADEC Technical Memorandum, Arsenic in Soil, dated March 2009; and notes 11 and 12 of Table B1 (ADEC 2013d).

Similar to arsenic, elevated baseline concentrations of total chromium are present at the mine site, but well below the ADEC action level for trivalent chromium. Because there are no anthropogenic sources of hexavalent chromium (Cr^{6+}), nor are mineral assemblages considered favorable for Cr^{6+} genesis (e.g., chromite), no further evaluation was conducted. Additional human health evaluation of all HAP metals based on published EPA Regional Screening Levels (RSLs) is provided in Section 4.10, Health and Safety, and includes metals for which no ADEC reference value is shown in Table 4.14-1.



Sources: PLP 2018-RFI009a

Average annual PM_{10} deposition ($g/m^2/yr$)

0.3 - 0.5	4.0 - 6.0
0.5 - 0.7	6.0 - 8.0
0.7 - 0.9	8.0 - 10.0
0.9 - 2.0	10.0 - 20.0
2.0 - 4.0	> 20.0

Alternative 1

- Natural Gas Pipeline
- Transportation Corridor
- Mine Site
- Ambient Air Quality Boundary

Other Features

- Local Roads
- Major Drainage Boundary

US Army Corps of Engineers®

2 0 2 4

Miles

DUST DEPOSITION DURING MINE SITE OPERATIONS

PEBBLE PROJECT EIS

FIGURE 4.14-1

Dust Control

The project design incorporates a number of measures to minimize fugitive dust. Coarse ore would be stockpiled in a covered steel-frame building to minimize dust emissions. Baghouse-type dust collectors would be present at each conveyor-fed ore transfer point between the coarse ore stockpile and semi-autogenous grinding (SAG) ("ball") mills. Water would be added during operations at the SAG mill to suppress dust. Specialized bulk cargo containers equipped with removable locking lids would contain thickened concentrates for transport to Amakdedori port.

The pyritic tailings and potentially acid-generating (PAG) waste would be stored sub-aqueously during operations, removing the potential for wind erosion and dust dispersion from sources with elevated metals concentrations. The bulk TSF would have tailings beaches, which would be susceptible to wind erosion and fugitive dust emissions throughout operations. The bulk TSF would eventually be reclaimed through contouring of surfaces and application of growth media for revegetation and surface stabilization, eliminating the beaches as a dust source following closure activities.

Erosion

The duration and extent of impacts from hydraulic erosion under planned conditions at the mine site would be during the year-round construction phase, coinciding with the longest period of soil disturbances. The magnitude of the impact of removing vegetative matting would be the exposure of fine-grained silty loam—volcanic ash mixtures in shallow surface soils (less than 30 inches deep) that are susceptible to water and wind erosion. Deeper soils consisting of coarser-grained glacial till and colluvium mixtures would be comparatively less susceptible to erosion. Much of the finer-grained (i.e., shallow) soil mixtures exposed during construction would be removed due to undesirable engineering properties (e.g., loading and compaction) required for infrastructure construction, and placed in salvaged growth media stockpiles.

Wind and hydraulic erosion is not anticipated to occur when soils are frozen during winter. Frozen soil conditions generally occur between 4 and 5 months per year (Hoefler 2010a). The greatest potential for hydraulic erosion would be during rainfall events that typically occur during the fall. Soil susceptibility to wind erosion is influenced by moisture and particle size. Wind-induced erosion would be comparatively less than hydraulically driven processes in the construction phase, due to seasonal meteorological conditions and cohesive forces associated with soil moisture. A soil matrix composed of larger grains is less capable of retaining moisture, but less susceptible to wind transport. Although finer-grained soils are generally less tolerant to wind erosion, they are more capable of retaining cohesive moisture. Moisture is anticipated to minimize wind erosion of finer-grained surface soils for most of the year; however, the potential for erosion would be greatest during drier periods lasting 1 to 2 months during the summer.

All runoff water that comes in contact with mine site facilities, or is derived from the open pit, would be captured, including any entrained sediment in runoff from erosion. A Water Management Plan has been developed, and includes water treatment options and strategic discharges of treated water (PLP 2018-RFI 019). A sediment control plan would address construction runoff and associated sediment control measures, BMPs, and adaptive control strategies.

Water management structures (e.g., berms, channels, collection ditches) would be designed to accommodate a 100-year, 24-hour rainfall event. Sediment control ponds would be designed to treat a 10-year, 24-hour rain event, and safely accommodate a 200-year, 24-hour rainfall event. Mine site water management infrastructure would include freshwater diversion channels, an open pit water management pond (WMP), the main WMP, the bulk and pyritic TSFs, the bulk

TSF main embankment seepage collection pond (SCP), seepage collection and recycle ponds, sediment ponds, and two water treatment plants. Water management design criteria and structure configurations are further discussed in Section 4.16, Surface Water Hydrology; and in the Operations Water Management Plan (Knight Piésold 2018a).

During construction, runoff upgradient of the TSFs would be intercepted by a cofferdam and released at a discharge point downgradient of all construction activities in the same watershed. Runoff from the TSF embankments during construction would also be captured. Similarly, runoff from larger excavations associated with the construction of long-term infrastructure (e.g., process plant, camps, power plant, and storage areas) would be routed to settling ponds prior to discharge. During operations, comparatively less soil erosion from water would occur because of diminished need for soil removal. Non-contact runoff would be captured in engineered diversion channels and discharged downgradient. In addition, completed construction of most long-term infrastructure would coincide with established water management and sediment control plan measures. Stormwater runoff from mine facilities that only requires sediment removal would be captured in sediment ponds, treated, and discharged under general APDES stormwater permits. Mine site drainage surface water that comes in contact with infrastructure would be diverted to water treatment plants for processing prior to discharge. Although water and sediment control during the operations phase would emphasize contact water minimization and management, runoff and sediment control measures would continue to be managed through BMPs and adaptive control strategies per the SWPPP(s). Reduction in water management during operations would be limited to concurrent reclamation of overburden stockpiles.

The magnitude, extent and duration of impacts from planned management of slurried tailings delivered to the bulk TSF would be the transport of dried, fine-grained tailings materials through wind erosion during operations. Bulk tailings would be pumped and discharged through spigots along the interior of the perimeter cell, with the slurry preferentially discharged to maintain an exposed tailings beach between the TSF embankment and supernatant pond. Although this approach minimizes potential risks associated with seepage effects on embankment stability, the fine tailings (e.g., beaches) would be susceptible to wind erosion when dried. Additional information regarding fugitive dust derived from the bulk TSF is presented in the Soil Quality discussion for the mine site.

The mine site would be reclaimed per an ADNR-approved reclamation plan that establishes requirements for designated post-mining land use. The reclamation plan would supplement or describe measures to control and mitigate erosion at the mine site through the post-closure period. Erosion during closure would be less than during construction, primarily because of comparatively less surface disturbances. Erosion would be greater during closure than operations because of reclamation earthwork required during closure. The magnitude of the impacts from reclamation would be the destabilization of large soil surface areas from decommissioning activities. Earthwork associated with the preparation and application of growth media would likely result in erosion until surface stabilization is achieved. At a minimum, similar measures established for construction in the sediment control plan would address runoff through sediment controls and BMPs. Additional measures may include future developments in available technologies or practices, and refined adaptive control strategies acquired throughout operations. Removal and reclamation of long-term water management infrastructure would progressively coincide with surface stabilization objectives established in the ADNR-approved reclamation plan.

The duration of impacts from erosion during reclamation from destabilized surfaces would likely continue for several years beyond closure. Prescribed design standards for reclaimed infrastructure and monitoring requirements would be established in the reclamation plan.

Continued monitoring would be required to implement any erosional control maintenance or adaptive control measures. Prescribed monitoring would likely occur annually until surface conditions are stabilized, and meet land use objectives. Although reclaimed infrastructure would be designed to withstand anomalous storm events (e.g., 100-year, 24-hour rain event), monitoring would be necessary immediately after any occurrence.

4.14.2.2 Amakdedori Port

This section describes potential effects on shore-based, upland soils at the Amakdedori port site during construction through closure. Offshore sediment impacts resulting from intertidal and open-water construction, operations, and closure of marine facilities are discussed in Section 4.18, Water and Sediment Quality.

Soil Disturbance

No current development exists at the Amakdedori port site. Shore-based soil disturbances would mostly be attributed to construction of the terminal and airstrip. The magnitude and extent of impact would be the disturbance of approximately 20 acres of soil at the Amakdedori port site. This magnitude of soil disturbances at the port would include the complete removal of soil cover at the terminal during construction and placement of engineered fill at the terminal. The duration of these disturbances would be long term to permanent and the impact would be certain to occur if the project is permit and the port is built. Because no construction would be required during operations, subsequent disturbances to soil would likely be limited. With the exception of necessary infrastructure to support shallow-draft tug and barge access to the dock, onshore port facilities would be removed during closure. No additional soil disturbances are anticipated during closure, and restoration of post-disturbance soil conditions would occur through reclamation activities (e.g., scarification, growth media, contouring, and seeding).

Soil Quality

Materials sites for engineered fill are well outside the Pebble deposit, and field review has not identified PAG rock at any of the road material sites. If PAG material were to be identified at a site evaluation prior to use, the material site would be moved (PLP 2018-RFI 035). Furthermore, coarse-grained, engineered fill textures would be less susceptible to erosion or fugitive dust generation, which would be suppressed through watering (PLP 2018-RFI 007). Therefore, engineered fill or locally sourced materials at the port site are not expected to introduce chemical impairments to soils.

The most probable source/activity of soil quality impairment would be concentrate handling. Sealed bulk containers would be emptied offshore in the hold of bulk carriers (i.e., ship), at a depth of no less than 20 feet below the hatch (PLP 2018-RFI 007). The calculated magnitude of total fugitive particulate matter generated on a yearly basis during offshore transfers is 0.002 ton per year (4 pounds). For these reasons, the magnitude and potential of soil quality impact from project activities at the port are considered negligible, and unlikely to impact soil quality in upland conditions. The geographic extent of soil quality impacts (if any) would be confined to the immediate port footprint, of which the duration would be predominantly limited to the construction and operations phases.

Erosion

Water- and wind-induced erosion would occur at the port site throughout construction, and to a limited extent during operation and closure. The potential for soil erosion would be greatest during the initial construction phase.

Earthwork during construction would incorporate erosion control measures specified in an approved SWPPP. Typical measures may include silt fences, hay bales, temporary sedimentation basins; and repurposed brush for berms and watering for dust suppression. BMPs may include crowning or in-sloping of running surfaces; and temporary drainage channels, berms, and catchment basins.

Hydraulic erosion during operations would be comparatively less than during construction due to little additional soil removal and effects of established SWPPP design features (e.g., culverts, swales). Erosion during closure would be less than during construction, but likely greater than during operations. Exposed ground surfaces at sites of removed infrastructure not required for post-closure would be susceptible to wind and water erosion for an interim period until reclamation and restoration activities are completed. The potential for erosion would be mitigated using measures similar to those described for construction.

4.14.2.3 Transportation Corridor

This section describes potential effects on soils along the transportation corridor. Impacts associated with the natural gas pipeline are also included in this section, because the pipeline would be buried in the road prism.

Soil Disturbance

Approximate soil disturbance acreages associated with the proposed transportation corridor include the following:

- Port Access Road – 408 acres
- Mine Access Road – 346 acres
- Kokhanok Airport Spur Road – 15 acres
- Iliamna Spur Road – 119 acres
- Water extraction site access roads – 4 acres (approximate)
- Ferry Terminals – 27 acres
- Material Sites – 241 acres total

Material Sites

The magnitude of disturbances would include the complete removal and segregation of surface soils and overburden materials considered unsuitable for construction purposes. The duration of the disturbance would be long term lasting through the life of the project, but these materials would be salvaged for future reclamation as a growth medium. These impacts on surface soils at material sites would be certain to occur if the project is permitted and constructed as described for Alternative 1. However, mitigation measures described in the following sections and in Chapter 5, Mitigation, would be expected to reduce impacts. Portions of sites no longer used for material extraction would be progressively reclaimed. This would mainly occur after the construction phase, once the bulk demand for materials has been met with infrastructure completion (e.g., roads). Material sites and access roads would continue to be used throughout operations for maintenance of project infrastructure, as needed. Less soil disturbance would occur during operations than during construction, but soil disturbance during operations would be caused by excavation or blasting on an as-needed basis. A need for materials would also persist throughout the post-closure period for continued road maintenance and other limited post-closure needs. Incremental reclamation of disturbance at materials sites would be required. Typical reclamation at gravel material sites would likely include grading and contouring of sidewall slopes; scarification or ripping to promote surface water infiltration and vegetation growth; application of salvaged growth media; and seeding with proposed mixtures as needed. No sidewall reclamation would be conducted at shot-rock material sites with 20-foot bench heights on exposed rock walls.

Soil Quality

Dust from truck traffic and wind erosion of road bed aggregate sourced from materials sites would not be expected to impact chemical concentrations in soils along the access roads. This is because material sites along the access roads are well outside the Pebble deposit; and surface soil conditions associated with the transportation corridor are chemically consistent with those described above and shown in Table 4.14-1 for the mine site study area (SLR et al. 2011a). Metal concentrations in mine site dust were considered to be of insufficient magnitude to have an adverse impact on surface soils. Field review has not identified PAG rock at any of the road material sites. If PAG material were to be identified at a site evaluation prior to use, the material site would be moved (PLP 2018-RFI 035). Therefore, the material sources are not expected to introduce chemical impairments to soil. Transportation of concentrates from the mine site would be in sealed containers with locking lids, and therefore are not expected to be a source of fugitive dust along the roads.

Erosion

Similar to all other project components, stormwater and erosion mitigation and control measures would incorporate structural and non-structural BMPs (PLP 2018d). Wind-induced erosion would be comparatively less than hydraulically driven processes throughout all phases of the project along the transportation corridor, due to seasonal meteorological conditions; physical attributes associated with soil types; infrastructure configuration and construction methods; and planned mitigation. Soils capable of retaining moisture in the project area are generally considered to have a low susceptibility to wind erosion, due to inherent moisture content from periodic precipitation or snowmelt throughout the year. For this reason, the potential for wind erosion would be greatest during drier periods lasting 1 to 2 months during the summer. If necessary, wind erosion can be mitigated through dust-control watering as needed during the summer.

The duration and extent of impacts from hydraulic erosion would be throughout the entire project lifecycle along the transportation corridor; this is evident based on erosion assessments conducted on the existing Williamsport-Pile Bay Road, approximately 30 miles northeast of the port access road. Precipitation events resulting in the greatest erosional losses from surface runoff and flooding generally occur from late September through November. Gently sloping or level transportation infrastructure would be less susceptible to erosional processes. These would include the ferry terminal sites and access roads constructed over glacial fluvial and moraine soil types (Table 4.14-2). Physical conditions more susceptible to hydraulic erosion along the transportation corridor include poorly drained, fine-grained loess or colluvium on sloped topography, waterbody crossings, road prism drainages (e.g., swales), higher-gradient slopes, and sidehill cuts. Approximate access road lengths traversing moderate and rough terrain requiring rock cuts are detailed in Table 4.14-2.

Table 4.14-2: Alternative 1 Road Lengths, Terrain, and Soil Types

Road Segment	Gentle Terrain	Moderate Terrain	Rough Terrain	Approximate Percent Soil Map Unit
Port Access Road	3.9 miles (10%)	9.8 miles (26%)	23.6 miles (63%)	20% (IA72), 80% (IA173)
Mine Access Road	26.7 miles (92%)	2.3 miles (8%)	None (0%)	59% (IA7), 37% (IA94), 4% (HY4)
Iliamna Spur Road	2.9 miles (41%)	4.1 miles (59%)	None (0%)	47% (IA7), 53% (IA9)
Percent Total Access Roads Terrain Type1	46%	22%	32%	

Notes:
[1] Kokhanok airport spur road is not included in the evaluation due to the comparatively short road length and similar conditions to other project access roads.
[2] IA7: Typic Cryandepts – Very gravelly, nearly level to rolling association.
[3] IA17: Dystric Lithic Crandepts – Loamy, hilly to steep association.
[4] IA9: Typic Cryandepts – Very gravelly, hilly to steep association.
[5] HY4: Pergelic Cryofibrists – Nearly level association.
Source: Rieger et al. 1979; PLP 2018

Construction-phase activities that would potentially cause or contribute to erosion include:

- Removal and clearing of vegetation for access roads, material sites, and terminal facilities.
- Overburden clearing and vegetative mat removal for cut and/or fill placement of engineered materials (e.g., aggregate, substrates).
- Overburden management that would include stockpiles or windrows of organic-rich materials and vegetation, or excavated substrates considered unsuitable for infrastructure construction.
- Development of material sites and material site access roads.
- Blasting of bedrock to support roadbed construction.

The magnitude of effects from erosion during construction would vary along project road segments depending on soil types and physical conditions present, seasonal conditions, and construction requirements. The extent of impacts from erosion may be localized at susceptible locations, such as waterbody drainages and crossings (e.g., culverts, bridges, and swales), wetlands, or intermittent sloped topography. Impacts of erosion, though generally expect to only occur during the construction phase, would be long term in that the results of the erosion would be evident until the sites are reclaimed. Broader areas considered more susceptible to runoff and erosion would include continuous segments of road through rough terrain; and to a lesser extent, moderate terrain. These conditions would require steeper roadbed grades and side-hill cuts that could result in greater erosion potential from runoff (i.e., greater energy) and slope failure.

Terrain and substrates along the port access road correspond with conditions that are considered most susceptible to erosion along the corridor. About 63 percent of the port access road would be predominantly constructed over rough, variable terrain (Table 4.14-1), where fine-grained soil types reportedly overlie shallow bedrock. Although conditions along the port access road appear most vulnerable to hydraulic erosion processes, the evaluation is based on generalized soil descriptions provided in the Exploratory Soil Survey of Alaska (ESS), (Rieger et al. 1979), and does not account for local variations in soil conditions or bedrock outcrops where no soil horizon may exist. With the exception of the northernmost 4- to 6-mile portion of the port access road route, blasting will be required for most roadbed construction, supporting the prevalence of shallow bedrock and moderate to rough terrain conditions (PLP 2018-RFI 084).

No rough terrain requiring rock cuts is present along the Iliamna spur road or the mine access road; however, each traverses approximately 59 percent and 8 percent of moderate terrain, respectively. The mine access road would be least susceptible to hydraulic erosion, based on terrain types traversed and soil conditions. Construction methods along the mine access road would require less backslope cuts (i.e., layback), foreslope contouring, and variation in roadbed grade, compared to other access roads. In addition, surficial glacial deposits and gravel fractions in existing soils along the mine access road and Iliamna spur road would be less susceptible to hydraulic erosion, compared to the port access road.

Similar to access roads, the magnitude of effects of hydraulic erosion at material sites would also vary based on source material competency (e.g., shot bedrock or aggregate) and conditions unique to each borrow site location. Construction of material sites and transportation corridor infrastructure would use structural and non-structural BMPs, and employ erosion control measures adequate to satisfy appropriate ADEC discharge permit requirements and coverage under an SWPPP (PLP 2018d).

Ground disturbances would be progressively restored throughout construction until stabilization and restoration are achieved. Most disturbances would likely be stabilized during construction, or several years thereafter, at locations considered less susceptible.

The least erosion would likely occur during operations, when stabilization of disturbed surfaces would be achieved through natural recovery, applied restoration measures, and long-term or permanent stabilization measures. Material sites and access roads would be progressively reclaimed. Typical reclamation BMPs at material sites include benching or sloping of sidewalls to suitable grades, based on material types (e.g., aggregate or bedrock); distribution of salvaged overburden growth media on pit floors and slopes; and tracking and seeding.

Continuous feedback from truck traffic during operations and/or prescribed follow-up inspections would identify areas of acute or persistent erosion. Areas of concern would be identified, and additional or more robust measures applied to meet local site-specific conditions. This would most likely be required along rough terrain associated with the port access road, and/or areas requiring permanent drainage controls (e.g., culverts, bridges, swales).

The magnitude of erosion during closure and post-closure would likely be greater than during operations. Some erosion may be cause by the removal and reclamation of long-term facilities (e.g., ferry terminals) before complete restoration and surface stabilization objectives are met. However, most erosion would likely be associated with permanent roads to the mine site. Monitoring frequencies in post-closure would typically be less than during operations, and there would be reduced access to equipment and resources. Required permanent transportation corridor access would result in an indefinite potential for erosion monitoring and maintenance.

4.14.2.4 Natural Gas Pipeline Corridor

This section describes potential effects on shore-based upland soils from pipeline infrastructure on the eastern side of Cook Inlet. Pipeline impacts for segments of the pipeline coincident with the transportation corridor are addressed above. The magnitude and extent of impact would be the disturbance of approximately 35 acres of soil associated with onshore stand-alone segments of pipeline under this alternative (i.e., western side of Cook Inlet); these soil types are common to the transportation corridor. Impacts would be short term during construction and would be expected to occur if the project is permitted and the gas pipeline is built. Pipeline activities resulting in disturbances to wetlands and submerged ocean and lake sediment are detailed in Section 4.22, Wetlands and Other Waters/Special Aquatic Sites, and Section 4.18, Water and Sediment Quality, respectively.

Soil Disturbance

The magnitude of acreage of shore-based soil disturbances from pipeline infrastructure on the eastern side of Cook Inlet is approximately 5 acres. This would include the compressor station, laydown area, access road, metering pad, and horizontal directional drilling (HDD) work area.

Erosion

Similar to other project components, mitigation and control measures would incorporate structural and non-structural BMPs to address erosion and stormwater runoff (PLP 2018d). The topography associated with the pipeline infrastructure on the eastern side of Cook Inlet is gently sloping or nearly level. Silty loam soils associated with these conditions are considered not be susceptible to erosion by water, but are vulnerable to erosion by wind, assuming the top cover is removed. Use of HDD would provide a sufficiently wide setback distance between the project footprint and Cook Inlet bluff (about 200 feet); project activities are not expected to contribute to ongoing natural erosion in this area (Section 3.15, Geohazards).

4.14.2.5 Alternative 1 – Summer-Only Ferry Operations Variant

This variant would require an increase in soil disturbances associated with the construction of designated concentrate container storage areas at the mine site and Amakdedori port. The magnitude and extent of impacts on soil would be the disturbance of approximately 37.5 acres of additional storage area at the mine site, and approximately 27.5 acres at Amakdedori port. The duration of these impacts would be long term, remaining throughout the mine operations, but not permanent, because they would be reclaimed during closure. These disturbances to soil would be certain to occur if the project is permitted and the Summer-Only Ferry Operations Variant is chosen and built.

This variant would also temporally compress road traffic during ice-free months, which could result in a greater potential for hydraulic and wind erosion along the transportation corridor.

4.14.2.6 Alternative 1 – Kokhanok East Ferry Terminal Variant

Despite a shorter transportation route and reduced ferry terminal footprint, the total acreage of soil disturbance under this variant would be greater than Alternative 1. This is attributed to greater material quantities required for road construction. The magnitude of the impact is 125 additional acres of disturbances from material sites. The total acreage of soil disturbance associated with the Kokhanok East Ferry Terminal Variant is approximately 60 acres greater than Alternative 1. These impacts on soils would be long term and would be expected to occur if the project is permitted and the east ferry terminal is built.

Although soil disturbance acreage is greater under this variant, the potential for erosion is likely to be less. A greater potential for erosion is associated with roads relative to material sites. Roads traverse a broader expanse of terrain and soil types (e.g., waterbodies, cross slopes, inclines) that have a greater point source potential for erosion. Roads typically require a greater diversity of erosion control measures. Engineered fill material sites inherently consist of coarser-grained materials (or bedrock) that are less susceptible to hydraulic and wind erosion. Furthermore, sediment runoff is often retained in the footprint of disturbance (e.g., depressions).

4.14.2.7 Alternative 1 – Pile-Supported Dock Variant

A pile-supported dock constructed at Amakdedori port would reduce the volume of fill material needed for dock access/construction; therefore, less surface disturbance is anticipated at material sites. The magnitude of surface disturbance impacts would be less under this Alternative 1 variant; the duration, extent, and potential would be comparable to Alternative 1.

4.14.3 Alternative 2 – North Road and Ferry with Downstream Dams

The following section describes impacts to soil resources under Alternative 2. Infrastructure descriptions, usage, physical reclamation, and closure would be the same as Alternative 1, but would occur at the locations described under this alternative.

4.14.3.1 Mine Site

The bulk TSF dam at the mine site would be constructed using different methods under this alternative (i.e., downstream method with buttress). The magnitude of the impact of this construction method on soils would be an increased impoundment footprint of 162 acres compared to Alternative 1; however, the total increase in additional acreage would be 155 acres. Overall, the duration and extent of impacts to soil from ground disturbances would be comparable to Alternative 1; however, there would be greater impact magnitude based on the increased acreage of disturbance. Erosion impacts would be the same as Alternative 1; however, there would be an increased potential for erosion based on infrastructure build-out.

4.14.3.2 Transportation Corridor

Soil Disturbance

Transportation corridor components under Alternative 2 would also incorporate two ferry terminals on Iliamna Lake, and road access to either the mine or port (i.e., Diamond Point port). The road would bypass all but 5 miles of the existing Williamsport-Pile Bay Road; however, these sections would require upgrades to accommodate larger vehicles. The magnitude and extent of soil disturbance acreages associated with Alternative 2 transportation infrastructure (including the co-located portion of roadbed pipeline) include:

- Mine site access road: mine site to Eagle Bay ferry terminal site – 505 acres / 36 miles
- Port access road: Pile Bay ferry terminal to Diamond Point port site – 209 acres / 18 miles
- Ferry terminal sites – 25 acres
- Material sites and access roads – 422 acres

Although disturbance mechanisms, nature of impacts, and erosion mitigation and control measures during construction, operations, and closure of transportation corridor infrastructure would be comparable to those described under Alternative 1, the overall magnitude of soil disturbance would be less. This is based on a comparatively smaller transportation corridor soil disturbance acreage required under this alternative. The total road length under this alternative would require approximately 37 fewer miles of road compared to Alternative 1. The total footprint of both ferry terminals would also be approximately 1 acre less. The duration and potential of impacts would be comparable to Alternative 1.

Soil Quality

Impacts to soil quality along the transportation corridor under Alternative 2 would be the same as described for the corridor under Alternative 1.

Erosion

Soil types and general terrain descriptors present along the Alternative 2 transportation corridor are summarized in Table 4.14-3. Terrain descriptors are based on the presence of shallow bedrock or terrain requiring blasting to accommodate road construction.

Table 4.14-3: Alternative 2 Approximate Road Terrain and Soil Types

ESS Soil Type	Gentle to Moderate Terrain	Moderate to Rough Terrain
IA7[1]	51% (~27 miles)	6% (~3 miles)
IA9[2]	9% (~4.8 miles)	< 1% (0.36 miles)
RM1[3]	15% (~8 miles)	9% (~4.5 miles)
SO11[4]	8% (~4.3 miles)	2% (~1 mile)
Percent Total Terrain Type[5]	83% (~44.1 miles)	17% (~9 miles)

Notes:
ESS = Exploratory Soil Survey of Alaska (Rieger et al. 1979)
< = less than
1 IA7: Typic Cryandepts – Very gravelly, nearly level to rolling association.
2 IA9: Typic Cryandepts – Very gravelly, hilly to steep association.
3 RM1: Rough Mountainous Land – Steep rocky slopes.
4 SO11: Humic Cryorthods – Silty volcanic ash over gravelly till, hilly to steep association.
5 Terrain type classification associated with planned blasting requirements (segments) for road construction.
Source: Rieger et al. 1979; PLP 2018d

A greater proportion of coarse-grained materials is present along the transportation corridor route based on generalized soil descriptions provided in the ESS, whereas the occurrence of finer-grained silt/sand loam mixtures are reportedly less prevalent than Alternative 1 (Table 4.14-3). Therefore, less wind erosion is anticipated under this alternative, based on the prevalence of coarser-grained substrates along the transportation corridor; a comparatively smaller acreage of soil disturbance that would reduce the potential for wind shear on disturbed surfaces; and a reduced vehicle travel distance for dust dispersion. Because the proposed route under this alternative is also lower in elevation than Alternative 1, overall wind-driven forces (e.g., velocity) are also likely to be less. However, this would not preclude occurrence of episodic high wind processes that are commonly associated with valley features present along the port access road.

Most hydraulic erosion mechanisms, nature of impacts, and mitigation and control measures during construction, operations, and closure of transportation corridor infrastructure would be comparable to those described under Alternative 1. Similar to Alternative 1, hydraulic erosion susceptibility under this alternative would be greatest along the southernmost port access road segment.

Heavy precipitation and flooding during fall months have previously resulted in significant hydraulic erosion losses along the Williamsport-Pile Bay Road (USACE 2007a; KPB 2014). Specific conditions that resulted in impassable erosion washout at multiple points along the Williamsport-Pile Bay Road in the fall of 2003 included culvert and bridge crossings, and surface water erosion in drainages aligned adjacent (e.g., swale or ditch) to the road (USACE 2007a).

Although the proposed route is commonly aligned with 5 miles of the existing Williamsport-Pile Bay Road, the remaining roadway would be newly constructed roadway to minimize conditions historically susceptible to erosional processes along the current Williamsport-Pile Bay Road alignment. The southernmost uplands road segment has comparatively fewer cross cuts along toe-slopes in areas of greater vertical relief, and traversed terrain is considered to be more gentle and moderate in character (Table 4.14-3). Rock cuts along the southernmost uplands segment and other discrete segments would require blasting; however, it would be comparatively less than the port access road under Alternative 1. Furthermore, roadway commonly shared with the existing Williamsport-Pile Bay Road would be improved to accommodate large trucks. These improvements would foreseeably account for historical erosion occurrence through road design and condition-specific mitigation and control measures.

Approximately 2.5 to 3 miles of road extending from the Diamond Point port site would follow the coastline of Iliamna Bay. This coastline road segment is considered most susceptible to erosion under all alternatives. The coastal road is situated along the toe-slopes of mountainous terrain, and would likely be subjected to marine-driven processes. The topographic relief immediately adjacent to the road from the port is characteristic of a high-energy environment, where natural hydraulic erosion and slope failure processes are likely to be more prevalent. Portions of roadway along this coastline segment could also be more susceptible to tidal action: ice scour/rafting, storm surge, and wave action. Additional discussion regarding slope failure processes and occurrence are presented in Section 4.15, Geohazards.

In summary, the greatest magnitude of corridor erosion under Alternatives 1 and 2 would occur along the port access routes. Erosion along the port access route under Alternative 2 would likely be less, based on a smaller acreage of soil disturbance and presence of terrain types that are associated with a reduced erosion potential. However, the initial 2 miles of road extending from the port under Alternative 2 could be the most erosion-susceptible segment of road. This nearshore segment of road is unique to Alternatives 2 and 3, and would require enhanced design and mitigation measures to account for the high-energy environment. The duration of these impacts would be long term and they would be expected to occur if Alternative 2 is chosen, and the project is permitted and transportation corridor is built.

4.14.3.3 Diamond Point Port

Soil Disturbance

Soils in the port footprint are reportedly associated with rough mountainous land (RM1) consisting of sparsely vegetated soil over shallow bedrock or stones/boulders. The port terminal facility and dredge material stockpile would result in the soil disturbances. The magnitude of shore-based soil disturbances at Diamond Point port would be approximately 41 acres. The estimated acreage of disturbance includes the footprints of the port terminal facility and uplands disposal of dredged materials (e.g., stockpile). The magnitude of dredge material stockpile footprints would total approximately 16 acres, and would be managed similarly to overburden stockpiles. Dredge stockpiles would include berms to contain sediments, collection of seepage, and stormwater runoff, as well as treatment in settling ponds prior to discharge (PLP 2018-RFI 099). These effects on soils would be long term and certain to occur if Alternative 2 is chosen and the Diamond Point port is permitted and built.

Most soil disturbance mechanisms and impacts during construction, operations, and closure at the port would be similar in magnitude, duration, and extent to those described under Alternative 1; however, disturbances unique to this alternative include the following:

- Blasting of shallow bedrock at discrete locations to accommodate port infrastructure
- Uplands disposal of dredge material

Soil disturbances during construction would involve grading and contouring of ground surfaces, and extensive blasting of shallow bedrock to accommodate port construction. Removal of soil considered unsuitable for construction purposes would be limited due to prevalent shallow bedrock and coarse alluvium outwash. The bermed dredge material stockpile would be built immediately adjacent to the port terminal to receive spoils from dredge channel clearance.

Because no additional construction would be required during operations, soil disturbances during port operations would primarily be limited to dredge material stockpile expansion from maintenance dredging. The magnitude of dredged materials to be stockpiled would be, at a minimum, half of the material dredged for channel construction and maintenance (approximately 325,000 cubic yards). This material would be disposed of on-shore in a bermed facility. Soil disturbance impacts associated with the dredge material stockpile could range from the direct burial of existing soils, to potential acute or obvious changes associated with any stockpiled marine sediment in an upland environment. These impacts would be long term, lasting for the duration of the project and would be expected to occur if Alternative 2 is chosen and permitted, and the Diamond Point port is constructed.

Soil Quality

Impacts to soil quality along the transportation corridor under Alternative 3 would be the same as described for the corridor under Alternative 1.

Erosion

Most hydraulic erosion mechanisms, nature of impacts, and mitigation and control measures during construction, operations, and closure of port facilities would be comparable to those described under Alternative 1. The magnitude, extent, duration, and potential of impacts due to erosion would also be comparable to Alternative 1. Because coarse alluvium outwash and shallow bedrock conditions at the port site are less susceptible to erosion, the period of greatest ground disturbance during port facility construction would generally result in less erosion than Alternative 1. However, unique conditions specific to this alternative that could potentially increase erosional susceptibility or require additional design and mitigation measures throughout construction, operations, and post-closure include the following:

- Uplands disposal of dredge material
- Topographic relief and slope stability

Hydraulic erosion of stockpiled dredge materials would be mitigated through proper impoundment and drainage design. Stockpiled materials could be susceptible to wind erosion, depending on the physical attributes of dredge materials (particle size distribution and cohesion); interim surface stabilization measures; constructed dimensions; and frequency and magnitude of coastal and seasonal winds. Physical conditions that are considered less susceptible to wind erosion include high moisture contents or frozen conditions; larger particle sizes; presence of surface cover, and lower slope angles to reduce wind shear. Mitigation measures that may reduce the potential for wind erosion include wind breaks, snow fencing, reduced slope angles, or watering during increased periods of susceptibility. Final closure of the stockpile would include drainage and surface stabilization. Typical measures that could facilitate stockpile surface stabilization include slope and top-cover engineering, tracking (rolling), seeding, and repurposing of material as growth media.

The topographic relief immediately inland of the eastern port footprint (to the jetty/causeway) is characteristic of an environment where natural hydraulic erosion and slope failure processes are likely to be more prevalent. Sloped ground conditions bordering the port footprint have a greater potential for increased surface water runoff, which could result in greater rates of scouring or aggradation. This could potentially include slope failure processes that indirectly impact port infrastructure. Recent slope failure occurrence (e.g., landslide) is present along the access road extending from the port to the jetty. These conditions would require additional design and mitigation measures; however, the potential for slope failure to compromise discrete portions of port infrastructure would likely persist. This would also include infrastructure at the base of headwall cuts in bedrock. Additional discussion regarding slope failure processes and occurrence are presented in Section 4.15, Geohazards.

4.14.3.4 Natural Gas Pipeline Corridor

The pipeline under Alternative 2 would come ashore at Ursus Cove. The pipeline would be constructed below grade along a valley floor, and eventually resurface at the Diamond Point port site after a short marine crossing of Cottonwood Bay. The magnitude of effects would be disturbance to 5.5 miles of uplands that coincide with shallow bedrock and coarse soil textures (e.g., boulder and cobble) in rough mountainous terrain; however, it is likely that an appreciable gravelly sand colluvium is present along the valley floor. The pipeline from the port would follow a shared road corridor towards the Pile Bay ferry terminal. The stand-alone pipeline (no road) between the Pile Bay and Eagle Bay road off-takes would be 36 miles in length.

<u>Soil Disturbance</u>

The magnitude and extent of upland ground disturbance associated with stand-alone pipeline components under Alternative 2 include:

- Stand-alone pipeline construction ROW – 516 acres
- Material sites and access roads – 306 acres
- Operation infrastructure (Compressor Station) – 5 acres
- Temporary construction access – 29 acres

Although the pipeline construction corridor would be 100 feet wide during construction to accommodate trench spoils and heavy equipment traffic, complete removal of the overlying vegetative mat would be limited to an 8-foot span directly above the trench. The total acreage of vegetative mat that would be completely removed during construction is approximately 40 acres. Shallow soil on the spoils and working sides of the trench would mostly be limited to disturbances from working equipment resulting in ground compaction, rutting, or tearing of ground surfaces. The duration and potential of impacts would be comparable to Alternative 1.

Construction would occur year-round along simultaneous or overlapping construction efforts on segments; construction would include preliminary ROW clearing and preparation, followed by pipeline installation, and rehabilitation/commissioning. Temporary pipeline camps and material sites would be required.

Soils that are more susceptible to surface disturbances (e.g., wetlands) would incorporate additional mitigation measures and BMPs. Working pads constructed of swamp mats along the working ROW would be used to minimize surface disturbances during summer months, and frost-packing of the entire construction ROW during winter months. Frost-packing would involve clearing the snow from the ROW to achieve a frost depth of 2 feet below ground surface. Although no other mitigation and restoration activities have been specified, common practices that could be used during construction include salvaging of timber for corduroy matting or ice-pad construction. To the extent practicable, backfilling would occur as soon as possible to minimize additional equipment efforts or soil disturbances. Temporary impoundment of saturated spoils and/or drainage control measures for water accumulation in the trench may be required for construction in wetlands.

Most mitigation and restoration measures would be conducted during and immediately after construction; however, follow-up measures may be required on a case-by-case basis, particularly after winter construction activities. Surface disturbances are expected to recover within the first few years following construction. Soil disturbances during operations would be less than during the construction period. The permanent pipeline ROW may require periodic brush-clearing to accommodate routine and non-routine pipeline monitoring and maintenance over the operational period. Disturbances may result from intermittent corrective maintenance activities or additional surface stabilization measures on a case-by-case basis.

Erosion

Similar to other project components, mitigation and control measures would incorporate structural and non-structural BMPs to address erosion and stormwater runoff. ESS soils corresponding to stand-alone segments of pipeline are summarized in Table 4.14-4:

Table 4.14-4: Alternative 2 Standalone Pipeline Soil Types

ESS Soil Type	Percent Total Alignment (Acreage)	Acres (Miles)
IA7[1]	31%	162 (~13 miles)
RM1[2]	14%	75 (~6 miles)
SO1[3]	<1%	1 (~0.5 mile)
SO11[4]	55%	290 (~24 miles)

Notes:
ESS = Exploratory Soil Survey of Alaska, Rieger et al. 1979
< = less than
[1] IA7: Typic Cryandepts – Very gravelly, nearly level to rolling association.
[2] RM1: Rough Mountainous Land – Steep rocky slopes.
[3] SO1: Typic Cryorthods – Silty loess to fibrous organic soils over gravelly till, nearly level to hilly.
[4] SO11: Humic Cryorthods – Silty volcanic ash over gravelly till, hilly to steep association.
Source: Rieger et al. 1979; PLP 2018d

The magnitude and extent of hydraulic and wind erosion impacts would be largest along pipeline segments in moderate to rough terrain, where finer-grained silty loess or volcanic ash materials are present at shallow depth. The duration and potential of these impacts would be similar to Alternative 1. The segment of stand-alone pipeline from the port road to Canyon Creek west of Pedro Bay generally coincides with finer-grained silty volcanic ash soils (shallow) overlying glacial till (SO11, Table 4.14-4). Slopes range from hilly to steep, and slightly less than half of this segment (12.3 miles) may require some blasting. Based on the presence of rougher terrain (e.g., blasting), steeper slopes, and finer-grained shallow soils, this segment is considered more susceptible to erosion relative to other sections of the pipeline route to the mine site.

Effective erosional management during and immediately after construction is anticipated through applied erosional control measures and BMPs; however, post-construction or operations phase, inspections may identify localized conditions requiring installation of long-term surface stabilization controls. Areas considered more susceptible to erosion, where longer-term surface stabilization controls may be required to promote recovery include, sloped topography, wetlands, and waterbody crossings.

The least amount of anticipated erosion would occur during closure and post-closure. The pipeline would be abandoned in place, and areas requiring more intensive surface stabilization measures would likely be addressed over the period of operation. Surface facilities associated with the pipeline would be removed and reclaimed.

4.14.3.5 Alternative 2 – Summer-Only Ferry Operations Variant

The Alternative 2 Summer-Only Ferry Operations Variant would have the same impact at the mine site as Alternative 1. However, the magnitude of impacts from the Alternative 2 Summer-Only Ferry Operations Variant would be approximately 28.8 additional acres of disturbance at the port, as compared to the Alternative 1 Summer-Only Ferry Operations Variant. The duration of the additional disturbances would remain throughout the period of mine operations, and be reclaimed during closure. It is certain that the impact on soil would occur if Alternative 2 with the Summer-Only Ferry Operations Variant is chosen and the project is permitted and built. No other pipeline, transportation corridor, or mine site infrastructure would change under this variant.

4.14.3.6 Alternative 2 – Pile-Supported Dock Variant

Impacts to soil resources under this variant would be the same as those described for Alternative 1.

4.14.4 Alternative 3 – North Road Only

A continuous overland access road would connect the Diamond Point port to the mine site. The magnitude, extent, duration and potential of impacts to soil resources at the mine site would be the same as Alternative 1, and those at the port would be the same as those described under Alternative 2.

Because the natural gas pipeline would predominantly be aligned with the transportation corridor under this alternative, both are collectively evaluated together for soil disturbance and erosion impacts. However, the magnitude of impacts from construction of the pipeline under Alternative 3 approximately 81 acres of disturbance to soils within the onshore, stand-alone pipeline footprint, in addition to 10 acres of material sites specific to the pipeline. The following section describes impacts for the transportation corridor that would be appreciably different under Alternative 3.

4.14.4.1 Transportation Corridor

Soil Disturbance

The gas pipeline trench would be adjacent to the road (road-bed prism) to facilitate construction, maintenance, and inspection. The pipeline(s) would use vehicle bridges to span major stream crossing, and HDD drilling or trenching across smaller drainages as appropriate. No Iliamna Lake ferry infrastructure would be required under this alternative, based on the continuous overland route to the mine site. The magnitude of estimated acreages of transportation corridor (and pipeline) ground disturbances under this alternative include:

- Shared road corridor/pipeline(s) – 1,036 acres (does not include stand-alone pipeline)
- Shared transportation and pipeline material sites – 717 acres (does not include stand-alone pipeline)

The total magnitude of acreage of ground disturbance from material sites and shared road and pipeline under this alternative is approximately 66 percent greater than Alternatives 1 and 2. The permanent need for transportation corridor access throughout post-closure would create a permanent ground disturbance in the footprint, unlike the approximately 500 acres of stand-alone pipeline corridor ground disturbance associated with Alternative 2 that would be expected to recover to pre-disturbance conditions during the operations phase. This impact would occur if Alternative 3 is chosen, and if the project is permitted and the transportation corridor as described for Alternative 3 is built.

Erosion

ESS soil types corresponding to transportation corridor terrain under Alternative 3 are summarized in Table 4.14-5.

Table 4.14-5: Alternative 3 Approximate Road/Pipeline(s) Terrain and Soil Types

ESS Soil Type	Gentle to Moderate Terrain	Moderate to Rough Terrain
IA7[1]	42% (~34.7 miles)	4% (~3.5 miles)
IA9[2]	6% (~5 miles)	<1% (0.36 mile)
RM1[3]	11% (~8.7 miles)	6% (~4.5 miles)
SO11[4]	15% (~12.3 miles)	16% (~13.5 miles)
Percent Total Terrain Type[5]	74% (~60.7 miles)	26% (~22 miles)

Notes:
ESS = Exploratory Soil Survey of Alaska, Rieger et al. 1979)
< = less than
1 IA7: Typic Cryandepts – Very gravelly, nearly level to rolling association.
2 IA9: Typic Cryandepts – Very gravelly, hilly to steep association.
3 RM1: Rough Mountainous Land – Steep rocky slopes.
4 SO11: Humic Cryorthods – Silty volcanic ash over gravelly till, hilly to steep association.
5 Terrain type classification associated with planned blasting requirements (segments) for road construction.
Source: Rieger et al. 1979; PLP 2018

Mitigation and control measures for erosion and stormwater runoff would incorporate structural and non-structural BMPs common to transportation and pipeline construction practices described under Alternatives 1 and 2. The greatest potential for hydraulic and wind erosion impacts would correspond with invasive ground disturbance during construction. Disturbed surfaces would remain susceptible to erosion until concurrent or follow-up stabilization is achieved. Permit required mitigation measures and BMPs are anticipated to alleviate most conditions throughout or immediately after construction.

More robust mitigation and follow-up stabilization measures during and after construction are likely to be required in areas of moderate to rough terrain, where fine-grained soil conditions exist. This coincides with the segment of stand-alone pipeline from the port road to Canyon Creek west of Pedro Bay under Alternative 2 (SO11 soils). The least amount of erosion would likely occur during operations, when stabilization of disturbed surfaces would be achieved through natural or applied restoration and stabilization measures, and continued (i.e., real-time) monitoring along the corridor. Erosion throughout post-closure would likely be greater than the operations phase, based on an indefinite need for transportation corridor access; a reduced erosion monitoring frequency; and reduced access to equipment and resources.

Summary of Erosion Impacts

Enhanced design and mitigation measures would be required along discrete segments; in particular, the segment of coastline road through rugged terrain from Diamond Point port (2.5 miles) under Alternatives 2 and 3. More robust mitigation and restoration measures may be needed in moderate to rough terrain with finer-grained soil conditions (iSO11 soils). The duration of erosion would vary from completion of the activity (e.g., construction or reclamation), to an indefinite period in post-closure. The extent of erosion effects would be mostly limited to the immediate vicinity of disturbance or footprint.

The overall magnitude, extent, and potential for erosion under this alternative are considered to be greater than the transportation corridor for Alternative 2, based on total footprint acreage, presence of fine-grained soils in moderate to rough terrain, and increased frequency of waterbody crossings. The duration would be comparable to Alternative 2, because both alternatives indefinitely retain transportation corridor infrastructure.

4.14.4.2 Alternative 3 – Concentrate Pipeline Variant

This variant includes an HDPE[1]-lined steel pipeline that would convey slurried copper and gold concentrates from the mine site to the port facility (PLP 2018-RFI 066). The pipeline would be predominantly buried sub-grade in the same trench as the gas pipeline, with approximately 36 inches of top cover. Impacts to soil resources at the mine site and port would be the same as those described under Alternative 2; however, a small soil disturbance increase would be anticipated due to a concentrate pipeline pump house (e.g., 1 acre), and pipeline booster station (0.7 acre).

The shared transportation and concentrate pipeline corridor would increase the road corridor width by less than 10 percent, resulting in a proportional soil disturbance increase. The duration and geographic extent of soil disturbance and erosion would be the same as Alternative 3; however, there would be an appreciable increase in erosion magnitude and potential, based on the additional acreage of disturbance associated with transportation corridor widening.

4.14.5 Summary of Key Issues

Table 4.14-6 provides summary statements of key issues and impacts from the project on soil resources.

Table 4.14-6: Summary of Key Issues for Soil Resource

Impact Causing Project Component	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variants
Mine Site			
Soil disturbance	*Alternative 1* ~8,086 acres (total) *Summer-Only Ferry Operations Variant* ~8,124 acres (total)	*Alternative 2* ~155 additional acres (downstream TSF construction) *Summer-Only Ferry Operations Variant* No change	*Alternative 3* No change from Alternative 1 *Concentrate Pipeline Variant* ~1.7 additional acres
Soil quality	*Alternative 1* Magnitude and potential: With	*Alternative 2* No change	*Alternative 3* No change

[1] HDPE = high-density polyethylene

Table 4.14-6: Summary of Key Issues for Soil Resource

Impact Causing Project Component	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variants
	the exception of antimony (+3.04%), the percent increase in baseline concentrations for all HAP metals from dust deposition in surface soils would be less than 1 percent; therefore, no adverse change to surface soil chemistry from fugitive dust deposition exists relative to baseline conditions. Extent: mine site (ambient air) boundary. Duration: Throughout post-closure. *Summer-Only Variant* No change	*Summer-Only Ferry Operations Variant* No change	*Concentrate Pipeline Variant* No change
Erosion	*Alternative 1* Magnitude: Within project design and permit requirements. Duration: Pre-activity levels within 100 years. Extent: Project boundaries. Potential: Inherent *Summer-Only Ferry Operations Variant* No change	*Alternative 2* Potential erosion increase from TSF build out. *Summer-Only Ferry Operations Variant* No change	*Alternative 3* No change from Alternative 1 *Concentrate Pipeline Variant* No change from Alternative 1
Transportation Corridor			
Soil disturbance	*Alternative 1* ~1,161 acres (includes shared pipeline) *Summer-Only Ferry Operations Variant* No change *East Ferry Variant* ~60-acre total increase due to material site acreage, but less wetland disturbance	*Alternative 2* Comparable acreage footprint but ~20 fewer miles of roadway (more material sites under Alternative 2). *Summer-Only Ferry Operations Variant* No change	*Alternative 3* ~1,753 acres (total) 66% greater than Alternative 1 and 2 *Concentrate Pipeline Variant* Increased Transportation Corridor but likely less than or equal to10%
Soil quality	*Alternative 1* Magnitude and Potential: No adverse change to surface soil chemistry from fugitive dust deposition. No PAG material from locally sourced material sites, seasonal emission mitigation/suppression through watering, and concentrate transport in sealed containers.	*Alternative 2* No change *Summer-Only Ferry Operations Variant* No change	*Alternative 3* No change *Concentrate Pipeline Variant* No change

Table 4.14-6: Summary of Key Issues for Soil Resource

Impact Causing Project Component	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variants
	Duration: Indefinite, based on continued post-closure transportation corridor access. Potential: Inherent; but low due to mitigation measures and fill source (material site) geo-chemistry assessment. *Summer-Only Ferry Operations Variant* No change		
Erosion	*Alternative 1* Magnitude: Approximately 30 miles of port road corridor in moderate to rough terrain (~33.4 miles total) that is associated with the presence of shallow fine-grained soils. May require some enhanced design and mitigation measures. Duration: Temporary to indefinite Extent: Project footprint Potential: Inherent; but greatest potential along port access road, with a low potential for other transportation components. *Summer-Only Ferry Operations Variant* Potential erosion increase due to greater road usage during ice-free months. *East Ferry Variant* Comparable but potentially less erosion based on shorter road length.	*Alternative 2* Magnitude and extent: Reduced based on smaller acreage of ground disturbance and increased presence of coarser soil types and gentler terrain. Duration: No change (temporary to indefinite) Potential: Increased along 2.5-mile coastline segment of port access road, where unique road design and mitigation measures would be required to minimize erosion potential; however, erosion potential will likely persist (e.g., topography and maritime conditions). *Summer-Only Ferry Operations Variant* Potential erosion increase due to greater road usage during ice-free months, but less than Alternative 1 variant based on shorter road length.	*Alternative 3* Magnitude, extent, potential: Greater than Alternatives 1 and 2 based on greatest footprint acreage and waterbody crossing frequency. However, magnitude and potential may be comparable to Alternative 1 (at a minimum) based on less-moderate to rough terrain that coincides with shallow fine-grained soil types. Duration: No change (temporary to indefinite) *Concentrate Pipeline Variant* Magnitude and potential: Greatest amongst all alternatives and variants due to less than 10% increase in transportation corridor width (i.e., Alternative 3). Duration: No change (temporary to indefinite) Extent: Comparable to Alternative 3.
Port Site			
Soil disturbance	*Alternative 1* ~20 acres (total) *Summer-Only Ferry Operations Variant* ~47.5 acres (total) *Pile-Supported Dock Variant* Reduced fill material demand and acreage.	*Alternative 2* ~41 acres (total) (~11 additional acres) *Summer-Only Ferry Operations Variant* Additional 28.8 acres	*Alternative 3* Same as Alternative 2 *Concentrate Pipeline Variant* Same as Alternative 2
Soil quality	*Alternative 1*	*Alternative 2*	*Alternative 3*

Table 4.14-6: Summary of Key Issues for Soil Resource

Impact Causing Project Component	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variants
	Magnitude: No adverse change to surface soil chemistry from fugitive dust deposition. No PAG material from locally sourced material sites; seasonal emission mitigation/suppression through watering. Concentrate transfer from sealed bins to bulk carriers conducted off-shore below deck. Calculated concentrate total emissions is approximately 4 pounds per year. Duration: Indefinite, based on continued post-closure port needs Potential: Low; however, greatest during the operational period during concentrate storage and handling. *Summer-Only Ferry Operations Variant* No change	No change *Summer-Only Ferry Operations Variant* No change	No change *Concentrate Pipeline Variant* No change
Erosion	*Alternative 1* Magnitude: Low and within project design and permit requirements. Duration: Indefinite and up to several years into post-closure Extent: Project footprint Potential: Inherent – low *Summer-Only Ferry Operations Variant* Increased erosion potential *Pile-Supported Dock Variant* Reduced erosion potential	*Alternative 2* Magnitude and Extent: Increased, based on larger acreage of ground disturbance/infrastructure, terrain, and dredge material stockpile. Duration: No change Potential: Increased, based on larger acreage of ground disturbance, terrain, and dredge material stockpile. *Summer-Only Ferry Operations Variant* Increased erosion magnitude and potential *Pile-Supported Dock Variant* Same as Alternative 1 Variant	*Alternative 3* Same as Alternative 2 *Concentrate Pipeline Variant* Same as Alternative 2
Natural Gas Pipeline (Stand-alone)			
Soil disturbance	*Alternative 1* ~40 acres (stand-alone total) *East Ferry Variant*	*Alternative 2* ~827 additional acres (includes pipeline material sites).	*Alternative 3* With the exception of 97 acres of stand-alone pipeline and material sites,

Table 4.14-6: Summary of Key Issues for Soil Resource

Impact Causing Project Component	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variants
	Shorter 3-mile pipeline length (change) based on shared Transportation Corridor.		the pipeline under this alternative is considered part of the commonly aligned/shared Transportation Corridor. See Alternative 3, Transportation Corridor key issues for soil disturbance. *Concentrate Pipeline Variant* Same as above
Erosion	*Alternative 1* Magnitude: Low and within project design and permit requirements based on limited ground disturbance and shared transportation corridor. Duration: Indefinite Extent: Project footprint Potential: Inherent, but low *East Ferry Variant* Decreased erosion potential	*Alternative 2* Magnitude, extent, and potential: Increased during construction and operations based on larger acreage of ground disturbance, length, and reduced accessibility. Magnitude and extent are considered comparable to Alternative 1 during post-closure based on stabilization, ground surface restoration, and in-place abandonment. Potential: Increased during post-closure. Duration: Comparable, based on shared transportation corridor segments.	*Alternative 3* Although the pipeline under this alternative is considered part of the commonly aligned transportation corridor for evaluation, the following key issue is considered: The potential for increased erosion susceptibility of shallow fine-grained soils in moderate to rough terrain from the port road to Canyon Creek west of Pedro Bay under Alternative 2 (stand-alone pipeline) would be reduced under Alternative 3 immediately after construction and throughout operation. This is due to continuous road access for monitoring and maintenance of surface stabilization and restoration measures. *Concentrate Pipeline Variant* Same as above

4.14.6 Cumulative Effects

The cumulative effects analysis area for soils encompasses the footprint of the proposed project, including alternatives and variants. In this area, a nexus may exist between the project and other past, present, and reasonably foreseeable future actions (RFFAs) that could contribute to a cumulative effect on soils. Section 4.1, Introduction to Environmental Consequences, details the comprehensive set of past, present, and RFFAs considered for evaluation as applicable. A number of the actions identified in Section 4.1, Introduction to Environmental Consequences, are considered to have no potential of contributing to cumulative effects on soils in the analysis area. These include offshore-based developments; activities that may occur in the analysis area, but are unlikely to result in any appreciable impact on soil resources (such as tourism, recreation, fishing, and hunting); or actions outside of the cumulative effects analysis area (e.g., Donlin Gold, Alaska LNG).

Past, present, and RFFAs that could contribute cumulatively to geologic resource impacts, and are therefore considered in this analysis, include:

- Pebble project buildout – develop 55 percent of the resource over 78-year period
- Pebble South/PEB*
- Big Chunk South*
- Big Chunk North*
- Fog Lake*
- Groundhog*
- Diamond Point Rock Quarry
- Lake and Peninsula Transportation and Infrastructure

**Indicates exploration activities only.*

4.14.6.1 Past and Present Actions

Past and present actions that have impacted soils in the analysis area are limited, and include transportation development where existing roads intersect the project footprint, and mineral exploration in locations where past or current activities have impacted soils (e.g., work pads or camp areas). Although these actions affect localized areas, they are additive to other actions that may occur, slightly increasing the total cumulative effect on geologic resources. Overall, the cumulative effects on soils from past and present actions are minimal in extent and minor in magnitude for all alternatives.

4.14.6.2 Reasonably Foreseeable Future Actions

No Action Alternative

The No Action Alternative would not contribute to cumulative effects on soils.

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 (Section 4.1, Introduction to Environmental Consequences), would include an additional 58 years of mining (for a total of 78 years) over a substantially larger mine site footprint, and would include increases in port and transportation corridor infrastructure. The mine site footprint would have a larger open pit and new facilities to store tailings and waste rock (Section 4.1, Introduction to Environmental Consequences, Figure 4.1-1), which would contribute to cumulative effects on geologic resources through removal of overburden, waste rock, and ore.

The Pebble mine expanded development scenario project footprint would impact approximately 34,790 acres, compared to 9,317 acres under Alternative 1. The magnitude of cumulative impacts to soil would vary from temporary soil disturbance to permanent soil removal. Similarly, erosion would vary from minimal surface stabilization efforts to indefinite erosion maintenance (e.g., roads, mine site infrastructure).

Other Mineral Exploration Projects – Mineral exploration is likely to continue in the analysis area for the mining projects listed previously in this section. Exploration activities, including additional borehole drilling, road and pad construction, and development of temporary camp and other support facilities would contribute to the cumulative effects on soils, although impacts would be expected to be limited in extent and low in magnitude.

Road Improvement and Community Development Projects – Road improvement projects would have impacts on soils through grading, filling, and potential increased erosion, and would contribute to cumulative effects in the analysis area. The most likely road improvements in the area would be in the development footprint of existing communities, with only Iliamna and Newhalen being considered to be in the analysis area for soils cumulative effects. Some limited road upgrades could also occur in the vicinity of the natural gas pipeline starting point near Stariski Creek, or in support of mineral exploration previously discussed. None of the anticipated transportation development in the analysis area would contribute greatly to cumulative effects on soils.

Additional RFFAs that have the potential to affect soils in the analysis area are limited to the Diamond Point rock quarry. That RFFA would include the excavation of rock, which would require removal of soil overburden materials, and result in a direct and cumulative effect on soils in the analysis area. Upland soil disturbances and erosion impacts would be limited to coarse soils occurring in rocky mountainous terrain. The estimated area that would be affected is approximately 140 acres (ADNR 2014a).

Alternative 2 – North Road and Ferry with Downstream Dams

Pebble Mine Expanded Development Scenario – Expanded mine site development and associated contributions to cumulative effects on soils would be similar for all alternatives. Under Alternative 2, project expansion would use the existing Diamond Point port facility; would use the same natural gas pipeline; and would use portions of the constructed portion of the North Road. A concentrate pipeline and a diesel pipeline from the mine site to Iniskin Bay would be constructed; both having potentially limited impacts on soils due to trenching activities. Cumulative effects on soils would be similar to those discussed under Alternative 1.

Other Mineral Exploration Projects, Road Improvement, and Community Development Projects – Cumulative effects of these activities on soils would be similar to those discussed under Alternative 1. Under Alternative 1, the proposed Diamond Point rock quarry has the potential to affect soils in the analysis area. The footprint of the Diamond Point rock quarry coincides with the Diamond Point port footprint under Alternatives 2 and 3. The increase in soil disturbance and erosion impacts (e.g., magnitude and geographic extent) would be the same as identified under Alternative 1. Cumulative impacts would likely be less under Alternative 2 due to commonly shared project footprints with the quarry site.

Alternative 3 – North Road Only

Pebble Mine Expanded Development Scenario – Expanded mine site development and associated contributions to cumulative effects on soils would be similar for all alternatives. Under Alternative 3, project expansion would use the Diamond Point port facility; would use the same natural gas pipeline and diesel pipeline; and would use the same north road and concentrate pipeline variant, but would extend the concentrate pipeline with a service road to Iniskin Bay.

Other Mineral Exploration Projects, Road Improvement, and Community Development Projects – Cumulative effects of these activities on soils would be similar to those discussed under Alternative 2.

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4.15 GEOHAZARDS

This section describes potential impacts of geologic hazards (geohazards) on project components that could affect the environment. The Environmental Impact Statement (EIS) analysis area for geohazard ranges from the immediate vicinity of the project footprint (e.g., slope instability) to regional areas with geohazards that could affect project facilities from long distances (e.g., earthquakes, volcanoes).

The impact analysis for geologic hazards considered the following factors:

- Magnitude – impacts are assessed based on the magnitude of the impact, as indicated by the anticipated effects of various possible geologic hazard events (e.g., repairable damage to mine features, ground settlement).
- Duration – impacts are assessed based on the project phase that they are expected to occur in (e.g., certain structures removed at closure), and how long repair of potential damage or interruption of activities may last.
- Geographic extent – impacts are assessed based on the location and distribution of occurrence of the expected effects from potential geologic hazard events (e.g., distant earthquake effects on mine site and port structures).
- Potential – impacts are assessed based on the likelihood of a geologic hazard event to occur during and after project development (e.g., based on expected recurrence interval[1] for certain geologic hazards).

The impact analysis incorporates an understanding of the probability of occurrence, and of planned mitigation in the form of planning, design, construction, operations, maintenance, and surveillance that can meaningfully reduce impacts from geohazards through closure and post-closure. Based on Pebble Limited Partnership (PLP) plan documents and engineering reports, planned mitigation methods (e.g., design and monitoring to withstand or detect geohazards) are considered part of the project description, and the impacts analysis includes this understanding. In some cases, planned mitigation may not be specified, but is considered typical or standard engineering practice. In cases where planned mitigation is unknown or unclear and the situation is not commonly addressed, the impact analysis takes the lack of planned mitigation into account.

This section describes the following potential impacts related to geohazards:

- stability of major mine structures during operations and closure.
- effects of earthquakes on project facilities.
- effects of unstable slopes on project facilities.
- effects of geotechnical conditions and coastal hazards on port structures and pipeline landfalls.
- effects of tsunamis and seiches on port and ferry terminals.
- effects of volcanoes on project facilities.

Potential impacts to the environment resulting from geohazard-caused upset conditions, such as an embankment failure, are addressed in Section 4.27, Spill Risk. As described in Section 3.14, Soils, permafrost has not been encountered in the mine site or other project areas based on field investigations; therefore, potential effects from permafrost hazards are not addressed in this section.

[1] **Recurrence interval** (or return period) is an estimate of the probability or frequency that certain geohazards are expected to occur, based on geologic and seismologic evidence.

Scoping comments expressed concerns that major faults occur in the proposed project area and may affect project facilities. Commenters requested that the EIS include detailed information about seismically active areas, geological faults and tectonic activity, and corresponding design features. They also requested information on how the proposed project facilities, particularly the tailings storage facility (TSF), would withstand earthquakes, and an analysis of potential impacts from volcanic activity, especially at Amakdedori port and along the pipeline, from Augustine Volcano.

4.15.1 No Action Alternative

Under the No Action Alternative, the Pebble Project would not be undertaken. No construction, operations, or closure activities would occur. Therefore, effects on project components from geohazards, seismic events, and other geotechnical conditions would not occur as a result of this alternative, and no impacts on the environment would result from such effects. Permitted resource exploration activities currently associated with the project may continue (ADNR 2018-RFI 073). PLP would have the same options for exploration activities that currently exist. In addition, there are many valid mining claims in the area and these lands would remain open to mineral entry and exploration. Natural geohazards such as those described in Section 3.15, Geohazards, would continue to affect existing communities and infrastructure in the region.

4.15.2 Alternative 1 – Applicant's Proposed Alternative

4.15.2.1 Mine Site

This section describes potential effects of seismic events and other geohazards on major structures at the mine site; the ability of the structures to withstand these hazards; and the likelihood that such hazards could produce related environmental impacts. Figures in Chapter 2, Alternatives, display the mine site layout; and Table K4.15-1 in Appendix K4.15 provides the buildout dimensions of embankments and impoundments that would contain tailings, waste rock, and/or contact water at the mine site. This section also addresses potential geohazard effects on the open pit.

Embankment Construction Material

The embankments for the tailings and water management facilities would be constructed of drilled and blasted bedrock removed from quarries A through C[2], and the overburden in the open pit (Chapter 2, Alternatives, Figure 2-4). Analyses were completed to determine the quantities of on-site embankment construction materials and project-related needs. Appendix K4.15 (Table K4.15-2 and Table K4.15-3) provide embankment material quantities that would be generated by quarries A through C and the open pit overburden, as well as the embankment material needs for the relevant mine site-related facilities, respectively.

Based on review of material properties and quantities provided by PLP (2018-RFI 015b; PLP 2019-RFI 108a), the combination of the three quarries and the open pit overburden would generate sufficient materials (between 6 and 32 percent more rockfill material than needed) to construct the embankments. Thus, the likelihood that additional material needs would be identified as the project progresses (with related project footprint increases) is low.

[2] Quarry A is shown as situated in the footprint of the bulk TSF; this quarry would be developed before the construction of the bulk TSF.

Embankment and Impoundment Design and Construction

The embankments and impoundments could be impacted by geohazards, including instability associated with seepage, internal erosion[3], and seismic (earthquake) events. The embankments would therefore be designed and constructed to be stable under both static (non-seismic) and seismic conditions, which is also required by relevant draft dam safety guidance documents (ADNR 2017a). The following summarizes the geohazard considerations for the proposed design and construction of the major embankments and impoundments, including the bulk TSF, pyritic TSF, water management ponds (WMPs), and seepage collection ponds (SCPs). More detailed information is provided in Appendix K4.15.

Bulk TSF. The bulk TSF would be designed to impound the bulk tailings, and includes a main (north) and south embankment with the following design and construction elements to prevent geohazard-related impacts:

- Siting in a single tributary watershed surrounded by bedrock knobs to focus potential impacts in one watershed and incorporate natural containment elements.
- Main (north) embankment centerline constructed[4] to reduce the footprint, with a buttressed downstream slope to enhance stability, which would result in 2.6 horizontal: 1 vertical (H:V) downstream embankment slope and a serrated near-vertical upstream face at the dam crest for the upper 280 feet of the embankment (Chapter 2, Alternatives, Figure 2-8).
- Permeable flow-through design with core/filter/transition zones materials to minimize water buildup in the TSF, prevent internal erosion, and remain functional after a seismic event.
- South embankment constructed using downstream methods[5], to include a downstream liner combined with a grout curtain to prevent upgradient groundwater flow into and beneath the impoundment.
- Bottom of south embankment core/filter/transition zones would tie into the top of the grout curtain zone, which would be keyed into bedrock to prevent leakage beneath the embankment.
- Underdrains beneath the TSF to further manage seepage flow.
- Water management to protect the dam from seepage pressure-related instability.
- Drainage ditches at the toe of the embankment slopes to prevent erosion and undercutting.
- Freeboard to contain the entire inflow design flood above the tailings beach.
- Excess pond water to be pumped to the main TSF SCP or main WMP.
- Higher south embankment elevation to direct overflow to water catchment facilities.

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[3] **Internal erosion**, also referred to as piping, is the formation of voids in a soil caused by the removal of material by seepage, and occurs when the hydraulic forces exerted by water seeping through the pores and cracks of the material in the embankment are sufficient to detach particles and transport them out of the embankment structure.

[4] **Centerline construction** is a method of dam (embankment) construction in which a rockfill dam is raised by concurrent placement of fill on top of the dam crest, the upstream slope including portions of the tailings beach, and the downstream slope of the previous raise.

[5] **Downstream construction** is a method of dam (embankment) construction in which a rockfill dam is raised in the downstream direction by placement of fill on top of the dam crest and downstream slope of the previous raise.

- Wide tailings beach to reduce seepage pressure on embankments, and promote subsurface drainage to the north with pond development against bedrock high to the southeast.
- Reduced tailings volume by using thickening methods or additional pumping capacity.
- Foundations to be placed on competent bedrock for increased stability.
- Each dam lift to undergo a thorough safety review, and adjusted as necessary.
- Dry closure methods to improve the stability for permanent in-place closure, with a closure cover design that would minimize infiltration.
- Monitoring performed during construction, operations, closure, and post-closure.

Pyritic TSF. The pyritic TSF would be designed to impound the pyritic tailings and potentially acid-generating (PAG) waste rock, and would include a continuous embankment around the northern, southern, and eastern sides with the following design and construction elements to prevent geohazard-related impacts:

- Fully lined, subaqueous storage cell during operations to minimize acid generation.
- Majority of the pyritic TSF in a single tributary valley.
- Liner protected with processed materials (sand and gravel) after installation to prevent damage from punctures or damage during waste rock placement.
- Liner installation completed in accordance with standard industry practices, and closely monitored.
- Water levels maintained for the life of the facility.
- Water levels and freeboard maintained to account for the inflow design flood, wave run-up, and wind set-up.
- Excess pond water controlled by pumping to the main WMP.
- Embankments prepared by removing overburden to competent bedrock.
- Tailings and waste rock moved into the open pit at closure.
- After closure, the liner removed and embankments graded/recontoured to conform to surrounding landscape and promote natural runoff and drainage.
- Monitoring included in all phases.

WMPs and SCPs. Two primary WMPs would be at the mine site (the main WMP north of the pyritic TSF, and the open pit WMP) to impound contact and open pit water, respectively. The SCPs would be downstream of the TSF embankments, and include those associated with the bulk TSF main and south embankments, and the pyritic TSF north, east, and south embankments. The facilities would include the following design and construction elements to prevent geohazard-related impacts:

- Fully lined to minimize seepage and risk of internal erosion.
- Rockfill embankments to promote stability.
- Main WMP embankment prepared by removing overburden to competent bedrock.
- Open pit WMP embankment design concept requiring potential weak foundation conditions encountered in the overburden materials (e.g., glacial lake deposits) to be excavated.
- Pond water volumes managed through reuse in the process plant, and treatment and discharge.

- Monitoring/seepage pumpback wells downgradient to detect and capture potential liner leakage.
- At closure, the WMPs to be removed and embankments graded/recontoured to conform to the surrounding landscape and promote natural runoff and drainage.
- Monitoring included during all phases.

Static Stability Analyses

Analyses were completed to evaluate the stability of the proposed embankments under static and non-seismic conditions. The following summarizes the static stability analysis. A more detailed discussion is presented in Appendix K4.15. The following major embankments and impoundments were analyzed:

- Bulk TSF main and south embankments
- Pyritic TSF north embankment
- Main WMP
- Bulk TSF main SCP
- Open pit WMP

The static stability analyses were completed using the computer program SLOPE/W. Input parameters were based on the results of field and office studies, and included the embankment configurations and assumed rockfill material, foundation materials, and stored materials. The results predicted the analyzed embankments would have a static factor of safety (FoS) between 1.7 and 2.0 (a static FoS of 1.1 or greater is considered stable). Additional static stability analyses would be completed in support of the final design.

As noted above, the Alternative 1 bulk TSF main embankment design would result in a serrated near-vertical upstream face at the dam crest for the upper 280 feet of the embankment that would partially rest on tailings. The potential for this configuration to liquefy during seismic events was reviewed by a panel of geotechnical experts during the EIS-Phase Failure Modes and Effects Analysis (FMEA) (AECOM 2018l). The stability analysis results do not rely on the strength of these materials, but rather on the strength of rockfill materials directly beneath and downstream of successive raises in the core zone and buttresses (Figure 2-8 and Figure K4.15-2). In other words, regardless of the low strength assigned to the tailings, the overall embankment did not fail in a downstream direction in the stability analysis. Therefore, the FMEA panel concluded that the likelihood of global instability of the buttressed centerline embankment design would be very low.

Seismic Stability Analysis

Active Surface Faults. The mine site is situated in a regionally seismically active area caused by the convergence of the Pacific and North American tectonic plates. The most significant seismically active geologic structure near the mine site is the Bruin Bay fault, which is situated about 70 to 80 miles to the east-southeast.

No mine facilities would be constructed on top of known active surface faults. As presented in Section 3.15, Geohazards, the closest potentially active fault to the mine site, the Lake Clark fault, is about 15 miles to the northeast. Recent mapping at the mine site and vicinity has not shown evidence of offset of surficial deposits along faults or lineaments in the area (Hamilton and Klieforth 2010; Haeussler and Waythomas 2011; Koehler 2010). This conclusion is further supported by Light Detection and Ranging (LiDAR) data that were collected in 2004 in the mine site area. The LiDAR-derived image was reviewed for possible indications of fault-related movement in surficial deposits. No lineaments were observed that suggest possible Quaternary fault-related movement southwest of the mapped termination (AECOM 2018m).

More detailed discussion regarding seismic sources and hazards in the greater project area is presented in Section 3.15, Geohazards, Appendix K3.15, and Appendix K4.15.

Seismic Hazard Analyses. The TSF embankments at the mine site would be regulated as Class I (high) hazard potential dams under the Alaska Dam Safety Program (ADSP) draft dam safety guidelines (ADNR 2017a; PLP 2017). Based on these draft guidelines, two levels of design earthquake must be established for Class I dams:

- *Operating Basis Earthquake* (OBE) that has a reasonable probability of occurring during the project life (return period of 150 to more than 250 years), for which structures must be designed to remain functional, with minor damage that could be easily repairable in a limited time. In other words, minor damage within allowable design criteria may be sustained at the TSF embankments following an OBE earthquake.
- *Maximum Design Earthquake* (MDE) that represents the most severe ground shaking expected at the site (return period from 2,500 years up to that of the Maximum Credible Earthquake [MCE]), for which structures must be designed to resist collapse and uncontrolled release.

The OBE can be defined based on probabilistic evaluations, with the level of risk (probability that the magnitude of ground motion would be exceeded during a particular length of time) being determined relative to the hazard potential classification and location of the dam (ADNR 2017a). The MDE may be defined based on either probabilistic or deterministic evaluations, or both (ADNR 2017a).

Ground-shaking from earthquakes is typically presented in terms of PGA, measured as a fraction (or percent) of gravity (g), which represents the intensity of an earthquake as it is applied to a structure, such as the TSF embankments. The degree of ground shaking and structural damage expected is related to earthquake magnitude, distance from active faults, and duration of shaking. For example, small local earthquakes may cause more ground shaking than large, more distant earthquakes; and large distant earthquakes with a lower PGA but longer shaking duration may cause more damage than smaller nearby earthquakes with a higher PGA. As such, the selected OBE or MDE may be based on more than one earthquake scenario. A number of potential earthquakes were evaluated in the probabilistic and deterministic seismic hazard analyses (see Appendix K4.15) to develop the OBE and MDE.

A conservative OBE corresponding to a return period of 475 years was adopted for the Pebble TSF designs (Knight Piésold 2013). Based on this return period, the estimated PGA has been determined to be 0.14g (or 14 percent of gravity acceleration). The design earthquake magnitude associated with this level of ground shaking includes:

- A magnitude 7.5 earthquake determined based on probabilistic seismic hazard analysis which considers a combination of potential faults (Appendix K4.15, Table K4.15-7) (Knight Piésold 2013; Wesson et al. 2007).
- A magnitude 9.2 earthquake on the Alaska-Aleutian megathrust (having the same PGA of 0.14g because it is more distant) based on deterministic seismic hazard analysis (Appendix K4.15, Table K4.15-8).

The MCE was selected as the MDE for the Pebble TSFs (KP 2013). Earthquake magnitudes and ground shaking associated with the MCE considered in TSF embankment design include:

- A magnitude 6.5 shallow crustal earthquake from an unknown fault assumed to occur directly beneath the mine site, with a PGA of 0.61g.
- A magnitude 8.0 intraslab subduction earthquake (similar to the source of the magnitude 7.0 Anchorage earthquake on November 30, 2018), with a PGA of 0.48g.

- A magnitude 7.5 earthquake on the Lake Clark fault, with a PGA of 0.29g.
- A magnitude 9.2 megathrust earthquake with a PGA of 0.14g.

Appendix K4.15 provides further discussion of the seismic sources and probabilistic and deterministic evaluations completed for the project to evaluate potential ground shaking associated with these earthquakes. The seismic hazard analyses would be updated in final design to support ADSP design and reporting requirements, incorporating best practices for analysis published since the Knight Piésold (2013) study (Bozorgnia et al. 2014) and updated USGS ground motion data as available (PLP 2018-RFI 008c).

Seismic Deformation Analysis. A pseudo-static deformation analysis was completed to predict the response of the largest embankment (the bulk TSF) to a seismic event, based on the OBE, as well as MCEs from four potential seismic sources (faults) with magnitudes ranging from 6.5 to 9.2 (Appendix K4.15). Predicted displacements in the embankment were estimated to be negligible for the OBE, and on the order of 4 to 5 feet of horizontal displacement and crest settlement under MCE loading conditions. The displacements were not large enough to truncate the filter or transition zones, and would not affect the functionality of embankment. The results were used to design the minimum freeboard requirements for the bulk TSF embankments.

The deformation and settlement analyses would be updated as part of the ongoing design of the TSFs and other embankments. Additional detailed modeling, including analyses using Fast Lagrangian Analysis of Continua (FLAC) numerical modeling software, would be completed during detailed design of the facilities to better define embankment displacements.

Summary of Stability Effects. The magnitude of direct effects on mine embankments from earthquakes, floods, static loading, slope failure, and foundation conditions could range considerably. Effects would not be measurable where designs are adequate for expected geohazards, such as moderate earthquakes, large precipitation events, or known unstable foundation conditions that are removed in construction. In terms of duration, effects could include damage that would be repairable in the short term (e.g., months) in the event of an OBE; or in the event of an MDE, effects could range up to damage that would not be easily repairable, but would not be expected to lead to structural collapse or uncontrolled release of contaminated materials. Assuming that facilities are planned, designed, constructed, operated, maintained, and surveilled as proposed and in accordance with ADSP guidelines (ADNR 2017a), in terms of extent, potential damage to facilities and indirect effects on the environment would be expected to remain within the footprint of the mine site. In addition to ADSP oversight, PLP would also establish an independent review board to review embankment designs and stability analyses as engineering analysis progresses (AECOM 2018k).

The duration of effects would vary depending on the facility and likelihood of geohazard occurrence. In the case of earthquake damage that would be easily repairable, impacts would be infrequent, but not longer than the life of the mine for facilities that would be removed at closure (e.g., embankments at the pyritic TSF). Impacts could occur in perpetuity for structures that would remain in place (e.g., bulk TSF embankments). Based on the conceptual designs, and assuming that current standard of engineering practice would be followed, the likelihood of global instability of the major embankments was considered to be very low (i.e., less than 1 in 10,000 probability) by geotechnical experts in the EIS-Phase FMEA (AECOM 2018l). Indirect effects on other downstream resources in the unlikely event of an embankment spill or release are discussed in Section 4.27, Spill Risk.

Open Pit Slopes

Numerical modeling was completed to predict the stability for three sections of the open pit walls with known weak rock conditions (Appendix K4.15, Figure K4.15-10). As described in Appendix

K4.15, the analyses evaluated both static and seismic conditions, and included modeling of disturbance factor zones that represent the predicted bedrock damage caused by rock mass relaxation[6] and crustal rebound[7] due to the excavation of the open pit, as well as blast damage close to the excavation surface (Hoek 2012). The modeling targeted a minimum acceptable FoS for the open pit walls of 1.3 for static conditions, and 1.05 for dynamic (earthquake) conditions. These values recognize that there would only be a single entry into the pit, and any instability involving the ramp could impact the operations. After closure, the static FoS would be reduced to an FoS of 1.1 due to the lack of access required into the pit, but this would be further reviewed during detailed design.

In terms of magnitude, the modeling results showed an FoS of 1.1 or greater for two of the three pit sections, indicating they would be stable under both static and earthquake loadings, and an FoS below 1.1 (indicating potentially unstable conditions) for the section through the northwestern side of the pit under both static and dynamic loadings in early closure after dewatering ceases.

Two additional closure scenarios were examined for the northwest section: 1) early closure with continued groundwater depressurization focused on the toe of the slope; and 2) with pit lake levels recovered to about half full (above the area of instability). The results indicate an FoS of 1.1 and 1.4, respectively, for the two scenarios (Appendix K4.15, Figure K4.15-12 and Figure K4.15-13), and suggest that with continued depressurization in the localized area of the northwestern section during early closure activities (e.g., backfilling), the pit wall would be stable.

Other Geohazard Considerations

Quality Assurance/Quality Control (QA/QC). A Construction QA/QC Plan would be developed to assure all quarries, embankments, impoundments, and liners are constructed and operated in accordance with the approved designs and specifications. The plan would specify actions for approving embankment materials, construction methodology, field testing, surveying, monitoring, and documentation. Alaska Department of Natural Resources (ADNR) (2017a) guidelines provide details on plan requirements, personnel responsible for QA/QC, key inspection items, and required post-construction document submittals.

Mining-Induced Seismicity. Induced seismicity refers to earthquakes and tremors that are thought to be caused by human activity through altering the stresses and strains in the earth's crust. Mining-related activities such as rock mass relaxation, crustal rebound, and blasting associated with the excavation of an open pit, have the potential to generate induced seismicity.

The US Geological Survey (USGS) compiled a list of mining-related induced seismicity in the US over the 27-year period between 1973 and 2000, during which there were a total of 47 seismic events attributable to mining-related induced seismicity. The recorded tremors were generally small, ranging in magnitude between 2.0 and 4.8 (USGS 2018f). One of the events occurred at the Usibelli Coal Mine in Alaska, with a magnitude 3.3 attributed to blasting, and possibly concurrent rock mass relaxation. The Usibelli Coal Mine is an open pit operation situated in a seismically active area similar to the proposed Pebble mine site[8] (WSM 2018).

[6] **Rock mass relaxation** is the unloading of rock stresses due to the removal of bedrock (e.g., underground mines and/or open pits).

[7] **Crustal rebound** isthe rise of a land mass due to removing an overlying weight or mass, such as excavating bedrock during open pit mining, which could be significant enough to be measurable, and therefore included in the computer modeling.

[8] Both are situated in strike-slip regimes with similar associated seismic mechanisms, but the magnitude of stress is higher at the Usibelli Coal Mine due to the tectonic forces that created Denali.

There does not appear to be an observed direct correlation between the weight of TSFs and/or stockpiles and induced seismicity at mining sites.

The open pit slope analysis above assumed seismic conditions that are likely greater than the highest magnitude mining-related induced seismic event recorded by the USGS (2018f). In addition, the seismic stability analysis performed in support of the mine site design (Appendix K4.15) took into consideration unknown shallow crustal earthquakes (Knight Piésold 2013), which is how a large mining-related induced seismic event would likely behave.

Seismic Impacts on Hydrogeology. The potential exists for impacts on hydrogeology resulting from a seismic event. For example, at the mine site, there are near-surface groundwater occurrences such as seasonal seeps and deeper groundwater that could be impacted (see Section 4.17, Groundwater Hydrology). Potential groundwater impacts could include changes in groundwater levels, volumes, and chemistry, including the locations of seeps. However, these types of changes commonly occur in the absence of seismic events due to other factors such as weather conditions (e.g., precipitation, temperatures) and changes in water chemistry (e.g., precipitation of naturally occurring constituents and/or bacteria in the water).

Groundwater conditions would be monitored throughout all stages of the mine project for both flow and chemistry purposes (Section 4.17, Groundwater Hydrology and Section 4.18, Water and Sediment Quality). If a major earthquake were to occur during project operations, an "extraordinary inspection" for any impacts would be required in accordance with the ADSP draft dam safety guidelines (ADNR 2017a), and in compliance with specific requirements of an operations and maintenance manual. The inspection would also identify adherence to design criteria for all major structures to ensure they continue to perform as designed. Changes to the groundwater monitoring program, facility design, and/or operation would be implemented as necessary to ensure protection of the environment.

Summer-Only Ferry Operations Variant

Under the Summer-Only Ferry Operations Variant, copper-gold concentrate would be stored in shipping containers at the mine site during the winter at a storage area northeast of the pyritic TSF (Chapter 2, Alternatives, Figure 2-39). Based on the surficial geology map (Section 3.13, Geology, Figure 3.13-2); the proposed copper-gold concentrate storage area is primarily underlain by surficial glacial outwash deposits, which generally consists of a mixture of sand- to gravel-sized material. The glacial outwash appears to thin to the northeast, with possible bedrock exposed near the northeastern boundary of the storage area.

During a large earthquake, the potential would exist for the stacked shipping containers to be impacted by differential settlement of the underlying glacial outwash due to being thicker to the southwest than the northeast, potentially resulting in toppling of the containers. The likelihood would depend on the magnitude and duration of the seismic event, height of container stacking, the in-place density of the foundation materials, and other factors. The impact would likely be mitigated through further investigation and foundation preparation such as compaction of near-surface materials.

4.15.2.2 Transportation Corridor

Earthquakes and Seiches

The transportation corridor would not cross any known active surface faults (Section 3.15, Geohazards, Figure 3.15-1). A trace of the Bruin Bay fault zone crosses the port access road within several miles of the Amakdedori port site; however, there is no evidence of Holocene offset at the surface for this segment of the fault (Plafker et al. 1994; Koehler et al. 2013).

Therefore, effects on transportation corridor facilities related to surface fault displacement would not be expected to occur.

The magnitude of impacts from ground shaking in the event of a major earthquake would be direct effects on transportation facilities, such as cracking, spreading, and settlement of terminal platforms, or damage to the ferry during construction. However, because the ferry terminals would not include fuel tank storage facilities, indirect effects on the environment in the vicinity of the terminals from fuel spills due to tank rupture would not be expected.

Earthquake- or landslide-induced seiches can damage shoreline structures, boats, and moored vessels in enclosed waterbodies, particularly if the natural period of a moored ship matches that of a seiche (Kabiri-Samani 2013). The historical occurrence of seiches in Iliamna Lake is unknown (see Section 3.15, Geohazards) (PLP 2018-RFI 013). In terms of magnitude, seiches several feet high have been documented in Southeast Alaska and the contiguous 48 states during past major Alaska earthquakes (McGarr et al. 1968; Barberopoulou et al. 2004; CBJ 2018); they would be expected to be around the size of maximum storm-driven waves on Iliamna Lake (USACE 2009a). Larger predicted seiche heights of 10 to 20 feet have been suggested for Bradley Lake on Kenai Peninsula and Lynn Canal at Skagway, respectively (CASA 1982; Stone & Webster 1987); however, seiches are more likely to occur in these narrow bodies of water than in Iliamna Lake.

A preliminary estimate of seiche potential in Iliamna Lake was conducted based on a 60- by 15-mile area representing the wide part of the lake where the Alternative 1 ferry would operate (AECOM 2018d). The results indicate the natural oscillation period of an earthquake-induced seiche would fall well outside the period range where earthquake ground motions carry the most energy, suggesting that earthquake-induced seiches would not be expected to occur.

Unstable Slopes

As discussed in Section 3.15, Geohazards, the north ferry terminal location is underlain by surficial deposits consisting of beach and lake terrace sand and gravel, and the south ferry terminal location by both volcanic bedrock and similar surficial deposits, neither of which is prone to unstable slope conditions (Chapter 2, Alternatives, Figure 2-23 and Figure 2-25).

In terms of potential extent of impacts from unstable slopes, several small areas of unstable slope deposits occur along the mine access road, near the junction between the mine access and Iliamna spur roads, and near the southern end of the port access road (Section 3.15, Geohazards) (Detterman and Reed 1973; Hamilton and Klieforth 2010). Over-steepened, potentially unstable slopes could also be created during the development of the geologic material sites. Typical engineering and construction practices such as engineered cuts, benching, and drainage controls (Chapter 2, Alternatives, Figure 2-16) would be used at these locations to minimize the potential for landslide impacts on the roads, material sites, and disruption of truck haulage. Therefore, if such effects were to infrequently occur, the duration and extent of impacts on the project and related effects on environmental resources would be easily repairable in the short term, and of limited extent in the immediate vicinity of the road footprint.

Based on the topography along the road corridor, avalanches would not be expected to occur during mine operations.

Summer-Only Ferry Operations Variant

There would be no difference in the magnitude and extent of geohazard-related impacts under the Summer-Only Ferry Operations Variant. Lake ice hazards (for year-round ferry operations under Alternative 1) are discussed under Section 4.16, Surface Water Hydrology.

Kokhanok East Ferry Terminal Variant

As described in Section 3.15, Geohazards, the Kokhanok East Ferry Terminal Variant location would be underlain by beach deposits near the shoreline, and volcanic bedrock farther upslope. The magnitude and potential for seismically related and unstable slope impacts would be expected to be similar to the south ferry terminal location west of Kokhanok.

4.15.2.3 Amakdedori Port

Earthquakes

Site-specific seismic hazard analyses were conducted for the port site as described in Appendix K4.15. The port would be designed to an appropriate seismic design code (Knight Piésold 2013). A PGA of 0.51g associated with a 2,500-year earthquake was preliminarily adopted as the design earthquake for the Diamond Point port based on probabilistic seismic hazard analysis (Appendix K4.15, Table K4.15-10) and International Building Code requirements. Based on fault conditions and seismicity in the region (Section 3.15, Geohazards, Figure 3.15-2, and Appendix K4.15, Figure K4.15-7), the magnitude and extent of ground shaking effects at the Amakdedori port site would be expected to be similar to or less than effects predicted for the Diamond Point port site. The seismic hazard analyses would be updated in final design (Knight Piésold 2013; PLP 2018-RFI 008c).

In terms of magnitude, the predicted ground shaking at the port would be roughly double that predicted for the mine site, reflecting the closer proximity of the port to potential subduction zone earthquakes (Appendix K4.15, Figure K4.15-8). Based on the deterministic seismic hazard analysis (Table K4.15-11), a PGA of 0.51g is associated with an intraslab subduction earthquake in the range of magnitude 7.5 to 8.0 from an epicenter about 20 to 25 miles away and 50 to 60 miles deep.

Stability of Sheet Pile Dock

An assessment of the static and seismic stability of the proposed sheet pile dock is presented in Appendix K4.15 and summarized below. As described in Section 3.15, Geohazards, the foundation materials for the offshore components would be limited to shallow borings about 3 feet deep, a near-surface geophysical survey, and extrapolation from a deeper onshore geophysical survey, which suggest that subsurface deposits consist primarily of sand and gravel. Additional geotechnical investigation would be conducted as the project design progresses.

In the absence of the additional foundation information and related engineering analyses, the proposed rockfill causeway and sheet-pile dock would have the potential to result in adverse impacts to the environment during construction and operations. The potential magnitude and extent of impacts could include:

- Structural instability and potential failure of the sheet-pile wharf as a result of seismic loading, foundation conditions, erosion at the base of the sheet pile, icing increasing gravity load on the sheets, and corrosion requiring regular monitoring of cathodic protection systems.
- Damage to the structures due to liquefaction of the seabed during a seismic event.
- Damage to the sheet pile wall during installation due the presence of boulders in the nearshore sediment, which could result in the release of the earthfill during operations.

The additional field investigation-related information would support more detailed design analyses to confirm whether the design would be feasible, and if so ensure construction, operations, and closure would be protective of the environment.

The port would be closed and undergo reclamation after the off-site transport of concentrate would be completed at Year 20 of operations. All structures and related earthfill would be removed, and the site reclaimed (PLP 2018-RFI 024). The duration of potential geohazard-related impacts would therefore be long-term, and the extent would generally be limited to the close vicinity of the dock footprint. With additional geotechnical investigation and stability analyses, dock design would be refined to address the potential for failure that could lead to adverse impacts on the environment.

Unstable Slopes

The Amakdedori port site is underlain by raised beach terrace deposits consisting of sand and gravel (Section 3.15, Geohazards), which are not prone to unstable slope conditions.

Tsunamis

Recent tsunami modeling for lower Cook Inlet (ASCE 2017b) predicts a run-up elevation in the Amakdedori area of 28.5 feet above mean high water, or about 42 feet above mean lower-low water (MLLW), for a very large earthquake with a 2,500-year return period (Section 3.15, Geohazards). The probability of this size tsunami occurring over the life of the port is roughly 1 in 35, assuming the port needs to be operational through closure phase 3 for a total of 70 years (20 years operations, plus 50 years closure). Older modeling by Crawford (1987) predicts run-up elevations in the Amakdedori area for smaller, more frequent, medium to large earthquakes (100- to 500-year events) of about 19 to 30 feet MLLW. The proposed elevation of the terminal patio is 35 feet MLLW (Figure 2-28) (PLP 2018-RFI 093). As discussed in Section 3.15, Geohazards, tsunamis can also be generated by local landslide events, such as the debris avalanches that have occurred on the flanks of Augustine Volcano. These have reached the sea about every 150 to 200 years, and are estimated to be capable of generating wave amplitudes in the range of 5 to 60 feet (Waythomas et al. 2006).

The 2,500-yearr return period event is the “maximum considered tsunami” in the latest industry standards (ASCE 2017a), which specify that certain structures be designed such that they are able to provide essential functions immediately following this event. In terms of magnitude and extent of impacts, for a large tsunami of this size and return period, the predicted run-up elevation could exceed the design elevation of the terminal by about 7 feet, potentially affecting facilities such as fuel tanks and concentrate container storage. Assuming the causeway and wharf elevations are the same as the 35-foot terminal elevation, equipment and activities on top of these structures would also be affected. For smaller tsunamis with a probability of occurrence in the range of 1 in 100 to 500 years, the predicted run-up elevation is below that of the port facilities, and the magnitude and extent of impacts on terminal facilities and related effects on the environment would be expected to be no worse than waves from large storm events.

A detailed tsunami analysis would be conducted in accordance with American Society of Civil Engineers (ASCE) (2017a) standards prior to final port design that would include a probabilistic assessment of tsunami sources (from both earthquakes and landslides) and numerical modeling to provide site-specific maximum run-up, inundation, and current velocity that would be incorporated into final design. The final terminal elevation would be revisited in final design based on these analyses. The causeway elevation and footprint would be as currently proposed, but would transition to the final terminal elevation if a change would be required. The port diesel fuel facility would be designed to withstand the 2,500-year event. The concrete containment barrier wall around the fuel tank farm (Figure 2-28) would be designed to protect against tsunami run-up. A risk analysis would be undertaken for other port components to determine the associated risk level and associated design event. Structures would be designed to withstand tsunami forces, protect against debris impacts, resist uplift, and ensure that scour does not form, which could undermine structures (PLP 2019-RFI 112).

If unmitigated, the magnitude of effects from a large tsunami could include risks to worker safety, equipment, and structures, such as the fuel storage tanks, concentrate containers, trucks, and cranes. (The effects of potential spill releases from project facilities are discussed in Section 4.27, Spill Risk.) Damage during a tsunami could result from initial wave crushing or buoyancy failures, which can cause tipping or sliding of fuel storage containers (Brooker 2011). The sheet-pile bulkhead design would expose the cross-sectional area to the hydrodynamic impact of the wave. A critical loading condition for the bulkhead could be the very low water level during the retreat phase of the tsunami, during which the stabilizing effect of water on the outside of the sheet-pile would be absent or diminished. Wave impacts and flooding of the upper part of the causeway would be expected to cause little damage and erosion, because the same type of riprap would be used to protect both the upper and lower parts (PLP 2018-RFI 093), and because the riprap would be designed to resist tide buoyancy and storm impacts. Some boat damage could result from barge/wharf or barge/ship collisions if loading and lightering activities at the wharf or off-shore mooring locations were to coincide with the arrival of a tsunami wave; however, tsunami warning infrastructure, which typically sends warnings within minutes (NOAA 2018e), may provide enough time to move vessels to avoid these impacts. Advance warning of the potential for local landslide-generated tsunamis from Augustine Volcano would be expected to be longer due to tracking of volcanic activity by Alaska Volcano Observatory (AVO).

In addition to proposed design mitigation described above, other measures would be employed to reduce the risk to personnel, such as early warning systems, vertical evacuation structures, and operational procedures and training on when to move to higher ground and secure critical equipment. Impacts to vessels at the two lightering locations would be analyzed during the tsunami studies to understand the response if a vessel happened to be in place during an event. For the majority of potential events, the vessels would not remain moored. Operational procedures would be in place such that, if volcanic activity is predicted or a tsunami warning issued, vessels would cease lightering operations and move to safer locations in deeper water (PLP 2019-RFI 112).

The likelihood of a large tsunami occurring at the port ranges from to very unlikely in any given year (i.e., 1 in 2,500) to moderately unlikely (i.e., 1 in 35) over the life of the port. If a tsunami were to occur, the intensity of impacts could range from minimal disruption of activities or boat damage, to terminal flooding and damage to infrastructure, though critical infrastructure such as the fuel tank farm would be expected to remain intact with proposed mitigation in final design. Infrastructure damage would be localized in the near vicinity of the port and mooring sites. The duration of impacts could range from hours to months (in the event repairs to non-critical infrastructure would be required).

Volcanoes

A number of active volcanoes have erupted in the last few decades within about 100 miles of the project area (Section 3.15, Geohazards, Figure 3.15-4). Of particular potential concern is Augustine Volcano, approximately 20 miles east-northeast of the Amakdedori port site. The magnitude of impacts from any of the active volcanoes could include ash clouds transported by wind, and fallout that disrupts construction and operations of project components, depending on prevailing wind direction and plume height. Volcanic ash particles are particularly abrasive, corrosive, and pervasive.

In terms of extent and duration, due to the distance from the volcano, effects at the mine site would be expected to be rare, occurring only once or twice over the life of the mine. Because the port facilities would be closer to the Augustine Volcano (within 20 miles), impacts from an Augustine plume would be expected to be more common at the Amakdedori port and on and moored ships. If ash fallout were to occur, it could affect most activities within the port footprint. The magnitude and extent of direct effects could include damage to equipment, engines, and compressor stations; and disruption of staffing, shipping, and fuel supplies. The duration of effects would be temporary, potentially lasting several days per incident. Ashfall effects on the project would not be expected to result in indirect effects from the facilities on other environmental resources. Typical mitigation would include a vulnerability analysis of facilities and equipment and hazard planning (Chapter 5, Mitigation).

As noted in Section 3.15, Geohazards, volcanic debris avalanches that flow into Cook Inlet are known to occur once every 150 to 200 years on average (Beget and Kienle 1992). Therefore, the likelihood of this scenario occurring during the project's life would be low, as would be the potential for these flows to reach the pipeline or port facilities.

Stability of Pile-Supported Dock Variant

The pile-supported dock would be constructed on trestle and dock piles (Chapter 2, Alternatives, Figure 2-43), and the footprint area would be about 0.5 percent of that required for the rockfill causeway and sheet-pile dock.

As with the sheet-pile dock, detailed engineering analysis has not been completed in support of initial design. The stability of a pile-supported dock is typically a function of structural design details and pile-soil interaction. The current state-of-practice is to use bending in the pile to resist lateral loads (e.g., wind, seismic, vessel impacts, and mooring loads) that may control pile embedment depths. Static stability analysis is typically conducted to determine the ability of the dock to accommodate and control maximum displacements from these loads, as well as global stability issues such as liquefaction. The survivability of a pile-supported structure in a large earthquake is generally considered better than bulkhead type structures, which do not perform well in major earthquakes, and are difficult to repair. For example, sections of the existing Port of Anchorage pile-supported dock survived the 1964 earthquake.

In terms of magnitude of impacts, the piles would likely experience similar metal corrosion as the sheet-pile dock; similar issues with construction in the event of boulders in the subsurface; and ice-related impacts that could be worse due to exposure of the piles to the elements (PLP 2018-RFI 071). As with the sheet-pile, additional geotechnical investigation and stability analysis would be performed during final design, and the results would provide a better understanding of dock behavior in response to geohazards, and whether boulders would be present that would hinder pile installation.

Based on the conceptual level of design and experience with similar structures, the likelihood of stability issues would be generally considered lower with the pile-supported dock, and survivability in a major earthquake generally greater than the sheet-pile dock. Unlike the sheet-pile dock, the pile-supported dock would not have the potential to release fill into the marine environment as a result of geohazard-related event. In the event of potential geohazard-related impacts to the pile-supported dock, the duration of effects would range from temporary (e.g., ice loads that would be repairable) to long-term requiring weeks or months to repair, and the extent would likely be limited to the footprint of the structure.

Summer-Only Ferry Operations Variant

There would be no difference in geohazard-related impacts under this variant for this component.

4.15.2.4 Natural Gas Pipeline Corridor

Earthquakes and Surface Faults

As described above for the transportation corridor, the natural gas pipeline corridor would not cross any known active surface faults (Section 3.15, Geohazards, Figure 3.15-1). Therefore, direct effects on the pipeline from surface fault displacements would not be expected to occur.

A major earthquake could cause liquefaction in unfrozen lowlands, stream crossings, and marine areas with fine sandy soils. This condition has the potential to cause buried pipelines to become buoyant; which, if not properly accounted for in design, could lead to pipe flotation and possible damage. The loss of soil shear strength during liquefaction could also lead to permanent ground movements through lateral spreading, flow failure, and settlement. Control measures for liquefaction and buoyancy (e.g., estimation of lateral spreading, use of select compacted backfill, increased cover depth, swamp weights, and post-earthquake inspection) are considered typical state-of-practice for high-liquefaction areas so that design deflection and stress on the pipe would not be exceeded. The proposed use of thicker walled pipe in marine areas would also help reduce the effects of liquefaction in Cook Inlet and Iliamna Lake. Therefore, pipe rupture and potential related environmental effects in the event of liquefaction would be unlikely. If pipe damage were to occur, the extent would be expected to be limited to the immediate vicinity of the liquefaction, and because the pipeline could be repaired in a timeframe of days to months, the duration of impacts would be short-term.

Unstable Slopes

A relatively unstable bluff roughly 200 feet high exists between the Anchor Point compressor station on Kenai Peninsula and Cook Inlet. To avoid the bluff, the pipeline would be constructed using horizontal directional drilling (HDD) from the compressor station to the pipeline's emergence point on the Cook Inlet seafloor to the west.

The HDD would begin at an elevation of about 207 feet on the eastern side of Sterling Highway, and drop down to an elevation of -12 feet MLLW or deeper[9] in accordance with the Pipeline and Hazardous Materials Safety Administration requirements (PLP 2018-RFI 011). The exact water depth at which the pipeline would emerge at the seafloor has not been determined, but is proposed to be deep enough to avoid navigational hazards (PLP 2018d).

During the life of the project, the bluff at Cook Inlet would likely continue to erode and retreat landward as a result of natural causes. With the use of HDD methods, the pipeline would pass well below and landward of the steep bluff at Cook Inlet, and avoid the unstable slope hazards (PLP 2018-RFI 011). Therefore, potential impacts on the project and related effects on the environment from this geohazard would be minimal because of this avoidance.

Coastal Hazards

The depth of pipeline cover west of the HDD installation location, and below the 12-foot water depth on the western side of Cook Inlet and in Iliamna Lake, would be sufficient to ensure that the top of the pipeline lies below the mudline. The minimum depth of cover above the 12-foot water depth would be 3 feet, which would reduce potential effects from coastal hazards such as shoreline drift, ice-rafting of surface boulders, or shifting sand waves. Section 4.16, Surface Water Hydrology, provides additional discussion of potential effects on the submerged pipeline.

[9] A 1,800-foot-long HDD pipeline would exit in approximately 12 feet of water MLLW, while a 2,000-foot-long HDD would exit in approximately 18 to 24 feet of water at MLLW. Current technology can accommodate a 2,000-foot-long HDD for in the 12-inch-diameter range as proposed (PLP 2018-RFI 011).

Kokhanok East Ferry Terminal Variant

There would be no difference in geohazard-related impacts under this variant for this component.

4.15.3 Alternative 2 – North Road and Ferry with Downstream Dams

4.15.3.1 Mine Site – Downstream Embankment

The bulk TSF main embankment under Alternative 2 would be constructed using downstream raises (Chapter 2, Alternative, Figure 2-45 through Figure 2-47), as compared to the buttressed centerline design under Alternative 1 (PLP 2018d; PLP 2018-RFI 075). Under Alternative 2, the overall downstream slope would be 2.6H:1V, which would be the same as the buttressed centerline-constructed embankment under Alternative 1. The upstream slope of the main embankment under Alternative 2 would be 2H:1V, versus the upstream slope under Alternative 1 that would be a serrated near-vertical upstream face at the dam crest for the upper 280 feet, and partially rest on tailings (Chapter 2, Alternatives, Figure 2-8).

As described in Appendix K4.15, the preliminary stability analysis for the downstream constructed main embankment calculated a FoS value on the order of 1.9 to 2.0 under static loading conditions, similar to that of the buttressed centerline design (Appendix K4.15, Table K4.15-5), thereby offering minimal additional stability over the Alternative 1 design. A schematic section of the main embankment at its ultimate height with the predicted potential slip surface is shown on Chapter 2, Alternatives, Figure 2-47.

The bulk TSF main embankment under Alternative 2 would be raised approximately 25 feet higher than the Alternative 1 design (embankment height approximately 570 feet) to provide equivalent bulk TSF storage capacity. The embankment fill would increase from 78 million cubic yards (yd^3) to 124 million yd^3, and the impoundment footprint area would increase by 119 acres (PLP 2018-RFI 075a). This would result in increased impacts on other resources such as material sites, substrate, and wetlands (Section 4.13, Geology; Section 4.18, Water and Sediment Quality; and Section 4.22, Wetlands and Other Waters/Special Aquatic Sites), but would not change the global stability of the embankment.

Summer-Only Ferry Operations Variant

There would be no difference in geohazard-related impacts under this variant for this component.

4.15.3.2 Transportation Corridor

Mine and Port Access Roads

Earthquakes. Referring to Chapter 2, Alternatives, Figure 2-49, Figure 2-50, and Section 3.15, Geohazards, Figure 3.15-1, the access roads under Alternative 2 would not cross any known active faults. The magnitude, extent, and duration of potential impacts related to ground shaking for the roads would be similar to those described above under Alternative 1. Even though the access road from Williamsport to Diamond Point would be adjacent to the shoreline of Iliamna Bay, as described below for the Diamond Point port site, potential tsunami-related impacts in Iliamna Bay would be expected to be less severe than at the Amakdedori port site because Iliamna Bay is more protected and shallower than Amakdedori.

Unstable Slopes*.* Several areas of unstable solifluction, colluvium, and landslide deposits have been mapped in the area northwest of Eagle Bay on the flanks of Roadhouse Mountain and along the mine access road west of Newhalen River (Section 3.15, Geohazards) (Detterman and Reed 1973; Hamilton and Klieforth 2010). Steep alluvial fan and talus deposits occur in incised valleys crossed by the eastern portion of the route east of Pile Bay (Detterman and Reed 1973). RRockfall hazards could also occur in this area of exposed bedrock where rock cuts would be likely. Steep unstable slopes and rockfall hazards would also be expected along the Diamond Point-Williamsburg waterfront section of the road.

Typical engineering and construction practices such as engineered cuts, benching, and drainage controls, as well as road maintenance, would be used to manage unstable slopes, to reduce the potential for landslide impacts on the roads during construction and disruption of truck haulage. Several locations along the existing Williamsport-Pile Bay Road would be rerouted under this alternative to avoid steep slopes, including approximately the eastern third of this area, and a shorter road segment close to Pile Bay. Unstable slopes could also lead to an increase in the likelihood of spills (Section 4.27, Spill Risk, provides an analysis of spill impacts from a truck spill scenario). The likelihood of such effects occurring would be expected to be greater for Alternative 2 as compared to Alternative 1, because there would be more areas of unstable slopes associated with the transportation corridors under Alternative 2. However, in terms of duration and extent, with appropriate designed engineering controls in place during construction and operations, impacts on the project and related effects on environmental resources would be easily repairable over the short term, and limited to the immediate vicinity of the road footprint.

The potential exists for avalanches to occur for portions of the road alignment between Williamsport and Pile Bay. However, the avalanches would be preventable using relevant best management practices (BMPs) such as hazard mapping, forecasting, and blasting if necessary. In terms of duration and extent, if avalanches were to occur, they would temporarily impact a local portion of the road until the snow could be removed.

Eagle Bay to Pile Bay Ferry

The magnitude, duration, and extent of potential impacts on the ferry terminals related to ground shaking would be similar to those described above under Alternative 1. Although the eastern end of the lake is narrower and deeper compared to the Alternative 1 ferry route—factors that can increase earthquake-generated seiche potential—the potential for occurrence would still be considered unlikely (AECOM 2018j). This analysis assumes that the risk of major landslide-generated seiches at the eastern end of the lake would be low, and there is little evidence of past major landslides in the lake bottom, assumptions that would be further investigated through collection of more detailed bathymetric survey data as design progresses.

Summer-Only Ferry Operations Variant

Under the Summer-Only Ferry Operations Variant, road traffic would be concentrated during the 6-month transportation season, which would include rainy months. Because heavy rain is often a trigger for slope failure, the potential for these impacts on road traffic and spill potential could be slightly greater under this variant, but would be balanced by fewer avalanche impacts due to lack of winter season traffic. Lake ice hazards are discussed under Section 4.16, Surface Water Hydrology.

4.15.3.3 Diamond Point Port

Referring to Chapter 2, Alternatives, Figure 2-52 and Figure 2-53, the Diamond Point port facility would use the same design concept as the Amakdedori port under Alternative 1[10], although with a footprint about four times bigger than at Amakdedori (PLP 2018-RFI 071).

As discussed in Appendix K4.15, in terms of magnitude and extent of impacts, ground shaking potential in the Diamond Point area is slightly greater than at Amakdedori. The Bruin Bay Fault extends along the western shore of Cook Inlet near the Diamond Point port site. Although there is no evidence for Holocene offset at the surface, this fault is associated with several small to moderate earthquakes up to M7.3 in 1943 (Stevens and Craw 2003).

Stability of Dock Structure

Sheet Pile Dock. The proposed sheet-pile dock would be the same potential to result in adverse impacts to the environment during construction and operations as discussed for the Amakdedori port site (see "Amakdedori Port," section above, and Appendix K4.15). As with Amakdedori port, the Diamond Point port facilities would be closed and undergo reclamation after the off-site transport of concentrate was completed at Year 20. All structures and related earthfill would be removed, and the site reclaimed (PLP 2018-RFI 024). The duration of potential geohazards-related impacts would therefore be long-term, and the extent would generally be limited to the close vicinity of the dock footprint. With additional geotechnical investigation and stability analyses, dock design would be refined to address the potential for failure that could lead to adverse impacts on the environment.

The magnitude of potential impacts for Alternative 2 could be greater than Alternative 1 due to the larger footprint and fill volume required for the Alternative 2 dock, and possible higher likelihood of boulders in the subsurface with related risk of short embedment or sheet-pile damage. As described in Section 4.18, Water and Sediment Quality, substrate conditions are generally finer-grained in Iliamna Bay than in Kamishak Bay. Because dock fill would partly consist of dredged material, in the event that potential geohazard-related impacts cause a release of fill to the marine environment, the extent of redeposition could be greater than under Alternative 1, and could range widely depending on season, tides, and wave conditions (e.g., from the close vicinity of the dock structure to the mouth of Iliamna Bay).

Pile-Supported Dock Variant

The Pile-Supported Dock Variant for the Diamond Point port would have potential geohazard-related impacts similar in magnitude, extent and duration as the Pile-Supported Dock Variant at the Amakdedori port under Alternative 1. The off-shore foundation conditions would likely be different than the Amakdedori site, which would affect the overall performance of the pile-supported system. If this variant is chosen, field conditions would be further investigated in support of final design.

Tsunamis

The magnitude, extent, duration, and potential for tsunami impacts at the Diamond Point port site would be similar or slightly less than those at the Amakdedori port site under Alternative 1. The predicted run-up elevation for the 2,500-year event is slightly less for Diamond Point (36 to 39 feet MLLW) than at Amakdedori (42 feet MLLW) (see Section 3.15, Geohazards), and would exceed the proposed terminal elevation by 1 to 4 feet (assuming the terminal and causeway/dock elevations would be the same as at Amakdedori [35 feet MLLW]). The potential for landslide-generated tsunamis affecting the port site and lightering locations would be

[10] A causeway constructed of earthfill embankment, and barge berth and wharf constructed of a sheet-pile wall wharf structure filled with earthfill.

considered similar to Amakdedori, because historic events have occurred radially around Augustine Volcano (Figure 3.15-5). The proposed engineering analyses and mitigation in final design that would occur at Amakdedori based on ASCE (2017a) industry standards (PLP 2018-RFI 112) would be expected to be the same for Diamond Point, assuming additional infrastructure (dredge material storage area and roads) would be included.

Volcanoes

The proposed Diamond Point port location would be approximately the same distance from volcanoes in the area, including Augustine Volcano, as the Amakdedori port under Alternative 1. Therefore, the potential for impacts would be similar to Alternative 1, with the magnitude, duration, and extent of impacts dependent on the severity of an ash cloud and the wind direction at the time of an eruption. However, in winter, the magnitude, extent, and duration of potential impacts from Augustine Volcano on the Alternative 2 port site could be greater than Alternative 1 due to dominant northwesterly winds in this area (Knight Piésold 2018g).

4.15.3.4 Natural Gas Pipeline Corridor

Referring to Figure 2-54, natural gas pipeline construction under Alternative 2 would follow a different corridor route west of Cook Inlet, and would therefore encounter different geology and related potential geohazards than Alternative 1 (Section 3.13, Geology and Section 3.15, Geohazards).

Earthquakes and Surface Faults

In western Cook Inlet, the Alternative 2 pipeline would be routed to Ursus Cove to avoid known boulders and reefs at the mouth of Iliamna Bay (PLP 2018-RFI 063). At about 3 miles before making landfall, the pipeline would cross a mapped fault trace of the potentially active Bruin Bay fault (Section 3.13, Geology, Figure 3.13-1 and Figure 3.15-1). Additional field investigation prior to final design (e.g., an offshore geophysical survey or onshore fault study at Ursus Head where the fault is mapped as having an upland component), would be needed to identify whether the fault is active and whether potential displacement mitigation in design would be necessary, if this alternative were to be selected.

Unstable Slopes

Steep unstable slopes are a known hazard to pipeline integrity, and have been known to cause operation interruptions and ruptures in other mountainous areas of the world (e.g., the Andes, Eastern Europe, and Sakhalin Island) (Lee et al. 2016). Unstable slopes mapped between Ursus Cove and Pile Bay, and for the Alternative 2 route west of Eagle Bay, are discussed above under the Alternative 2 transportation corridor. The pipeline segment between Pile Bay and Eagle Bay crosses areas of exposed steep bedrock with the potential for rock instability, and alluvial fan and talus deposits, which could be unstable on steeper slopes. The corridor would avoid mapped landslide deposits on the flanks of Knutson and Roadhouse mountains.

Typical engineering and construction practices such as engineered cuts, rock stabilization, benching, and drainage controls would likely be used at these locations to reduce the potential for rockslide and landslide impacts to the pipeline. Additional mitigation, such as long-term slope monitoring, may be necessary in select areas. With these controls, the likelihood of slope failures occurring during the construction and operation that would affect pipeline integrity would be expected to be minimal. In terms of potential, duration, and extent, related effects on environmental resources would also be expected to be minimal, repairable in the short-term, and limited to the immediate vicinity of the pipeline right-of-way (ROW).

Coastal Hazards

The depth of the pipeline as it approaches Ursus Cove from Cook Inlet, as well as the underwater crossing of the bay to Diamond Point, would be sufficient to ensure that the top of the pipeline lies below the mudline. The minimum depth of cover above the 12-foot water depth would be 3 feet, which would be expected to reduce potential effects from coastal hazards, such as shoreline drift or ice-rafting of surface boulders.

4.15.4 Alternative 3 – North Road Only

Under Alternative 3 and its variants, the magnitude, extent, duration, and likelihood of impacts at the mine site (including concentrate pumphouse) and natural gas pipeline corridor would be the same as those described under Alternative 2. The following section describes impacts for the transportation corridor and port that would be different under Alternative 3 and its variants.

4.15.4.1 Transportation Corridor

All Road Routes, Mine Site to Port

Geohazards-related impacts resulting from construction and operation of the Alternative 3 north access road from Diamond Point to the mine site would be generally the same as the combination of road and natural gas pipeline corridors described under Alternative 2. However, the likelihood of slope stability issues occurring along the all-road route would be higher between Eagle Bay and Pile Bay than under Alternative 2, due to the wider road ROW (compared to the Alternative 2 pipeline-only in this area) and greater need for engineering controls (such as wider cut and fills) to mitigate potential slope impacts. There would also be a slightly higher likelihood of spills due to the longer road route through steep terrain (Section 4.27, Spill Risk provides an analysis of spill impacts from a truck spill scenario), and greater potential for avalanches to occur that would be preventable using relevant BMPs described above for Alternative 2.

Appropriate engineering controls and BMPs described in Chapter 5, Mitigation, would reduce the likelihood of slope failures occurring along the all-road route. In terms of duration and extent, related effects on environmental resources would also be expected to be repairable over the short-term (days or weeks), and of limited to the immediate vicinity of the access road ROW footprint.

Concentrate Pipeline Variant

Because the concentrate pipeline would be installed in the same trench as the natural gas pipeline, the magnitude, extent, duration, and likelihood of impacts from geohazards, such as unstable slopes would be similar to the Alternative 2 natural gas pipeline corridor and Alternative 3 all-road route. There would also be a slightly higher likelihood of minor spills due to the additional potential contaminant source from the concentrate pipeline along steep terrain, which would be partially mitigated through leak detection systems (Section 4.27, Spill Risk, provides analysis of spill impacts from a concentrate spill scenario).

4.15.4.2 Diamond Point Port

Geohazard-related impacts would have the same magnitude, extent, duration, and likelihood as those described for Alternative 2, except for the concentrate storage and bulk handling described below.

Concentrate Pipeline Variant

Due to the mapped presence of alluvial fan deposits in the proposed footprint of the concentrate storage facility and steep slopes above the facility, the potential for unstable slopes would exist during the construction and operation (Detterman and Reed 1973). If this variant were selected, the final design would include a geotechnical investigation to confirm foundation and slope conditions to ensure the facility construction and operation would avoid or mitigate unstable slopes.

As noted under Alternative 2, the impacts from a tsunami at the Diamond Point port site would be similar or less severe than at the Amakdedori port under Alternative 1. However, if a tsunami were to occur, it would have a higher potential to result in a contaminant release to the marine environment under this variant; this is because this variant includes bulk storage of concentrate and the others do not. Section 4.27, Spill Risk, provides analysis of spill impacts from a concentrate spill scenario. Effects would be unlikely to occur, and the duration of impacts could range from hours to months (in the event repairs would be required). Typical mitigation might include a vulnerability analysis of equipment and facilities, incorporation of flooding into design (e.g., tie-downs), emergency action planning with tsunami escape routes, or consideration of design changes to facility armoring and elevation (Chapter 5, Mitigation).

4.15.5 Summary of Key Issues

Table 4.15-1 provides a summary of the key impact-related issues for geohazards.

Table 4.15-1: Summary of Key Issues for Geohazards

Impact Causing Project Component	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variants
Mine Site			
TSF and WMP Embankment Stability	Low probability of embankment instability with static stability analysis (FoS 1.7-2.0), foundation preparation, seepage design, and flood controls incorporated into design. Temporary repairable damage in OBE, and 4 to 5-foot displacement/ settlement in MCE, would not result in effects on the environment outside of the footprint. Duration long-term with removal of pyritic TSF and WMPs at closure and dry closure of bulk TSF.	Design provides marginal additional stability over Alternative 1 design (FoS 1.9-2.0 for both).	Same as Alternative 1.
Open Pit Slope Stability	Low to medium likelihood of localized unstable slopes in lower pit in early closure, to be mitigated through targeted groundwater depressurization while lake rises.	Same as Alternative 1.	Same as Alternative 1.
Container Storage and Pumphouse	*Summer-Only Ferry Operations Variant:* Low likelihood of earthquake toppling effects at container storage area with foundation preparation.	Same as Alternative 1.	*Concentrate Pipeline Variant*: Impacts at pumphouse similar to Alternative 1.

Table 4.15-1: Summary of Key Issues for Geohazards

Impact Causing Project Component	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variants
Transportation Corridor			
Road Construction and Operations	Low likelihood of unstable slope impacts on roads. *Summer-Only Ferry Operations Variant and Kokhanok East Ferry Terminal Variant:* Similar impacts to Alternative 1.	Low to medium likelihood of unstable slope impacts along road corridor; effects temporary and localized with engineering controls and maintenance. *Summer-Only Ferry Operations Variant:* Similar impacts to Alternative 2.	Slightly higher likelihood of unstable slope effects than Alternative 2 due to longer route in steep terrain; effects similar to Alternative 2 with engineering controls and maintenance. *Concentrate Pipeline Variant*: Low likelihood of minor spills due to unstable slopes.
Ferry Terminals and Operations	Earthquakes: Low likelihood of temporary ground-shaking effects such as cracking, spreading, and settlement of terminals. Low likelihood of seiches and unstable slope effects. *Summer-Only Ferry Operations Variant and Kokhanok East Ferry Terminal Variant:* Similar impacts to Alternative 1.	Similar impacts to Alternative 1.	Similar impacts to Alternative 1.
Ports			
Dock Construction and Operations	*Proposed Sheet-Pile Dock:* Low to medium likelihood of stability effects on dock, and potential for fill escaping sheet-pile into marine environment. Tsunamis: low likelihood of temporary (repairable) effects such as dock or fuel tank damage. Volcanic ash from Augustine: low likelihood of port operations interruption. *Pile-Supported Dock Variant*: Lower likelihood of stability effects than sheet pile dock.	*Proposed Sheet-Pile Dock:* Slightly higher likelihood and extent of stability effects than Alternative 1, due to 4x larger structure and finer fill material. Tsunamis: slightly lower intensity than Alternative 1 due to lower predicted run-up elevation. Volcanic ash from Augustine: slightly higher likelihood of effects during winter due to prevailing winds. *Pile-Supported Dock Variant*: Lower likelihood of stability effects than Alternative 2 proposed sheet-pile dock.	*Proposed Sheet-Pile Dock:* Impacts same as Alternative 2. *Concentrate Pipeline Variant*: Low likelihood of unstable slope effects on storage facility. Tsunamis: Same likelihood as Alternative 2, but with slightly higher risk of contaminant release.

Table 4.15-1: Summary of Key Issues for Geohazards

Impact Causing Project Component	Alternative 1 and Variants	Alternative 2 and Variants	Alternative 3 and Variants
Natural Gas Pipeline Corridor			
Construction and Operations – Cook Inlet	Low likelihood of pipe damage form liquefaction. No active fault crossing effects.	Liquefaction impacts similar to Alternative 1. Low likelihood of active fault crossing (Bruin Bay fault) and displacement effects.	Liquefaction impacts similar to Alternative 1. Surface faults: same as Alternative 2.
Construction and Operations – Upland Areas	Low likelihood of unstable slope effects on pipeline.	Low-medium likelihood of unstable slope effects (such as operations interruption or rupture) between Diamond Point and Roadhouse Mountain; expected to be mitigated through typical engineering controls and monitoring.	Same as Alternative 2.

4.15.6 Cumulative Effects

The cumulative effects analysis area for geologic hazards encompasses the footprint of the proposed project, including alternatives and variants. In this area, a nexus may exist between the project and other past, present, and reasonably foreseeable future actions (RFFAs) that could contribute cumulatively to geologic hazards-related impacts. Section 4.1, Introduction to Environmental Consequences, details the comprehensive set of past, present, and RFFAs considered for evaluation as applicable. A number of the actions identified in Section 4.1, Introduction to Environmental Consequences, are considered to have no potential of contributing to cumulative geologic hazard effects in the analysis area. These include offshore-based developments, activities that may occur in the analysis area but are unlikely to result in any appreciable cumulative effect with regard to geohazards, or actions outside of the geologic hazards cumulative effects analysis area (e.g., Donlin Gold, Alaska Liquefied Natural Gas [LNG]). RFFAs that are in the analysis area and would involve earthworks resulting in possible geohazard-related impacts would be considered to have potential cumulative effects. Past, present, and RFFAs that could contribute cumulatively to geologic hazard impacts, and are therefore considered in this analysis, include:

- Pebble Project buildout – development of 55 percent of the resource over a 78-year period.
- Pebble South/PEB mineral prospect exploration.
- Groundhog mineral prospect exploration.
- Diamond Point rock quarry.
- Lake and Peninsula transportation, infrastructure and energy projects.

4.15.6.1 Past and Present Actions

Past and present actions in the analysis area would not be expected to contribute cumulatively to geologic hazards. While past or current actions in the analysis area have included some minor earthworks, the effects are minor both in magnitude and extent, and are not expected to be a significant factor in increased geologic hazards. Similarly, while there have been past volcanic and earthquake events in the region, they have not contributed to any increased geologic hazard risk in current conditions.

4.15.6.2 Reasonably Foreseeable Future Actions

No Action Alternative

The No Action Alternative would not contribute to cumulative geologic hazard effects.

Alternative 1 – Applicants Proposed Alternative

Pebble Mine Expanded Development Scenario. An expanded development scenario for this project, as detailed in Introduction to Environmental Consequences, Table 4.1-2, would include an additional 58 years of mining and 20 years of milling (for a total of 98 years) over a substantially larger mine site footprint, and would include increases in port and transportation corridor infrastructure. The mine site footprint would have a larger open pit and new facilities to store tailings and waste rock (Introduction to Environmental Consequences, Figure 4.1-1), which could contribute to cumulative geologic hazard effects.

The Pebble Project buildout would require additional earthworks and mine-related facilities. The magnitude of potential geohazard-related impacts would be similar to the proposed project, with added stability risk and potential cumulative effects on the Upper Talarik Creek (UTC) drainage due to the large waste rock pile that would be required in the buildout scenario. However, because the projects would likely use some of the infrastructure already developed under the proposed project, the net impacted geographic area would likely be less than developing mines at new greenfield sites in terms of geohazards. In addition, additional storage containment improvements such as extended or new tailings dam facilities would require review and approval from the State of Alaska.

The potential for geohazard impacts along the transportation corridor, ports, and pipeline would increase under the expanded mine scenario, as both the north and south access corridors and two ports would be used. This would potentially add the effects of unstable slopes along the north access road to those of Alternative 1. In addition, the development of a port at Iniskin Bay would increase the likelihood of impacts from dock instability, volcanic ashfall, and tsunamis. For example, in the case of tsunamis, the likelihood of a large tsunami with a 2,500-year return period occurring would increase due to the longer life of the project. The probability of this size tsunami occurring at either port over the life of the expanded mine is roughly 1 in 15, assuming the ports would be functioning for approximately 148 years total (98 years operations, plus 50 years of closure activities).

Other Mineral Exploration Projects. Mineral exploration at the Pebble South/PEB and Groundhog prospects could have a minor cumulative effect on geologic hazards, depending on the extent of infrastructure development that were to occur. Under any pre-development exploration scenario, effects on geologic hazards would be expected to be temporary and minor, and limited to potential cumulative effects on infrastructure shared with the Pebble Project.

Road Improvement and Community Development Projects. Road improvement projects could have limited impacts on geologic hazards, and therefore contribute to cumulative effects in the analysis area. Lake and Peninsula Borough (LPB) and State of Alaska transportation, infrastructure, and energy projects include possible upgrades to the Williamsport-Pile Bay Road, which is the same alignment that would be used under Alternatives 2 and 3. If either of these alternatives is selected, the net magnitude and geographic extent of unstable slope effects may be relatively low, because the mine access road would already be rerouted or upgraded for maintaining slopes. If the road were to be further widened as part of a transportation improvement project, there would likely be additional impacts.

Additional RFFAs that have the potential to affect geologic resources in the analysis area are limited to the Diamond Point rock quarry. That RFFA would include the excavation of geologic resources, and could have a cumulative effect on geologic hazards such as slope instability effects, although such these would be expected to be minor and limited to the immediate area around the proposed quarry site.

Alternative 2 – North Road and Ferry with Downstream Dams and Alternative 3 – North Road Only

Pebble Mine Expanded Development Scenario. Mine site expansion would be the same as Alternative 1, but overall cumulative effects under Alternatives 2 and 3 with expanded mine development would be less than that of Alternative 1 with expanded mine development, because the expanded mine scenario under Alternatives 2 and 3 would not use the south access corridor or Amakdedori port site. Under these alternatives, project expansion would use the existing Diamond Point port facility, the same natural gas pipeline, and the constructed portion of the north access road. A concentrate pipeline and a diesel pipeline from the mine site to Iniskin Bay would be constructed, both having potentially limited impacts on geologic hazards due to trenching and other earthworks required.

Other Mineral Exploration Projects, Road Improvement and Community Development Projects. Cumulative effects of these activities on geohazards would be similar to those discussed under Alternative 1. The Diamond Point rock quarry is the same location proposed for the Diamond Point port site under Alternatives 2 and 3; hence, there would likely be a relatively minor net increase in geohazard impacts, such as dock stability effects on the marine environment.

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