3.10 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 the project on potentially affected communities. There are federal and state laws and regulations, such as the Clean Air Act, Clean Water Act, 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 evaluation; and in a more singular, medium-specific manner in individual sections such as Section 3.20, Air Quality, and Section 3.18, Water and Sediment Quality.

The Environmental Impact Statement (EIS) analysis area for this evaluation corresponds to an area that could be affected by the mine site, transportation corridor, and natural gas pipeline for each alternative through changes in economic, subsistence, and health resources and activities; or through releases and discharges to the environment. Overall, as listed in Table 3.10-1, the EIS analysis area includes eight communities in the Lake and Peninsula Borough (LPB), seven communities in the Dillingham Census Area, two communities in the Kenai Peninsula Borough (KPB), and three communities in Bristol Bay, as well as surrounding regions and the Municipality of Anchorage (it is likely that some project workers would come from this urban population). Not all communities are assessed for all health effects, because some effects may be more relevant to some communities than others. Although it is possible that additional communities may occasionally use the EIS analysis area, these communities capture those most likely to use the areas with the greatest magnitude of potential impacts from the project (e.g., potential impacts to air quality, water and sediment quality, soils, wildlife and fish, and transportation), and are adequate to assess potential project impacts in this EIS with respect to health-related impacts.

This evaluation is intended to document baseline health and safety status in the EIS analysis area so that project-related positive and negative health and safety consequences for the project and alternatives may be identified and evaluated in Section 4.10, Health and Safety, as to their likelihood and degree; and mitigation measures may be recommended to minimize potential negative impacts that could occur as a result of the project. Human health data for the EIS analysis area are generally available at broad regional scales, but some data are available at the community level. Differences between the two scales are distinguished, where possible, to the extent relevant for this evaluation.

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.

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

Table 3.10-1: Potentially Affected Communities

Potentially Affected Communities	HECs Evaluated	Level of Evaluation	
		Community[5] and Regional	Regional
Lake and Peninsula Borough			
Lake and Peninsula Borough	All, as needed[1]		X
Iliamna Lake/Lake Clark Region	All, as needed[1]		X
Nondalton	All	X	
Iliamna	All	X	
Newhalen	All	X	
Port Alsworth	All	X	
Pedro Bay	All	X	
Kokhanok	All	X	
Igiugig	All	X	
Levelock	All	X	
Dillingham Census Area			
Dillingham Census Area	All, as needed[1]		X
Nushagak/Bristol Bay Region	All, as needed[1]		X
Ekwok	All	X	
Koliganek	All	X	
New Stuyahok	All	X	
Dillingham	All, particularly HECs 1, 3 & 4 [2]	X	
Clark's Point	HECs 3 & 4 for Subsistence [3]	X	
Manokotak	HECs 3 & 4 for Subsistence [3]	X	
Aleknagik	HECs 3 & 4 for Subsistence [3]	X	
Bristol Bay Borough			
Bristol Bay Borough	All		X
King Salmon	HECs 3 & 4 for Subsistence [3]	X	
Naknek	HECs 3 & 4 for Subsistence [3]	X	
South Naknek	HECs 3 & 4 for Subsistence [3]	X	
Kenai Peninsula Borough			
Kenai Peninsula Borough	All		X
Ninilchik	HECs 3 & 4 for Subsistence [3]	X	
Seldovia	HECs 3 & 4 for Subsistence [3]	X	
City of Anchorage and Matanuska-Susitna Borough			
Anchorage Mat-Su Region	All, particularly HEC 1 [4]		X

Notes:
[1] Regions and boroughs are evaluated, as needed, based on the lack of or uncertainty with the community-level data.
[2] Dillingham is farther from the project than the other 11 potentially affected communities, but it is likely that some project workers would come from this population, and it is possible that subsistence users from this population could use the EIS analysis area. Therefore, the primary impacts would be expected to be socioeconomic in HEC 1, and subsistence impacts in HECs 3 and 4. Dillingham is represented in the information provided for the Dillingham Census Area.
[3] Potential subsistence impacts for these communities are evaluated in HECs 3 and 4, and are represented in the information provided for the larger boroughs in which they reside (Dillingham Census Area, Bristol Bay Borough, and Kenai Peninsula Borough).
[4] Anchorage is outside the Bristol Bay drainages and farther from the project, but it is likely that some project workers would come from this urban population, and the primary impact would be expected to be socioeconomic (HEC 1).
[5] Community-level evaluations were performed as data permitted.
HEC = Health Effect Category

3.10.1 Health

For the purposes of this document, and consistent with Alaska Department of Health and Social Services (ADHSS), health is defined not merely as the absence of disease, but 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). Therefore, it represents an integrated state of physical, social, and mental well-being. Health is affected by environmental, social, cultural, and genetic factors often called "determinants of health." Community health in Alaska, with its environmental and social setting and complex blend of health determinants, is in many ways different from national health trends in the US (ADHSS 2015). Resource development projects, such as mining activities, can often affect the health of nearby communities in complex ways; impacts may be both positive and negative.

Funding and completion of an HIA following Alaska guidelines is strictly voluntary in Alaska, and is not required by either Alaska State law or federal law (ADHSS 2015). Although voluntary, Alaska's HIA toolkit guidance helps project applicants and policy-makers understand both the negative and positive health impacts of a proposed project, and create plans to enhance the positive and reduce the negative impacts. The toolkit provides a broad-based but tiered process that allows the scope of the HIA to be focused on a sub-set of finite, plausible health impacts (clearly defined causal connection between the project and the anticipated health impact) identified through a screening and scoping process. Therefore, although this health evaluation describes the broad health effects categories (HECs) and several typical health metrics for each category included in the ADHSS guidelines, emphasis is focused on assessing key issues and potential impacts identified during scoping (as required by NEPA), and those expressed by stakeholders.

There is generally overlap between the affected communities in relation to the project components and phases for all alternatives and variants (see Chapter 2, Alternatives, for a description of alternatives and variants); therefore, the functional classification of baseline information for the affected communities was at the scale of the EIS analysis area and through the end of the closure phase. Specific affected community distinctions by component, area, or phase are only denoted when relevant.

3.10.1.1 Assumptions and Limitations

Focus on Most Relevant Human Health Effects Categories and Diseases—Important goals of developing an HIA are that it should be useful in understanding project consequences, and should help to inform project decisions. It should consider those health-related issues that are relevant to the project, or of concern to the stakeholders and affected communities. The HIA toolkit outlines a broad set of eight types of HECs to be considered for an HIA in Alaska. However, not all effects categories are relevant or likely for every project. This health evaluation has been streamlined to focus on the HECs that could be directly impacted by the project or may be expressed as a primary stakeholder concern, based on the project description and review of concerns expressed by stakeholders and community members as summarized in the Pebble Project EIS Scoping Report (Appendix A). Among the range of concerns expressed by the communities and stakeholders during the scoping process, the highest health-related concerns included anxiety about possible social, psychological, and behavioral health impacts; concerns about short-term economic gains versus potential long-term environmental devastation; fear of increased traffic-related accidents and injuries; potential exposure to toxic chemicals in air, water, and other environmental media; chemical impacts on availability and quality of subsistence foods, particularly fishing resources; and potential overloading of existing infrastructure and services. The key issues for the health evaluation were then identified by considering the stakeholder concerns in the context of the project description, including the design and operation features and the impact avoidance, mitigation, and monitoring measures already proposed by Pebble Limited Partnership (PLP).

Therefore, the primary focus of this health evaluation includes HEC 1: Social Determinants of Health; HEC 2: Accidents and Injuries; HEC 3: Exposure to Hazardous Materials; and HEC 4: Food, Nutrition, and Subsistence Activity. Baseline information for these HECs is discussed in this section and Appendix K3.10. These HECs are considered relevant because they assess social, financial, and health impacts that may arise directly from project-related employment and economic activities (HEC 1); accidents and injuries related to a variety of new construction and transportation facilities required for the project (HEC 2); possible health effects related to chemicals that the public may be exposed to during project activities (HEC 3); and impacts on food availability and harvesting activities that may occur in the project footprint or affected areas (HEC 4).

The remaining health effects categories are less likely to have plausible, causal connections with or easily measurable impacts from the project. The baseline status of these HECs is briefly summarized in this section, but is discussed in more detail in Appendix K3.10 for purposes of completeness.

Identifying Potentially Affected Communities—The communities included in this health evaluation are consistent with the recommendations in the HIA guidance that potentially affected communities should be identified on the basis of multiple factors, including geographic proximity to the project, potential for economic impact (e.g., work force recruitment areas, population influx areas), potential use areas in relation to project footprint (e.g., subsistence activity areas), and areas of health disparities. The project would cover a relatively large geographical distance. The transportation corridor would extend approximately 72 miles, and the natural gas pipeline would extend approximately 210 miles. The potentially affected communities, including children and adults, that were identified for the health evaluation correspond to the EIS analysis areas, which are the basis of Section 3.3, Needs and Welfare of the People—Socioeconomics, and Section 3.9, Subsistence. The populations of the communities in the EIS analysis area for the health section range from very small, rural communities closer to the mine site to larger, more urban communities farther away. The locations of the selected areas are illustrated in figures for Section 3.4, Environmental Justice. These potentially affected communities, regional areas, and the HECs for which they are evaluated in this section are listed in Table 3.10-1.

The majority of the health evaluation is focused on 11 individual communities that represent the five larger boroughs/census area of the EIS analysis area. This section focuses on the 11 potentially affected communities geographically closest to the project in the Bristol Bay drainage basins: those most likely to be potentially impacted by the project. These communities include eight Iliamna Lake/Lake Clark communities in the LPB, and three Nushagak/Bristol Bay communities in the Dillingham Census Area. The eight LPB communities are closest to the project, and include Nondalton, Newhalen, Kokhanok, Port Alsworth, Iliamna, Pedro Bay, Levelock, and Igiugig. In 2018, the LPB had a population of 1,663, while these small rural communities had approximate population ranges of 33 to 227 people. These eight communities may be more directly impacted, both positively and negatively, compared to communities farther away, due to their relative proximity to the project components, and were evaluated for all HECs at the community level when data permitted. Three Nushagak/Bristol Bay communities (i.e., New Stuyahok, Koliganek, and Ekwok) in the Dillingham Census Area (census area population 5,021 in 2018) were also identified as geographically close to the project, and were evaluated at the community level when data permitted. These three communities had populations ranging from 106 to 496 in 2018. This section also evaluates impacts to the nearby community of Dillingham (at a regional level for health effects) and nearby boroughs and municipalities, because it is likely that some project workers would come from these populations. The 2018 populations for these communities were 2,382 in Dillingham, 58,471 in the KPB, 879 in the Bristol Bay Borough, and 295,365 in the Municipality of Anchorage (ADOL 2018; USCB 2018).

For subsistence-related health impacts, a total of 19 individual communities distributed throughout the larger boroughs and census areas are evaluated. The communities evaluated for subsistence impacts in this section (in HECs 3 and 4) were slightly different from the communities evaluated for socioeconomic impacts. The local communities evaluated for subsistence effects include the eight affected communities in the LPB, and two of the three affected communities in the Nushagak/Bristol Bay area (the data are insufficient to evaluate subsistence for Ekwok), as well as nine additional communities that are farther from the project, but are known to use the area for subsistence (see Section 3.9, Subsistence). The nine additional subsistence-related communities include four communities in the Dillingham Census Area (Dillingham, Clark's Point, Manokotak, and Aleknagik), three communities in the Bristol Bay Borough (Naknek, South Naknek, and King Salmon), and two communities in the KPB (Ninilchik and Seldovia). Section 3.9, Subsistence, and Appendix K3.9 focus on six of the Iliamna Lake communities geographically closest to the project that show a particularly high level of subsistence activities in the EIS analysis area (Iliamna, Newhalen, Pedro Bay, Nondalton, Igiugig, and Kokhanok), but also present baseline details on traditional ecological knowledge (TEK), seasonal rounds, and subsistence harvest patterns for all 19 communities. Although it is possible that additional communities may occasionally use the EIS analysis area, these 19 communities, particularly the six Iliamna Lake communities, capture those most likely to use the area and are adequate to assess potential project impacts in this EIS with respect to subsistence-related health impacts.

The limitation of evaluating health impacts to communities based on proximity to the project components is that some effects may not be directly related to the distance between the community and the project component, such as employment opportunities. The rural location of the mine and the planned on-site housing camps make traditional commute times irrelevant; therefore, the communities that would contribute to the workforce may include more than those closest to the site. Also not directly related to distance would be changes in a community from project features, such as communities that might want to use project components like the Amakdedori port during the operations phase. These factors that are not dependent on distance also warrant consideration.

Age and Scope of Available Information—This EIS relies on previously compiled baseline information for most of the HECs, which date from about 2002 to 2017, with the majority from 2008 to 2017. More current data were accessed, when available, with a focus on the effects categories and diseases most relevant to human health effects.

For five categories (i.e., Social Determinants of Health; Accidents and Injuries; Food, Nutrition, and Subsistence Activity; Water and Sanitation; and Health Services Infrastructure), this health evaluation primarily relies on the data and conclusions from Section 4.3, Needs and Welfare of the People–Socioeconomics; Section 4.12, Transportation and Navigation; and Section 4.9, Subsistence, and supplements those sections as appropriate. For infectious diseases and non-communicable and chronic diseases, the baseline description focuses on the top several diseases in each category based on their public health significance and occurrence frequency. The sources of data cited also provide information on less prevalent diseases and conditions.

Health data are not always available at the community level for these potentially affected communities, due to privacy concerns and very small community sizes. To address these limitations, regional data sources in and near the EIS analysis area, including the LPB, Bristol Bay Borough, Dillingham Census Area, KPB, and Municipality of Anchorage, were included in the evaluation. Of these, only Anchorage is considered an urbanized area, and although it is neither geographically close to the project nor in the Bristol Bay drainages, it is likely that some project workers would come from this population. The other boroughs are considered remote, rural areas and are in or close to the EIS analysis area.

3.10.1.2 Demographic Summary of Potentially Affected Communities

The eight Iliamna Lake/Lake Clark communities and three Nushagak/Bristol Bay communities in or geographically closest to the project are generally comparable in median age and high school-level education rates to state averages, but lower in rates of college-level education and median income levels. With the exception of Port Alsworth, the individual communities in LPB and the Dillingham Census Area are majority Alaska Native populations. Bristol Bay Borough, Kenai Peninsula, and Anchorage have closer correspondences with state-level trends; particularly Anchorage, with its much larger population. To provide context for the health evaluation, a brief summary of the demographic data is presented in Table 3.10-2 for the 11 communities geographically closest to the project, as well as regional data. More detailed demographic information for these 11 communities, including seasonal impact on employment, top employment sectors, population changes, age range percentages, gender percentages, and housing, is presented in Section 3.3, Needs and Welfare of the People–Socioeconomics. The nine additional communities that were evaluated only for subsistence impacts are represented in the information provided for the larger areas in which they reside (Dillingham Census Area, Bristol Bay Borough, and KPB).

Table 3.10-2: Demographic Summary

Subject	Alaska Native[1] Population (2017)	White[2] Population (2017)	Median Age (2018)	High School Graduate or Higher (2018)	Earned College Degrees (2018)	Median Household Income (2018)	Unemploy-ment Rate (2018)
Lake and Peninsula Borough	67.6%	22.4%	32.3	88%	16%	$45,208	13.2%
Nondalton	73.6%	13.6%	31.8	85%	11%	$38,750	25.0%
Iliamna	75.4%	16.9%	34.8	97%	19%	$93,750	6.1%
Newhalen	82.5%	9.6%	25.3	90%	17%	$36,250	8.0%
Port Alsworth	10.2%	68.8%	18.9	99%	49%	$86,667	1.3%
Pedro Bay	50.0%	16.7%	57.3	100%	11%	$53,750	18.2%
Kokhanok	91.9%	8.1%	28.1	81%	8%	$41,250	30.8%
Igiugig	89.1%	10.9%	29.0	86%	21%	$48,750	0.0%
Levelock	97.9%	2.1%	24.5	83%	2%	$25,000	16.3%
Dillingham Census Area	72.9%	17.5%	30.1	86%	17%	$58,708	11.4%
Ekwok	100.0%	0.0%	28.3	69%	0%	$28,750	39.5%
Koliganek	82.9%	9.4%	26.6	83%	20%	$53,750	11.1%
New Stuyahok	97.3%	0.4%	24.8	78%	3%	$43,750	23.8%
Dillingham	56.5%	28.0%	31.6	91%	22%	$75,764	5.1%
Bristol Bay Borough	34.6%	52.0%	41.8	93%	20%	$79,500	6.8%
Kenai Peninsula Borough	7.3%	83.6%	40.6	93%	24%	$65,279	8.6%
Anchorage	7.3%	63.7%	33.1	93%	35%	$82,271	5.8%
State of Alaska	14.2%	65.3%	33.9	92%	29%	$76,114	7.7%

Notes:
[1]Alone, or in combination with one or more other races.
[2]Alone, non-Hispanic.
See Section 3.3, Needs and Welfare of the People—Socioeconomics, for additional discussion and details.
Demographic and socioeconomic profiles of the potentially affected communities are presented in McDowell et al. 2011a; McDowell 2018a; in Section 3.3, Needs and Welfare of the People—Socioeconomics; and Section 3.4, Environmental Justice. The Alaska Native Health Status Report (ANTHC 2017a) presents recent state and regional overviews of sociodemographic highlights demographics, education attainment, unemployment, poverty, and household income), as well as mortality highlights, morbidity highlights, and maternal, infant, and child health highlights.
Sources: USCB 2018

3.10.1.3 Baseline Community Health Conditions

Baseline conditions are defined as the current health status of the potentially affected communities, in the absence of or prior to the project. Information for the 11 potentially affected communities geographically closest to the project and evaluated for all HECs is presented, and compared to other local and regional data as warranted, and compared to state or US data. Primary data sources include government, regional, community, and academic sources.[1] As noted earlier, the individual communities in the Dillingham Census Area, KPB, and Bristol Bay Borough that were evaluated only for subsistence impacts are not included here, but are included in the respective borough-level data.

Although statewide data offer some context, the HEC discussions in this section are limited to health endpoints that have relevant and recent regional and local data available (older data are presented as warranted or if current data were not available). When available, local community data are representative of very small populations. Comparisons of statewide rates with local small population community rates should be interpreted with caution due to the statistical uncertainty associated with small populations, and because the statewide rates represent a mix of large and small population data. For regional rates based on fewer than 20 cases, they should also be viewed with caution because they may not be statistically reliable.

It is important to recognize that communities and populations are composed of many sub-groups with different levels of health status, access to healthcare, and susceptibility to health impacts leading to disparities in health status. Age, gender, ethnicity, income level, education, and other factors greatly affect the health status of individuals and households.

3.10.1.4 Health Effects Categories

HEC 1: Social Determinants of Health

It is widely recognized that social and economic factors and access to healthcare have a strong causal relationship with health status (WHO 2018; ODPHP 2018). Factors such as income, education, isolation, and early access to healthcare are termed social determinants of health (SDH) because any changes in these factors, positive or negative, can lead to corresponding changes in the physical, mental, and social health of the population. Outcomes of SDH such as infant mortality, suicide rates, or dental health serve as indicators of overall community health status and health needs. Any project-related impacts to the SDH of the affected communities, especially small communities, may result in immediate and substantial impacts on key aspects of community health (e.g., increased income levels as a project benefit may make preventive healthcare more affordable and result in a drop in avoidable serious health issues). Oral health is an important and commonly used health indicator by public health agencies such as the Centers for Disease Control and the ADHSS, because it represents both behavioral and structural risk factors.

The ADHSS Technical Guide (ADHSS 2015) suggests a broad list of SDH for consideration. For the purposes of this evaluation, a limited subset of SDH representing a range of physical, mental, and social factors was selected that covers a range of population sectors from infants to adults, and has the most value as overall indicators of community health status. Physical metrics of SDH include life expectancy, adequate prenatal care, infant mortality, and oral health. Psychosocial metrics of SDH include teen pregnancy rates, adult mental health, suicide (overlaps with HEC 2), alcohol use, binge drinking, and crime (e.g., assault and rape). Many of these SDH for the affected

[1] Primary data sources include the Alaska Department of Commerce, Community, and Economic Development, Alaska Department of Environmental Conservation, Alaska Department of Fish and Game, ADHSS, Alaska Department of Labor and Workforce Department, Alaska Native Tribal Health Consortium, Alaska State Troopers, Bristol Bay Area Health Corporation, Bristol Bay Native Association, Cook Inlet Region, Inc. Foundation, Commercial Fisheries Entry Commission, US Department of Commerce, Bureau of Economic Analysis, US Census Bureau, US Centers for Disease Control and Prevention, US Department of Health and Human Services, World Health Organization, and other government, regional, community, and academic sources.

communities are evaluated in Section 3.3, Needs and Welfare of the People—Socioeconomics. SDHs, such as isolation and cultural change, lack meaningful available data at the community level of health, but are addressed in a larger context in Section 3.7, Cultural Resources, and Section 3.9, Subsistence.

For those SDH not covered in Section 3.3, Needs and Welfare of the People–Socioeconomics, Table K3.10-1 in Appendix K3.10 summarizes the additional relevant SDH and important indicators for this HEC, because they may potentially be impacted by the project. The Bristol Bay, Kenai Peninsula, and Anchorage regions have similar Alaska Native life expectancies to the state, but these rates are approximately 7 to 8 years lower than state and national life expectancies for whites (ANTHC 2017b). The Iliamna Lake/Lake Clark communities had rates of adequate prenatal care comparable to the urban Anchorage region. In comparison to these rates, the Nushagak/Bristol Bay communities, LPB, Dillingham Census Area, and Bristol Bay Borough all had higher rates of inadequate prenatal care, particularly the Nushagak/Bristol Bay communities (ANTHC 2016a; McDowell 2018b). The Nushagak/Bristol Bay communities and the Bristol Bay region had higher teen pregnancy rates than the Dillingham Census Area, the Kenai Peninsula, and Anchorage (ANTHC 2016c). With regard to oral health, the Bristol Bay, Kenai Peninsula, Anchorage, and state rates were all fairly similar for Alaska Natives, but they all had higher rates of tooth loss compared to Alaska Whites (ANTHC 2017c, d).

Mental health is measured as self-reported stress, depression, and problems with emotions in the past 30 days (ANTHC 2017e; McDowell 2018b). Although the average statewide number of poor mental health days was 20 percent higher for Alaska Natives than Alaska Whites (ANTHC 2017e), the LPB, Dillingham Census Area, and Bristol Bay Borough all self-reported lower rates of poor mental health (all races) than state rates reported for all races, whites, and Alaska Natives (McDowell 2018b). Binge drinking is measured as self-reported adults aged 18 years of older who have had five or more drinks (men) or four or more drinks (women) on one or more occasions in the past 30 days (ANTHC 2017g) or in one sitting (McDowell 2018b). The LPB and Dillingham Census Area self-reported lower rates of binge drinking (all races) compared to state rates, while Bristol Bay Borough reported rates higher than the state (McDowell 2018b). The overall violent crime rate in the Dillingham Census Area is nearly double the rate in the urban Anchorage region and the state, and more than four times the rate in the Kenai Peninsula region and nationally (FBI 2017). Specifically, aggravated assault and rape were much higher in the Dillingham Census Area compared to other regional, state, and national rates. There were no violent crime rates reported for the Bristol Bay Borough (FBI 2017), but these results appear erroneous (perhaps the 2017 data were not yet tabulated into the FBI database), because reported crimes in 2016 in Bristol Bay include assault, burglary, forcible entry, larceny-theft, and motor vehicle theft (McDowell 2018a). Although not exhaustive, these metrics indicate that some areas of health status where the rural communities are comparable to or better off than urban areas, and some health needs where rural areas fare worse, project-related activities may lead to improvement or further worsening, as discussed in Section 4.10, Health and Safety.

Overall, the affected communities whose health may be most impacted by the project in the EIS analysis area (or may use the area for residence, subsistence, or recreation) are the remote, rural communities in the Bristol Bay Region (which includes the LPB, Bristol Bay Borough, and Dillingham Census Area) and Kenai Peninsula Region. The remote communities generally have lower levels of employment, income, formal educational attainment, and access to amenities than urban communities. Although they are comparable to the larger urban areas in some areas of health, there are other areas such as alcohol consumption where the rural areas may have higher health needs.

HEC 2: Accidents and Injuries

Accidents and injuries include both fatal and non-fatal incidents that are primarily unintentional and affect the mortality and morbidity rates of a community. Unintentional injury (e.g., falls, poisoning, drowning, and motor vehicle crashes) is the third leading cause of death in the state, and a leading cause of death in most regions (ADHSS 2017a; ANTHC 2017i), including the Iliamna Lake/Lake Clark Communities, Dillingham Census Area, and Bristol Bay Borough (McDowell 2018b). Intentional incidents include homicide and suicide (note: suicide overlaps with HEC 1, psychosocial stress). An understanding of baseline rates of accidents and injuries is important to understand whether any aspects of the project could lead to changes in these parameters. For example, surface transportation elements of the project could alter the rates of motor vehicle and other land transport accidents.

Information regarding unintentional deaths and injuries, leading causes of hospitalization, and suicide rates was available for most of the regions in the EIS analysis area (see Table K3.10-2). In comparison to national and state rates, the levels of unintentional deaths and injuries in the potentially affected communities were higher. Overall, falls were the number one cause of hospitalizations in Alaska, as well as the EIS analysis area, with the exception of Bristol Bay.

Vehicle incidents and causes related to land transport were ranked as the number one cause of hospitalization in Bristol Bay (other land transport), as number two (other land transport) in the LPB, and number two (other land transport) and number three (motor vehicle) in Dillingham Census Area. These rankings are similar to one another and to the state of Alaska overall, where vehicle accident hospitalizations are ranked as the number two (motor vehicle) and number four (other land transport) causes of hospitalization for the state of Alaska overall (ANTHC 2015, 2017c, j; McDowell 2018b). Baseline data for other transportation accident types (e.g., ferry, barge, air) were not readily available, which may be due to low number of occurrences, because none are listed as leading causes of hospitalizations. Numeric data on rates or numbers of accidents by cause or type of transportation were not readily available.

Suicide mortality rates varied by region, but it was the fourth leading cause of death among Alaska Native people during the period from 2012 to 2015 (ANTHC 2017f). Suicide mortality rates for the Dillingham Census area, Anchorage, and state are similar. In comparison to the Dillingham Census Area, Anchorage, and the state, Bristol Bay regional rates are higher, and Kenai Peninsula regional rates are lower (ANTHC 2017f; McDowell 2018b). However, due to the low number of documented suicide mortality cases in the Dillingham Census Area, Bristol Bay region, and Kenai Peninsula region, these rates may not be statistically reliable, and should be viewed with caution.

HEC 3: Exposure to Potentially Hazardous Materials

Environmental exposure to hazardous chemicals through the air, land, or water is considered a health determinant. Baseline data may be qualitative in terms of proximity to known contamination sources, or quantitative through analytical data collection (e.g., water quality data, soil analytical data). Overall, baseline conditions of exposure to potentially hazardous chemicals may include the occurrence of localized poor air quality in some areas due to outdoor dust or indoor air pollution, as well as elevated levels of a few naturally occurring metals in soils, surface waters, groundwater, and some food sources. Dust from unpaved roads may circulate contaminants that can be deposited onto surface water and further redistributed to sediments.

Air Quality—The role of poor air quality on community health, particularly with regard to respiratory disorders, has been well-documented (WHO 2016). Air pollutant concentrations that are lower than the Alaska Ambient Air Quality Standards (AAAQS) provide public health protection, including protecting the health of sensitive populations such as asthmatics, children, and the elderly. Section 3.20, Air Quality, presents background concentrations for criteria pollutants for each project component that are representative of the ambient environment, and include the contributions from nearby and other background sources. These background air quality data are sufficient for establishing baseline EIS analysis area conditions for NEPA purposes. All measured criteria air pollutants in the region containing the project are below AAAQS. The project is far from any potential sources of lead (e.g., airfields); and absent large regional anthropogenic sources, there is no reason to expect measurable concentrations of hazardous air pollutants in the project area except for what is biogenic in nature (see Section 3.20, Air Quality).

Burning trash, generating power using diesel generators, and heating homes using wood stoves are possible practices in the potentially affected communities in the EIS analysis area that could contribute to localized poor air quality indoors and outdoors. Unpaved roads are a major source of dust and may circulate pollutants in dust, which affects air quality and may also settle on food sources. There are also indoor air quality issues with the use of old wood and fuel oil burning stoves, which may be made worse by spending a lot of time indoors in winter.

Water Quality—The baseline water quality data are provided in Section 3.18, Water and Sediment Quality. The baseline surface water data were obtained from the waterbodies in the EIS analysis area that would be most affected by project activities, including North Fork Koktuli, South Fork Koktuli, Upper Talarik Creek, Frying Pan Lake, Iliamna Lake, and surface water data along the western and eastern parts of the north access route of the transportation corridor. Baseline surface water resources in the vicinity of the mine site and Alternative 1a, Alternative 1, Alternative 2, and Alternative 3 transportation corridors had numerous detections of naturally occurring trace elements/metals, but only a few mean concentrations exceeded the selected applicable State of Alaska water quality standards (WQS) protective for all designated water uses (most stringent of human health and ecological criteria, including drinking water supply and household use): aluminum in the western portion of the north access road, and aluminum and copper in the eastern portion of the north access road. Although cyanide was only occasionally present in detectable concentrations, none of the mean concentrations were above the WQS. See Section 3.18 and Appendix K3.18, Water and Sediment Quality, for further details on water quality criteria.

The baseline groundwater data were obtained from individual wells along the watershed in each lithologic group in and outside the Pebble deposit area. Baseline groundwater had numerous detections of naturally occurring trace elements/metals, with mean concentrations of aluminum, copper, iron, lead, manganese, molybdenum, and zinc exceeding the most stringent of either drinking water standards or WQS for aquatic life criteria, because groundwater could discharge to surface waterbodies. For further details, see Section 3.18, Water and Sediment Quality. Several community drinking water wells are situated along the transportation corridors: Nondalton City Well, Newhalen Public Well #2, Iliamna Weathered Inn Well, and the Pedro Bay Tribal Council Well. Arsenic was reported as above drinking water standards in the Nondalton, Newhalen, and Pedro Bay wells, while pH was reported above drinking water standards in the Newhalen, Pedro Bay, and Iliamna wells. Arsenic is a naturally occurring element in rock and soil, and often present in trace amounts in groundwater. Concentrations of arsenic in groundwater are generally associated with volcanic deposits and gold-mining areas, and high concentrations of arsenic in groundwater are largely the result of arsenic-containing minerals (e.g., iron-sulfide and copper-sulfide minerals) dissolving naturally over time from weathered rock and soils.

Existing Potentially Hazardous Materials Sites—There are numerous known contaminated sites in the EIS analysis area that are under federal or state agency oversight. The following summarizes the number of open Alaska Department of Environmental Conservation (ADEC)-regulated contaminated sites listed for each of the boroughs in and in the vicinity of the EIS analysis area on ADEC's contaminated sites database, as of March 2018 (ADEC 2018d):

- Lake and Peninsula Borough—30 open sites
- Bristol Bay Borough—60 open sites
- Dillingham Census Area—25 open sites
- Kenai Peninsula—130 open sites

In addition, there are four US Environmental Protection Agency (EPA) Comprehensive Environmental Response, Compensation, and Liability Act sites in Anchorage (EPA 2018a), as well as US Army Corps of Engineers (USACE) formerly used defense sites in the LPB (four sites) and the KPB (10 sites). Contaminants of concern from these sites include, but are not limited to: metals, asbestos, polychlorinated biphenyls, petroleum hydrocarbons (e.g., fuel, lubricants), pesticides, and solvents. All these sites are under active oversight by government agencies, and agency directives are expected to control or prevent exposure to the general public. Additionally, no contaminated site records coincided with or were in proximity to the project footprint. Therefore, the proximity of these sites is not expected to contribute to the baseline exposure to hazardous materials.

Potentially Hazardous Materials Exposure through Subsistence—People may be exposed to chemicals in food sources through food-web transfer (chemicals accumulated by fish, wildlife, or edible plants). The accumulation of chemicals in biological tissues is called bioaccumulation; increasingly higher concentrations of chemicals at higher levels of the food-web is called biomagnification. However, not all chemicals have the propensity to bioaccumulate or biomagnify. Examples of metals that may bioaccumulate to some degree include arsenic, lead, and mercury; mercury also can biomagnify.

In the EIS analysis area, baseline trace element (metal) data were collected for soil, vegetation, and fish tissue, as well as sediment and surface water, and are provided and discussed in Section 3.14, Soils; Section 3.26, Vegetation; Section 3.24, Fish Values; and Section 3.18, Water and Sediment Quality. Exposure to these trace elements/metals from these media, resources, and from ambient air may have the potential to impact human health from direct exposure, including inhalation; or through dietary exposure, including the potential for some of these trace metals to bioaccumulate in tissue. Bioaccumulation can occur either from the direct exposure pathway (i.e., inhalation of metals in air or dust) or from the dietary pathway (e.g., metals may bioaccumulate and biomagnify in wildlife and fish, which may then be consumed by subsistence users). In addition, exposure to infants can occur through maternal transfer of dietary metals. Exposure to these trace elements through direct and dietary exposure represents baseline hazardous exposure potential for the potentially affected communities in the EIS analysis area.

HEC 4: Food, Nutrition, and Subsistence Activity

The role of adequate and high-quality food and nutrition is of paramount importance to health. In Alaska, subsistence activities greatly contribute to community nutrition to provide dietary items such as fish, game, and berries that are highly nutritious, and support cultural and social cohesion (ANHB 2004). The level of physical activity involved in harvesting subsistence foods also contributes to a more active lifestyle and confers additional health benefits (overlaps with HEC 7, because low physical activity is considered a chronic disease contributing factor). Therefore, subsistence activities and nutrition play a large role in the physical and social health of communities; changes to these dietary habits and food security may lead to changes in health. For example, if the footprint of a project has a substantial overlap with traditional hunting or fishing areas such that people's access to these resources is reduced or subsistence users avoid harvesting resources near regional extractive industrial developments due to contamination concerns (whether real or perceived), this may lead to changes in subsistence harvesting patterns and dietary composition, such as reduced fishing or hunting activity, and the purchase of lower-quality, processed foods. The health consequences may include a more sedentary lifestyle along with lower nutritional health status. Conversely, positive impacts may also occur if increased income from increased employment allows food-insecure households to purchase more equipment for subsistence harvesting, or to purchase more nutritious food.

As discussed in Section 3.3, Needs and Welfare of the People–Socioeconomics, the cost of living in Alaska is higher than the national average, with Alaska ranked as the third most expensive state nationally, based on costs of living in the four largest Alaskan cities, including Anchorage. However, the price of food in Alaska is even higher in small rural communities that are not connected to the Alaska main road system. In some communities, staple goods, such as food and fuel, cost more than twice as much as they do in Anchorage because the items need to be transported by barge or air. For example, during an August 2018 visit to Iliamna, the price of a half-gallon of whole milk was $13.49, which is equivalent to $27 a gallon, and is nearly nine times the 2017 national average price of $3.16 (Statistica 2018). For additional discussion, see Section 3.3, Needs and Welfare of the People–Socioeconomics.

Although the cost of living can be high in rural communities, it can be offset by subsistence hunting and fishing to supplement the needs of families and communities. Subsistence activities are a central feature of Alaska Native history and society, support healthy diet and nutrition, and are an important aspect of preserving cultural heritage and mental health. Subsistence foods are vital in small rural communities, and are often the basis of many local economies. These foods are important for food security due to high cost of living/food in the region, and are widely recognized as healthier than market food options (USDA 2004). Subsistence foods include salmon, shellfish, game and wildlife (e.g., moose and caribou), and plants and berries. Section 3.9 and Appendix K3.9, Subsistence provide subsistence harvest activity details for each of the potentially affected communities. As shown in Table K3.10-3 in Appendix K3.10, the LPB, Dillingham Census Area, and Bristol Bay Borough report a higher subsistence lifestyle (approximately 2.5 times) than Alaska's population overall (McDowell 2018b). These subsistence lifestyle rates correspond with LPB and Bristol Bay Borough self-reporting higher percentages of physical activity compared to Alaska overall, but do not correlate with the Dillingham Census Area, which was only slightly above Alaska overall (McDowell 2018b; see Table K3.10-5 in Appendix K3.10). However, this may be due to how the baseline data for the communities was measured, because subsistence lifestyle and physical activity were both self-reported and defined by the respondent.

Percentages of nutritional intake and weight are similar between the LPB, Dillingham Census Area, Bristol Bay Borough, and the state, with some noted differences (McDowell 2018b). Table K3.10-3 in Appendix K3.10 presents nutritional baseline data, while overweight/obese baseline data are presented in Table K3.10-5 in Appendix K3.10 (weight overlaps with HEC 7, because it is considered a chronic disease contributing factor). Bristol Bay Borough self-reports as more likely to be overweight/obese according to body mass index, and eat fewer than five daily servings of fruits and vegetables compared to Alaska overall; while Dillingham Census Area self-reports a higher percentage of adults who consume one or more sugar-sweetened beverage or soda per day (not including 100 percent juice or artificially sweetened drinks) compared to Alaska overall (McDowell 2018b).

Poverty levels and rates of malnutrition, as well as cost of living/food and access to and the quantity and quality of subsistence resources have the potential to impact food security and health. Food security is defined by the US Department of Agriculture (USDA) as, "access by all people at all times to enough food for an active, healthy life" (ADF&G 2018v). Food security data, as collected by the Alaska Department of Fish and Game (ADF&G), include subsistence foods and store-bought foods. As shown in Table K3.10-3 in Appendix K3.10, the potentially affected communities in the LPB had percentages of families with incomes below the federal poverty level threshold[2] (2012-2016) ranging from 28.6 percent (Kokhanok) to 0 percent (Igiugig and Pedro Bay); while those in the Dillingham Census Area ranged from 28.1 percent (New Stuyahok) to 5.7 percent (Koliganek). Overall, approximately 15 percent of both LPB and Dillingham Census Area families and just 4 percent of Bristol Bay Borough families fell below the federal poverty level threshold (McDowell 2018a). These borough/census area rates are lower than those living below the poverty level threshold for Alaska Natives statewide, and fairly similar to national whites, at 6.7 percent (2011-2015) (ANTHC 2017a).

Subsistence activities remain an important food source for a large proportion of households in the EIS analysis area reporting using and harvesting (Section 3.9, Subsistence), although it is difficult to quantify how variability in subsistence activities would influence food security. Although subsistence frequently involves no monetary exchange, the contribution of food procured by hunting and fishing and sharing can be a significant contributor to household and community welfare (see Section 3.3, Needs and Welfare of the People—Socioeconomics).

HECs of Low Relevance

As noted earlier, the relevance to the project of the remaining HECs outlined in the HIA toolkit is expected to be low. These include Infectious Diseases (HEC 5), Water and Sanitation (HEC 6), Non-communicable and Chronic Diseases (HEC 7), and Healthcare and Safety Services and Infrastructure (HEC 8). These issues may be addressed by planned project programs and measures, or fall outside the project activity footprint. Therefore, they are briefly summarized here; additional details are included in Appendix K3.10.

HEC 5: Infectious Diseases

HEC 5 evaluates the role of infectious diseases in the health, mortality, and morbidity of populations. Appendix K3.10 and Table K3.10-4 provide details on leading infectious disease rates for the EIS analysis area community regions, when available, and the state of Alaska, as well as childhood immunization rates. Overall, reportable infectious diseases (influenza and pneumonia) were the tenth leading cause of death to all races in Alaska (ADHSS 2017a), but regional rates were not readily available. Regional Alaska Native rates of sexually transmitted infections (as represented by chlamydia and gonorrhea) are comparable to or lower than state Alaska Native rates, while the more urban Anchorage region has rates higher than the state average (ANTHC 2017k, l).

HEC 6: Water and Sanitation

HEC 6 evaluates water and sanitation for the potentially affected communities because the lack of safe water supply (i.e., running water) and suitable sewage disposal can represent a major public health and community development problem. Appendix K3.10 provides details on water and sanitation for the EIS analysis area community regions. In the Bristol Bay Region (which includes Bristol Bay Borough, the Dillingham Census Area, and LPB), 99 percent of households had water and sewer services; while in the Kenai Peninsula, service was 100 percent (ANTHC 2017n).

HEC 7: Non-Communicable and Chronic Disease

Because non-communicable and chronic diseases can consume a large part of healthcare resources and affect the overall health status of a population, HEC 7 evaluates the incidence of

[2] The federal poverty threshold is updated for inflation, but does not vary geographically and is based on pre-tax income (ANTHC 2017a).

such diseases; but in the context of evaluating an individual project, it may be difficult to attribute a single project-related cause to changes in disease incidence. Appendix K3.10 and Table K3.10-5 provide details on non-communicable and chronic diseases for the EIS analysis area communities and regions, as well as chronic disease contributing factors. Overall, Iliamna Lake/Lake Clark, Nushagak/Bristol Bay communities, Anchorage, and the state have similar leading causes of death (cancer and heart disease) and similar cancer death rates, with the exception of higher cancer rates in Iliamna Lake/Lake Clark communities and LPB (McDowell 2018b; ADHSS 2017a; ANTHC 2017a, i, o). The leading types of cancers causing deaths in the potentially affected communities are colorectal and lung/bronchus cancers. Colorectal cancer death rates are higher in the LPB and Dillingham Census Area compared to the state; conversely, lung/bronchus cancer death rates are lower in these two areas compared to the state (McDowell 2018b). Cancer incidence is variable, but generally similar between the regions, state, and national rates, with the exception of lower incidence in the Dillingham Census Area (colorectal as the leading type) and higher in the Kenai Peninsula Region (McDowell 2018b). Heart disease rates in the Iliamna Lake/Lake Clark communities, Nushagak/Bristol Bay communities, and LPB were higher than both Anchorage and state rates (McDowell 2018b; ADHSS 2017a; ANTHC 2017a, i, p).

HEC 8: Health and Safety Services Infrastructure and Capacity

An important measure of the health-related resilience and support structure of a community is the quality and quantity of healthcare and safety services that are available to the residents. HEC 8 evaluates potential impacts to the capacity of existing healthcare and safety services. Appendix K3.10 and Table K3.10-6 provide details on health services, hospitalizations, and adequacy of health services in the EIS analysis area. Overall, the LPB, Bristol Bay Borough, and the Dillingham Census Area report lower or similar access to health services (McDowell 2018b). All of these communities, with the exception of Port Alsworth, have a health clinic served by 1 to 5 health aides. Although there are some variations in the top three leading causes of hospitalizations by year and region, pregnancy/childbirth and newborn/neonate complications of pregnancy and childbirth or newborn/neonate conditions are consistently leading causes. The LPB, the Dillingham Census Area, Bristol Bay Borough, Kenai Peninsula, and Anchorage are all designated as Medically Underserved Area/Population.

Table K3.10-7 provides a summary of the available safety services for the eight Iliamna Lake/ Lake Clark communities in the LPB and the three Nushagak/Bristol Bay communities in the Dillingham Census Area, including number of village public safety officers (VPSO) or village police officers (VPO), ambulances, fire trucks, and emergency medical technicians (EMT) or emergency trauma technicians (ETT). Only two of these communities (New Stuyahok and Koliganek) are served by a VPSO and/or VPO; the communities without rely on Alaska State Trooper coverage. Three communities have an ambulance, fire truck, and EMTs (Newhalen, Nondalton, and Iliamna). Three other communities also have ambulances: one with a fire truck (Igiugig) and two with an EMT (Pedro Bay and New Stuyahok). Of the remaining communities, Kokhanok is served only by ETTs, Levelock is served only by a fire truck, Koliganek is only served by EMTs, and Port Alsworth and Ekwok are not served by any of these safety services. Overall, these communities have lower access to safety services than larger nearby communities, such as the city of Dillingham, which has a police department and a hospital (McDowell 2018a, 2018b), and Anchorage.

3.10.2 Safety

Safety, as defined by compliance with OSHA and MSHA regulations, or other types of design, structural, operational, and accident or hazard prevention programs cannot be described for the

EIS analysis area under baseline conditions, because there is no project activity. Safety is discussed with reference to the project in Section 4.10, Health and Safety.

Baseline safety for the potentially affected communities "outside the fence" were included under HECs discussed in this section (e.g., violent crime under HEC 1, accidents and injuries under HEC 2, health and safety infrastructure and capacity under HEC 8).

3.10.2.1 Pipeline Reliability and Safety

The transportation of natural gas by pipeline involves some risk to the public in the event of an accident and subsequent release of gas. The greatest hazard is a fire or explosion following a major pipeline rupture. Section 4.27, Spill Risk, discusses the risk of a natural gas release from the pipeline.

Methane, the primary component of natural gas, is colorless, odorless, and tasteless. Although there are differing opinions regarding methane's relative toxicity, for the purpose of this EIS, methane is considered toxic, in keeping with its listing on the EPA's Toxic Substances Control Act inventory, and is a simple asphyxiate. If breathed in high concentration, oxygen deficiency can result in serious injury or death. Methane has an auto-ignition temperature of 1,000 degrees Fahrenheit (°F) and is flammable at concentrations between 5 and 15 percent in air. Unconfined mixtures of methane in air are rarely explosive. However, a flammable concentration in an enclosed space in the presence of an ignition source can explode. It is buoyant at atmospheric temperatures and disperses rapidly in air.

The US Department of Transportation (USDOT) is mandated to set pipeline safety standards under Title 49, United States Code Chapter 601. The USDOT's Pipeline and Hazardous Materials Safety Administration oversees the national regulatory program to ensure the safe transportation of natural gas and other hazardous liquids by pipeline. The USDOT pipeline standards are published in 49 Code of Federal Regulations (CFR) Parts 190 to 199. Parts 190, 191, 192, and 199 apply to the pipeline. The pipeline and aboveground facilities associated with the project must be designed, constructed, operated, and maintained in accordance with the USDOT Minimum Federal Safety Standards in 49 CFR Part 192. The regulations are intended to ensure adequate protection for the public and to prevent natural gas facility incidents and failures.

Area classifications based on population density in the vicinity of the pipeline are defined by 49 CFR Part 192, which also specifies more rigorous safety requirements for populated areas. The class location unit is an area that extends 220 yards (660 feet) on either side of the centerline of any continuous 1-mile length of pipeline. The four area classifications are defined as follows:

- Class 1—Location with 10 or fewer buildings intended for human occupancy.
- Class 2—Location with more than 10 but fewer than 46 buildings intended for human occupancy.
- Class 3—Location with 46 or more buildings intended for human occupancy, or where the pipeline lies within 100 yards of any building, or small, well-defined outside area occupied by 20 or more people on at least 5 days a week for 10 weeks in any 12-month period.
- Class 4—Location where buildings with four or more stories aboveground are prevalent.

The pipeline and aboveground facilities associated with the project must be designed, constructed, operated, and maintained in accordance with Part 192 of the pipeline safety regulations, which prescribe minimum safety requirements for the transportation of natural gas.

3.11 AESTHETICS

Aesthetics can refer to the perception of beauty by one or a combination of the senses, and can apply to the quality of life experienced by the general public and property owners (40 Code of Federal Regulations [CFR] Part 230.53). Aesthetic attributes addressed in this analysis focus on perceptual elements of the visual environment (including the night sky), soundscape, and olfactory elements (i.e., smell). Visual and olfactory attributes are difficult to measure, and are addressed qualitatively.

3.11.1 Environmental Impact Statement Analysis Area

The Environmental Impact Statement (EIS) analysis area for aesthetic resources extends west from Happy Valley on the Kenai Peninsula and 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 (20-mile radius for night-sky impacts)
- A 10-mile radius from the ferry terminals (13-mile radius for night-sky impacts)
- A 20-mile buffer from the transportation corridor and natural gas pipeline (night-sky impacts not assessed)
- A 25-mile radius around the ports considered in each action alternative (13-mile radius for night-sky impacts)

For visual impacts, these distances were selected based on the relationship between distance, scale, and anticipated visibility. Visual contrast created by the project components is directly related to size and scale, as compared to surroundings. Larger-scale components (such as the mine site) would be most visible. Likewise, visual contrast decreases as viewing distance increases (BLM 1986). The distances noted above are the maximum distance that components would be expected to be noticeable to the viewer. The EIS analysis area also takes into account lands owned by seven Alaska Native Claims Settlement Act (ANCSA) corporations. The ANCSA does not provide provisions for the protection or management of visual resources; however, individual landowners may implement such management policies.

The visibility of night lighting may extend beyond what is visible under daylight conditions, and is estimated at a maximum of 20 miles for the mine site (similar to the skyglow effects from Red Dog Mine in northwestern Alaska), and 13 miles for the ferry terminals and ports (similar to skyglow effects from the Red Dog port). These distances are the maximum distance that changes to night sky due to skyglow are assumed to begin to occur, and were estimated using data from the New World Atlas of Artificial Night Sky Brightness (Falchi et al. 2016a, b), which reports artificial sky brightness for the entire world using high-resolution satellite data. These two facilities were used as proxies for estimating night-lighting impacts from the mine site, ferry terminals, and ports because of the similarity in their size and type of operations to the mine site and associated facilities. Night-sky impacts from the rest of the transportation corridor and natural gas pipeline are not evaluated, because no night lighting would be anticipated.

3.11.2 Methods for Establishing Baseline Conditions

Baseline visual resource conditions were established by: 1) completing a regulatory and management review; 2) developing a viewshed analysis to determine where the project could be visible (i.e., seen areas); 3) assessing landscape character attributes, viewer groups and related visual sensitivity, and visual distance zones (visibility) in the EIS analysis area; 4) analyzing viewer sensitivity from established Key Observation Points (KOPs); 5) estimating night-sky conditions based on data available from the New World Atlas of Artificial Night Sky Brightness (Falchi et al. 2016a, b) and National Park Service (NPS) monitoring data for one location in Lake Clark National Park and Preserve (NPS 2013b); and 6) assessing baseline soundscape. These methods are consistent with procedures identified in the “Guide To Evaluating Visual Impact Assessments for Renewable Energy Projects” (NPS 2014b).

3.11.2.1 Regulatory and Management Framework

The regulatory and management framework review included federal, state, and local planning documents for planning areas with a geographic connection to the project area. The review focused on identifying specific regulations, planning objectives pertaining to visual resources or scenery management, or reference to valued scenery.

Per 33 CFR Part 320.4, applications for Department of the Army permits may involve areas that possess recognized scenic, conservation, or recreational values. Full evaluation of public interest requires that due consideration be given to the effect that the proposed activity may have on values such as those associated with wild and scenic rivers, national rivers, national parks, estuarine and marine sanctuaries, and other areas that may be established under federal or state law for similar or related purposes. Recognition of those values is often indicated by state, regional, or local land use classifications, or by similar federal land management objectives or policies. Action on permit applications should be consistent with and avoid adverse effects on the values or purposes that those classifications, controls, or policies were established for. Additional policies specifically applicable to certain types of activities are identified in 33 CFR Parts 321 through 324.

The project area is in the Alaska Department of Natural Resources (ADNR) Bristol Bay and Kenai planning units. These areas are managed per the Bristol Bay Area Plan (ADNR 2013a) and the Kenai Area Plan (ADNR 2001), respectively, to maintain the quality and diversity of the natural environment, and protect heritage resources and the character and lifestyle of the community.

3.11.2.2 Viewshed Analysis

Locations in the EIS analysis area where the project could potentially be seen were determined by implementing a viewshed analysis using geographic information system (GIS) viewshed modeling. This analysis determines potential project visibility based on the relationship between topography, height of project components, average eye height of the viewer, and height of vegetation. The resulting seen area represents an area or locations on the landscape where project features may be visible; however, it does not represent any measure of detectability of these features, or level of impact to aesthetic quality. This information informed the analysis of project visibility, including scale dominance and contrast (see Section 4.11, Aesthetics).

Pebble Limited Partnership (PLP) developed viewshed analyses for all alternatives (PLP 2018-RFI 034a, PLP 2018-RFI 034c, PLP 2019-RFI 034e, PLP 2020-RFI 034g), which were used to form the basis of analysis in Section 4.11, Aesthetics. Models were developed using assumptions of bare earth and vegetation (i.e., considering the potential screening effects of vegetation) for Alternative 1a and Alternative 1, and bare earth only for Alternative 2—North Road and Ferry with Downstream Dams and Alternative 3—North Road Only, at a viewer height of 5 feet, 5 inches. Bare earth was used for Alternative 2 and Alternative 3 as a conservative approach, with screening attributes of vegetation considered qualitatively based on results of the Alternative 1a and Alternative 1 viewsheds.

The resulting viewshed was clipped to buffer distances for each component specified by the EIS analysis area. The completed viewshed analyses are provided in Appendix K4.11.

3.11.2.3 Landscape Character

Landscape Character—Landscape character attributes were determined by dividing the EIS analysis area into geographic units defined by prevailing physiography (Wahrhaftig 1965), and then determining landscape character in each geographic unit. Landscape character attributes were described in terms of typology: the basic elements of form, line, color, and texture of prevailing landform, water, vegetation, and cultural modification. This approach was applied across the analysis area to ensure that baseline data in visual resources were collected consistently.

Viewer Groups—Viewer groups were identified through coordination with recreational, cultural, and subsistence resources, as well as review of scoping comments. These sources aided in understanding how specific locations in the EIS analysis area are used, and the types of viewer groups that may be associated with those uses. Characteristics of identified viewer groups, such as seasonality, amount of use, and predominant viewer activity, were included in this inventory.

There is seasonal variation in the number and type of viewers in the EIS analysis area. A majority of visitors come to experience the naturalness, and abundance of resources, from May through October (see Section 3.5, Recreation). This seasonal access corresponds with fishing and hunting activities and is the high season for recreation, tourism, and subsistence. Access to fishing and hunting areas for recreational and subsistence use is via aircraft, boat, and all-terrain vehicle (ATV). Commercial activities consist of fisheries, recreation, and tourism.

There are commercial recreation fishing lodges and camps on the Kvichak and Alagnak rivers. Several lodges provide guided fishing services on the main stem of the Alagnak River and at the outlet of Nonvianuk Lake, with one on the Kulik River. Together, these lodges support the majority of the visitation for fishing in the area. Access to the fishing lodges and camps is through aircraft or motorized boat. The elevated position from an aircraft provides a contextual experience, allowing the viewer to see broad expanses of the landscape.

Although the majority of recreation and tourism occurs in the summer, ongoing subsistence activity and inter-village travel occur in the winter. Because the wet grounds and waters freeze, travel via snowmachine provides access to areas not available in the warmer seasons.

Viewer Platforms—Viewer platforms are considered those locations where individuals are likely to experience views of the landscape in the EIS analysis area. Viewers in the EIS analysis area include local residents and communities, as well as those engaging in subsistence activities, recreation, or travel.

- **Local Communities**—Communities along the shoreline of Iliamna Lake consist of Iliamna, Newhalen, Pedro Bay, Kokhanok, and Igiugig. The community of Nondalton is to the north at the edge of Lake Clark National Park and Preserve. The landscape is dominated by vast panoramic views of Iliamna Lake, with a backdrop of the mountains of the Big River Hills.
- **Subsistence Areas**—See Section 3.9, Subsistence, for subsistence activity locations. Summer access to these areas is primarily via boat and ATV; while in winter, travel predominantly follows the frozen rivers and landscapes via snowmachine. Air travel is also prevalent throughout the year.
- **Recreation Areas—**Recreation extends from the fishing camps along Iliamna Lake into Lake Clark National Park and Preserve, Katmai National Park and Preserve, up the Koktuli River Watershed, and into the tundra of the Big River Hills, and includes the Newhalen and Gibraltar rivers. Outfitters provide guide services from fishing and hunting camps to remote locations in the Big River Hills, and fishing areas on Iliamna Lake and Kamishak Bay in the Cook Inlet. The McNeil River State Game Sanctuary and Refuge receives annual visitors as well.

- **Transportation Routes**—Several transportation routes used by industry, local communities, and subsistence and recreational users are limited to air travel, boat, ATV, and snowmachine. Short, unimproved roads connect the communities of Newhalen and Iliamna to Nondalton in the winter; although in the summer, that route involves an impassable river crossing. In the winter, there are transportation routes across Iliamna Lake or along its shores between the lake communities (see Section 3.12, Transportation and Navigation, for information on existing land, air, and water transportation routes).
- **Air Travel**—Low-altitude local aircraft may fly over the project area during scheduled air service or on route to remote communities or hunting/fishing destinations.

Distance Zone—Project visibility (i.e., distance zones) was assessed by subdividing into three zones based on relative distance from travel routes (land or water-based) or observation points. Common travel routes included common commercial flight paths and common local flight paths. Distance zones were classified as:

- Foreground (i.e., 0 to 0.5 mile from view point)
- Middleground (i.e., 0.5 mile to 5 miles)
- Background (i.e., over 5 miles)

3.11.2.4 Key Observation Points

KOPs representing common and/or sensitive viewer locations were established in the EIS analysis area. These locations represent point-based (e.g., vistas and residential areas), linear (e.g., roadways), and area-based (e.g., subsistence or recreational use areas) viewer locations. The KOPs were used as standard locations to describe existing visual resources at a localized scale, and to assess potential effects that may result from the project. A total of 15 KOPs were identified for use in the analysis, as described in Table 3.11-1 and shown in Figure 3.11-1.

3.11.2.5 Night Sky

The night sky is a combination of both natural and human-caused sources of light. Natural light sources include moonlight, starlight from individual stars and planets, the Milky Way, zodiacal light (i.e., sunlight reflected off dust particles in the solar system), the aurora borealis, fire, lightning, meteors, and airglow. Airglow is caused by radiation striking air molecules in the upper atmosphere, and appears similar to a faint aurora (NPS 2016f). Artificial lighting increases the night sky's brightness—an effect known as artificial skyglow. Artificial skyglow can affect the night sky for large distances, and for that reason is the most visible effect of light pollution (Falchi et al. 2016a).

The existing quality of the night sky is estimated based on data from the New World Atlas of Artificial Night Sky Brightness (Falchi et al. 2016a, b) and the NPS night-sky monitoring report at Keyes Point near the northern shore of Lake Clark in Lake Clark National Park and Preserve (NPS 2013b). The New World Atlas of Artificial Night Sky Brightness shows light pollution as the ratio of artificial sky brightness to natural brightness. For areas protected for scenic or wilderness character, a ratio of 1 to 2 percent indicates areas where attention should be given to protect a site from future increases in light pollution (Falchi et al. 2016a). A ratio of 8 to 16 percent is considered polluted from an astronomical point of view, meaning observations of astronomical features begin to be affected. The NPS (2013b) monitoring report includes photographs depicting natural airglow, as well as monitoring data and narrative, including the Bortle Class based on the Bortle Dark-Sky Scale as reported by the NPS observers. The Bortle Dark-Sky Scale is a nine-step scale used to rate sky conditions at an observation site from Class 1 (i.e., an excellent dark-sky site) to Class 9 (i.e., an inner-city sky) (Bortle 2001). Data from these two sources were used to estimate existing night-sky quality in the EIS analysis area.

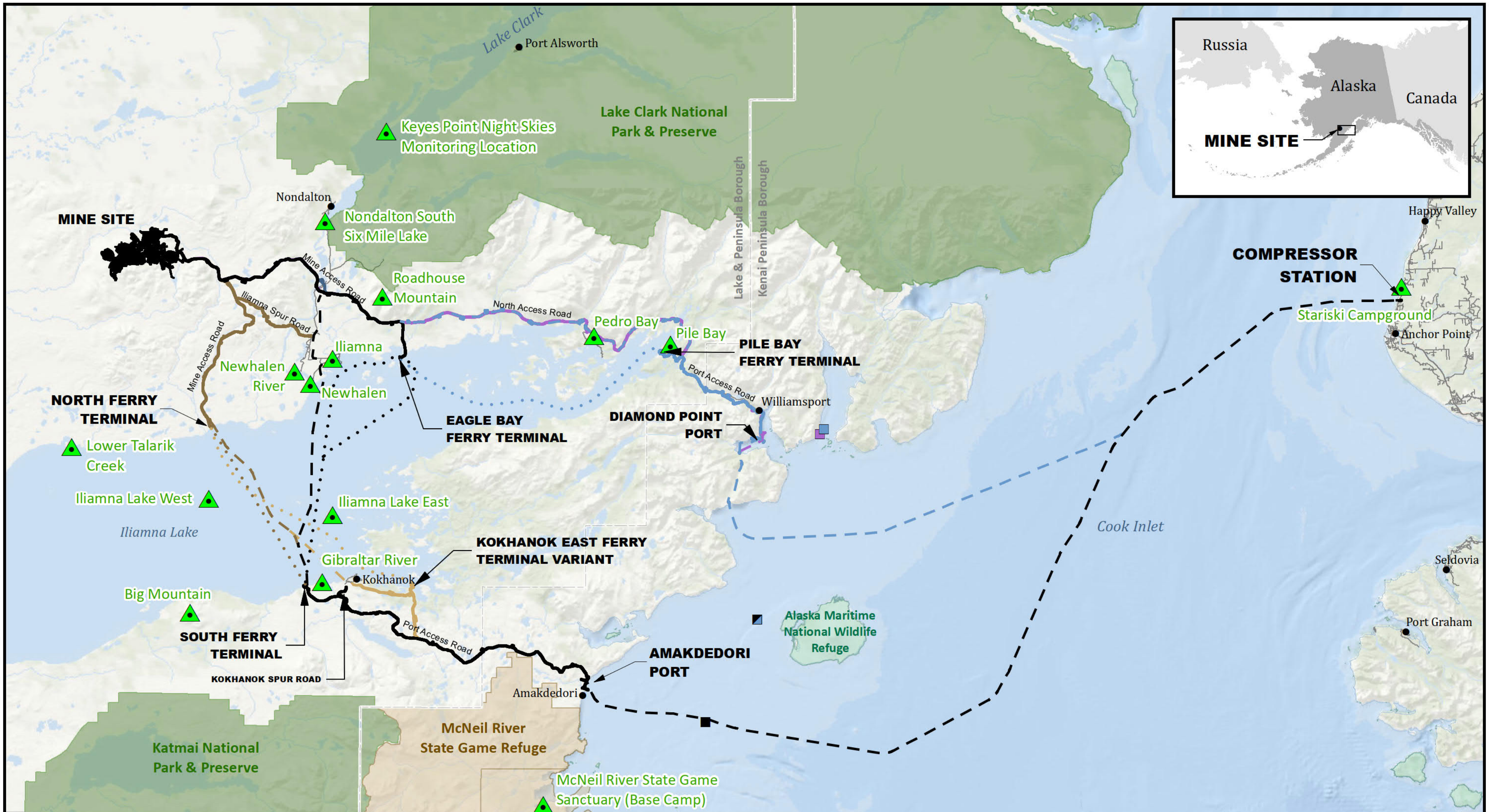
Table 3.11-1. Key Observation Points

KOP Number	Location	KOP Type	Viewer Group	Viewer Sensitivity	Project Component	Distance Zone	Viewer Geometry[1]	Viewer Activity
1	Stariski Campground	Point	Recreationists; Tourists	High	compressor station	Foreground to Middleground	At Grade	Stationary
2	McNeil River State Game Sanctuary (Base Camp)	Area	Recreationists; Tourists	High	Amakdedori port; port access road	Middleground	At Grade	Stationary—Transient
3	Iliamna Lake West	Area	Residents; Subsistence Users	Moderate-High	north ferry terminal; mine access road	Foreground to Background	At Grade; Inferior	Stationary—Transient
4	Iliamna Lake East	Area	Residents; Subsistence Users	Moderate-High	south ferry terminal; port access road	Foreground to Background	At Grade; Inferior	Stationary—Transient
5	Newhalen River	Linear	Residents; Subsistence Users; Recreationists	High	mine site; mine access road	Background	At Grade	Transient
6	Roadhouse Mountain	Point	Recreationists; Subsistence Users	Moderate	mine site; mine access road	Foreground to Middleground	Superior	Stationary
7	Big Mountain	Point	Recreationists; Subsistence Users	Moderate	mine site; port access road	Middleground; Background	Superior	Stationary
8	Nondalton South	Point	Residents	High	mine site; mine access road	Background	At Grade; Inferior	Stationary—Transient
9	Iliamna	Point	Residents	High	mine access road	Middleground	At Grade	Stationary
10	Newhalen	Point	Residents	High	mine access road	Background	At Grade	Stationary
11	Pedro Bay	Point	Residents	High	north access road	Foreground	At Grade	Stationary
12	Pile Bay	Point	Residents	High	port access road	Foreground	At Grade	Stationary
13	Gibraltar River	Point	Recreationists; Subsistence Users	Moderate	south ferry terminal	Foreground to Middleground	At Grade	Transient
14	Lower Talarik Creek Special Use Area	Point	Residents, Recreationists; Subsistence Users	Low	north ferry terminal	Background	At Grade; Inferior	Transient
15	Lake Clark National Park and Preserve Keyes Point Night Skies Monitoring Location	Point	Residents, Recreationists; Subsistence Users	Low	mine site, mine access road	Background	At Grade	Transient

Notes:

[1] Viewer geometry refers to the spatial relationship of the viewer to the object, including the vertical and horizontal angle; and is defined in Section 4.11, Aesthetics.

KOP = Key Observation Point



Sources: PLP 2020-RFI168; PLP 2019-RFI153; ADNR

US Army Corps of Engineers

5 0 5 10
Miles

Key Observation Points

Action Alternatives

- Lightering Locations
- Ferry Routes
- Natural Gas Pipelines
- Alternative 1a
- Alternative 1
- Alternative 1 Kokhanok East Ferry Terminal Variant
- Alternative 2
- Alternative 2 Newhalen River North Crossing Variant
- Alternative 3

Other Features

- Local Roads
- Borough Boundary
- National Park
- National Wildlife Refuge
- State Game Refuge/Sanctuary

KEY OBSERVATION POINTS

PEBBLE PROJECT EIS

FIGURE 3.11-1

3.11.2.6 Soundscape

Information on soundscape was derived from applicable noise and vibration concepts, as well as methodologies used in characterizing noise of the affected environment (AECOM 2018c) (see Section 3.19, Noise). The ambient sound level (i.e., soundscape) is a composite of sound from all sources, including natural background and anthropogenic sources. Existing ambient sound levels are often the starting point for analyzing project-associated noise impacts, because such environmental noise analysis typically compares project-associated noise to either existing ambient or natural background sound, based on applicable adverse effect or impact assessment criteria. Existing ambient sound was evaluated for the EIS analysis area, including the mine site, port, transportation corridor, and natural gas pipeline corridor for each alternative and variants, as well as the surrounding area where project-associated noise could have a direct effect on human receptors.

3.11.3 Landscape Character

The landscape setting in the visual resources EIS analysis area includes mountain ranges surrounded by river valleys, rivers, shrub tundra, marshy lowlands, wetlands, coastal shoreline, estuaries, and ocean inlet environments. Primary river drainages intersecting the EIS analysis area include the Mulchatna, Nushagak, and Koktuli rivers. Waterways provide access to remote recreational and subsistence use areas. Human development in the EIS analysis area is generally limited to areas in and around geographically isolated communities and small fishing and hunting lodges. Development includes roads, airstrips, docks, houses, schools, community centers, and other structures in the communities.

3.11.3.1 Regional

The EIS analysis area is in portions of four different physiographic units: Nushagak-Big Hills, Nushagak-Bristol Bay Lowland, Aleutian Range, and Alaska Range (Wahrhaftig 1965). The landscape character of each physiographic unit is influenced by the fluvial geomorphologic, hydrologic, vegetation cover, elevation, and landforms.

The **Nushagak-Big River Hills** are characterized by flat-topped ridges ranging in elevation from 1,500 feet to the west, 2,500 feet to the east, and 4,200 feet to the north. The Big River Hills unit drains to the Kuskokwim River from primary tributaries. The southern section of the physiographic unit drains to the Mulchatna and Nushagak rivers. Vegetation communities consist of spruce, birch, and cottonwoods along riparian corridors (Shacklette et al. 1969; ADNR 2005).

The **Nushagak-Bristol Bay Lowland** is dotted with moraine lakes rising from sea-level to an elevation of 300 to 500 feet at its high point. Linear narrow belts of elevated topography enclose large glacial lakes fed by upland hydrology. The lowland is drained by the Nushagak River and other rivers flowing to the estuaries of Bristol Bay. This physiographic unit is characterized by the marine phase of the tundra climate with mild winters and short, cool summers. Dominant vegetation includes moist wet tundra plant communities. Standing water, mosses, sedges, and low-growing shrubs cover the landscape with clumping stands of alder, willow, and patches of stunted spruce and birch growing along the riparian edges of major streams and rivers (Shacklette et al. 1969; Bailey 1995).

The **Aleutian Range** consists of heavily glaciated U-shaped valleys, rugged ridges, and mountain peaks anchored between the Pacific Ocean and the Bering Sea. This range runs west to the Aleutian Islands, with an elevation ranging from 1,000 to 4,000 feet. The Aleutian Range is flanked by large volcanic peaks elevating upward to 8,500 feet. Steep rivers drain south to the Pacific Ocean, while braided meandering rivers run slowly to the Bering Sea. The western end of the Aleutian Range drains into the Bristol Bay Lowland, feeding hundreds of small lakes and ponds. Vegetation is sparse and consists of spruce, birch, and cottonwoods along riparian corridors; and a spattering of open low-shrub tundra as the elevation increases (Shacklette et al. 1969; Kevin Waring & Associates 2015a).

To the east, the **Alaska Range** connects with the Aleutian Range between Iliamna Lake and Mount Spurr. This mountain range extends over 600 miles to the Canadian border. The heavily glaciated mountain ranges average between 7,000 and 10,000 feet in elevation, with a number of peaks exceeding 10,000 feet. The Alaska Mountain range is the divide for rivers flowing from the Yukon Territory south to the Gulf of Alaska. The southern section drains through glacial streams to the Kuskokwim River and to the Nushagak or Kvichak rivers, eventually flowing into Bristol Bay (Shacklette et al. 1969; Kevin Waring & Associates 2015a).

3.11.3.2 EIS Analysis Area

Mine Site

The mine site would be in the southern section of the Nushagak-Big River Hills physiographic unit. This landscape is characterized by the rugged Sharp, Pig, Kaskanak, and Groundhog mountains that appear prominent and distinct from the surrounding lowlands and Iliamna Lake.

Views from ridgetops are largely panoramic; however, there is more enclosure in drainages and low-elevation areas. Topography is dominated by numerous rounded hills that appear consistent and well-defined by the converging lines of drainages. As elevation increases, trees become stunted and vegetation becomes intermixed with short alpine tundra and exposed rock outcrops.

The upper sections of Upper Talarik Creek and North Fork and South Fork Koktuli rivers meander through eroded, braided wetlands and tundra flowing into Iliamna Lake to the Kvichak River, before draining into Bristol Bay. The Talarik Creek floodplain is characterized by exposed flat grasslands and low sand dunes created from strong winds with little vegetation diversity. These river systems provide important travel routes to remote areas for subsistence use in the summer and winter.

Single-day tours are almost exclusively via aircraft. Visitors are flown into surrounding parks and other destinations over the project area to access bear-viewing locations along the coastline, in the estuaries, and up the stream corridors and over the glaciers of Four Peaks Mountain. Multi-day commercial tours either stage outside the park on large boats in Kamishak Bay, or at lodges in the park.

Viewer groups in this area include individuals engaged in subsistence or recreational activities. These individuals experience the landscape from fixed points while fishing or viewing wildlife, and can be transient as they move through the landscape on foot, snowmachine, boat, or aircraft. Small aircraft are used to provide access for fishing and hunting areas; and to a lesser extent, provide tours for nature viewing. Areas on the flight paths provide an expansive view of the landscape settings. During winter months when the ground is frozen, overland travel via snowmachine is common.

Transportation Corridors

The transportation corridor would be a linear system that cuts through the Nushagak-Big River Hills and Nushagak-Bristol Bay Lowland physiographic units.

Under Alternative 1a, Alternative 1, and Alternative 2, the transportation corridor would cross Iliamna Lake. The shallow shoreline is made up of meandering inlets, checkered islands, and long, fine edges. Low topographic relief provides extensive panoramic views extending across the tundra to Iliamna Lake. In the immediate foreground, the wet shrub tundra presents limited obstruction to vast views of the surrounding landscape. To the west are the Bristol Bay lowlands, made of wet shrub tundra, marsh lands, and hundreds of small lakes. Northern views feature the rounded mountains of the Nushagak-Big River Hills.

Viewer positions along Iliamna Lake are either from the shoreline or from a boat on the water. Access to the surrounding landscape for commercial, subsistence, and recreational uses are via the main airport and community of Iliamna. Air transportation is a prominent form of travel in the area. From the elevated position in an aircraft, a viewer can relate to the expansive, undisturbed landscape setting. There is minimal lighting visible from the existing communities, which is primarily seen in the winter months when there is limited daylight. In 1999, the State of Alaska established the Lower Talarik Creek Special Use Area as a high-value resource for fish and wildlife habitat and subsistence harvest, as well as local and commercial recreation (ADNR 2005). Viewer groups in this area include individuals engaged in subsistence or recreational activities, as well as travelers.

Parts of Alternative 1a, Alternative 2, and Alternative 3 include transportation corridors on the northern end of Iliamna Lake. This portion of the lake is characterized by the broad floodplains of Chekuk Creek, Knutson Creek, and the Pile River. The ridgelines of Three Sisters Mountain, Knutson Mountain, and Roadhouse Mountain rise prominently from the river valleys. Lake Clark National Park and Preserve is to the north and east of the transportation corridor access roads at the northwestern edge of the Alaska Range. The features are visible from aircraft while traveling in and out of the park or local communities.

Roadhouse Mountain is a popular summer ATV route southwest of the mine site along the border of Lake Clark National Park and Preserve and the northern end of Iliamna Lake. Expansive 360-degree panoramic views dominate the viewer experience from the top of Roadhouse Mountain. Significant visual features include Iliamna Lake and its distinctive shoreline. The marshy wet lowlands and the river valleys of the Nushagak-Big River Hills dominate the foreground view, while Sharp, Groundhog, and Kaskanak mountains frame the background views.

The Alagnak River is designated as a Wild River in the Wild and Scenic River System. The Alagnak River is about 45 miles west of the mine site, 30 miles from Iliamna Lake, and more than 20 miles from the Alternative 1a and Alternative 1 transportation corridor (outside of the EIS analysis area considered under Alternative 2 and Alternative 3). The Alagnak River provides opportunities for exemplary Alaska recreation due to remoteness, scenery, and sport fisheries. The Alagnak River is accessed by aircraft and from the western side of Katmai National Park and Preserve. The river has a reputation of being a world-class fishery, and is considered to be one of the most popular fly-in fishing destinations in southwestern Alaska.

The McNeil River State Game Refuge is in the EIS analysis area under the Alternative 1a and Alternative 1 port access roads and Amakdedori port. Section 3.5, Recreation, describes bear viewing, and the McNeil State Game Refuge and Sanctuary as a premier destination for viewing brown bears. The Alaska Department of Fish and Game operates a visitor bear-viewing program at McNeil River from early June through late August. Guided bear viewing and private visitor bear viewing occur during the month of July (ADF&G 2018b) (see Section 3.23, Wildlife Values).

Soundscape

Noise receptors in the analysis area for the transportation corridors generally include subsistence users, recreationists, and residents. The existing ambient noise level is estimated to be comparable to "wilderness ambient," as described for the mine site and port analysis areas (see Section 3.19, Noise) with a 35 decibel day-night average noise level (L_{dn}) (see Section 3.19, Noise, for additional information on baseline noise conditions in the EIS analysis area).

Amakdedori Port

The Amakdedori port site (Alternative 1a and Alternative 1) is on state lands designated for habitat use in the Kenai Peninsula Borough area boundary. The area in the northern part of the Aleutian Range is wet shrub tundra, collecting runoff forming wet meadows, bogs, and hundreds of small lakes.

Viewer groups include private outfitters who operate single- and multi-day commercial tours to Katmai National Park and Preserve from May through September. Single-day adventure tours are offered from as far away as Anchorage and as close as Dillingham.

Diamond Point Port

The Diamond Point port site (Alternative 2 and Alternative 3) is in Iliamna Bay on the western side of Cook Inlet. The bay is characterized by the rugged topography of the Chigmit Mountains, which steeply slope to the water. The existing Williamsport-Pile Bay Road is at the northern tip of the bay, connecting Williamsport to Pile Bay Village on Iliamna Lake. Viewer groups include local residents and recreationists traveling to and from Lake Iliamna.

Natural Gas Pipeline

The landscape character of the pipeline rights-of-way (ROWs) is the same as those described for the transportation corridors, because the pipelines would be co-located with the transportation corridor of either Alternative 1 or Alternative 3; the discussion for the transportation corridor under Alternative 2 and Alternative 3 is relevant to the Alternative 2 pipeline route, with the exception of the portion between Diamond Point port and Ursus Cove for Alternative 2 and Alternative 3, and the portion between the lakeshore and the transportation corridor under Alternative 1a. The pipeline would terminate on the Kenai Peninsula near Anchor Point and Anchor Point Recreation Area. Views from this area include Cook Inlet and distant peaks of the Aleutian Range. The area is populated with residents, recreationists, tourists, and commercial operators using Cook Inlet and the Kenai Peninsula as a base to access the natural and remote setting of Bristol Bay, Iliamna Lake, and the national park units.

3.11.4 Night Sky

Night-sky conditions in the EIS analysis area are almost entirely pristine, with a ratio of artificial night brightness to natural night brightness of less than 1 percent. There is one exception surrounding the Iliamna Airport, where artificial night lighting affects the quality of the night sky. Artificial brightness is between 8 to 16 percent of the natural background in an approximately 5-mile radius around the airport, which is considered polluted on an astronomical point of view (Falchi et al. 2016a). The ratio of artificial brightness to natural brightness is 1 percent or greater in an approximately 6-mile radius around the airport. The NPS performed night-sky monitoring at Keyes Point near the northern shore of Lake Clark, describing the area as having moderate naturally occurring airglow. This monitoring did not identify any visible lights or domes anywhere along the horizon that could be seen with the naked eye, and assigned the location as Bortle Class 2 (NPS 2013b). A Bortle Class 2 indicates a “typical truly dark site,” where airglow may be weakly apparent along the horizon and the Milky Way appears highly structured to the unaided eye, indicating high-quality night sky (Bortle 2001).

3.11.5 Soundscape

Baseline noise levels of the EIS analysis area are compatible with outdoor ambient sound levels consistent with a “wilderness ambient,” classification (baseline noise level of 35 dBA L_{dn}) (see Section 3.19, Noise).

3.12 TRANSPORTATION AND NAVIGATION

The Environmental Impact Statement (EIS) analysis area for this section includes the local and regional transportation and navigation resources that could be affected by the mine site, port, transportation corridor, and natural gas pipeline corridor for each alternative and variants. This includes surface transportation from the mine site to Cook Inlet and a small section of the Sterling Highway on the Kenai Peninsula; air transportation from airports across the region (Dillingham to Anchorage); water transportation on Cook Inlet and Iliamna Lake; and navigable rivers from the mine site east to Cook Inlet. Navigation resources also include deepwater port construction and use from local to global users. The navigability of each project component is discussed.

The major mode of transportation between communities in and outside of this region is by air and water. Surface transportation is most often used for travel in communities and can include on-road and off-road transport via cars, trucks, snowmachines, all-terrain vehicles (ATVs), dog sleds, and horses (DOWL 2016).

3.12.1 Surface Transportation

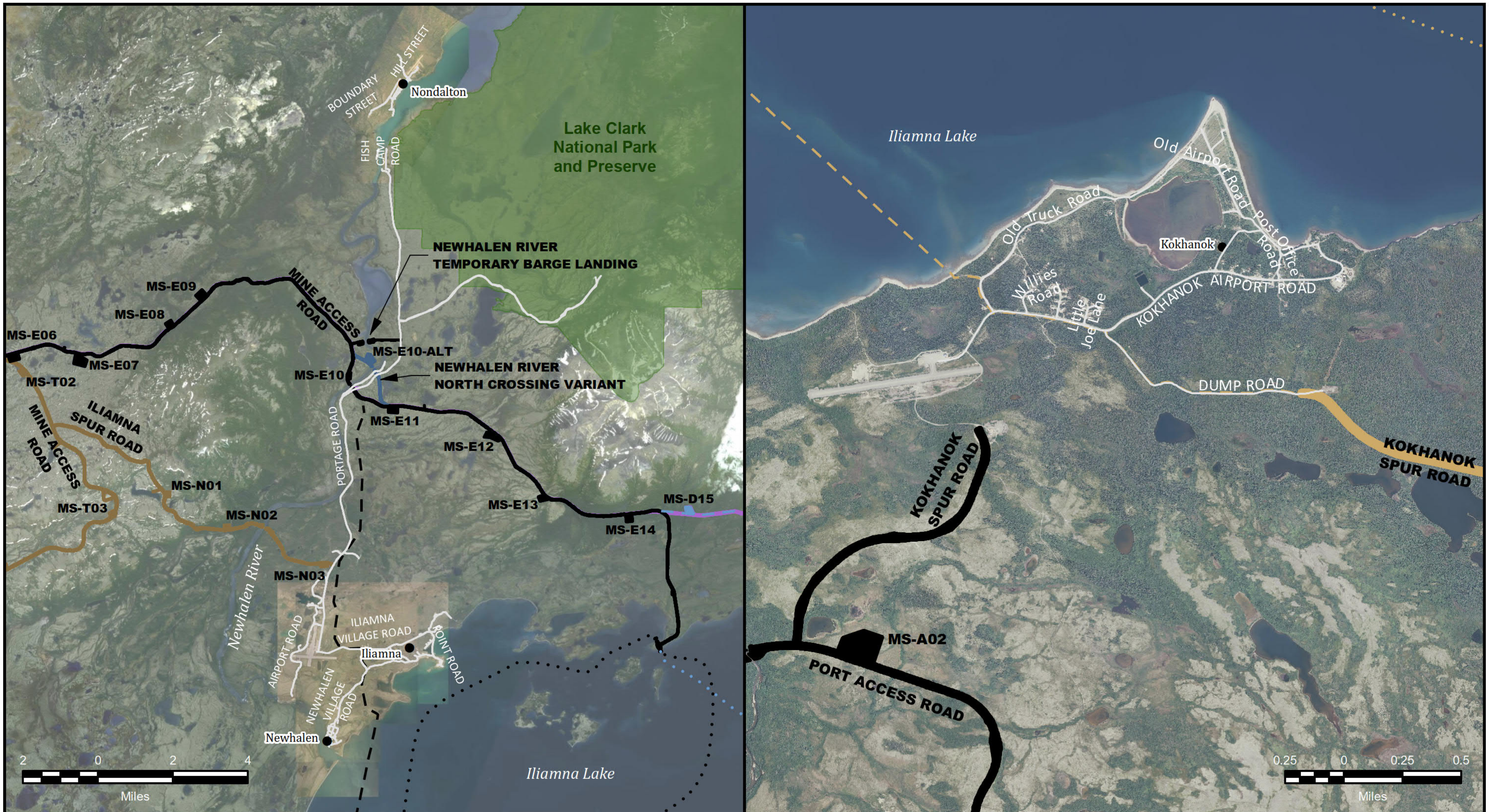
No existing roads provide direct access to the mine site or the port sites. Surface transportation in the area consists of off-road transport via ATVs and snowmachines between villages and to subsistence areas (Fall et al. 2006). Using off-road vehicles with a curb weight of less than 1,500 pounds on State-managed lands does not require a permit from the Alaska Department of Natural Resources (ADNR 2011).

There is potential for overland traffic through the EIS analysis area to access Native Allotments and private lands close to the mine site. The closest Native Allotments to the mine site include an area approximately 25 miles to the west, and land in the community of Nondalton to the east. Privately owned land exists approximately 15 miles to the north at Nikabuna Lakes (LPB 2015). Native Allotments and other private lands are shown in Section 3.2, Land Ownership, Management, and Use, Figure 3.2-1a through Figure 3.2-1e.

The road systems in the transportation corridors for all alternatives are primarily undeveloped, with the exception of local community roads, the Iliamna-Nondalton River Road (14 miles), and the Williamsport-Pile Bay Road (15 miles), with limitations. In 2017, the annual average daily traffic count for the busiest road in the Iliamna/Newhalen road system was 424 cars per day. Nondalton roads experienced 50 to 60 cars per day, and Kokhanok local roads had an average of 75 cars per day (ADOT&PF 2018b). Iliamna, Newhalen, and Nondalton are connected to one another, but the 15-mile road from Iliamna to Nondalton is only passable when the Newhalen River is frozen (ADCCED 2018b). Existing roads in and near the communities of Iliamna, Newhalen, Nondalton, and Kokhanok are provided in Table 3.12-1 and shown in Figure 3.12-1.

Table 3.12-1: Community Roads

Community	Miles of Local Roads
Iliamna/Newhalen	12
Nondalton	3
Iliamna-Nondalton River Road	15
Kokhanok	3
Pedro Bay	5
Williamsport-Pile Bay Road	15



Sources: PLP 2020-RFI168;
PLP 2019-RFI153; ADOT&PF

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Action Alternatives

- Ferry Routes
- Natural Gas Pipelines
- Alternative 1a
- Alternative 1
- Alternative 1 Kokhanok East Ferry Terminal Variant
- Alternative 2
- Alternative 2 Newhalen River North Crossing Variant
- Alternative 3

Other Features

- Existing Road Infrastructure
- National Park

EXISTING ROADS: ILIAMNA, NEWHALEN, NONDALTON, AND KOKHANOK

PEBBLE PROJECT EIS

FIGURE 3.12-1

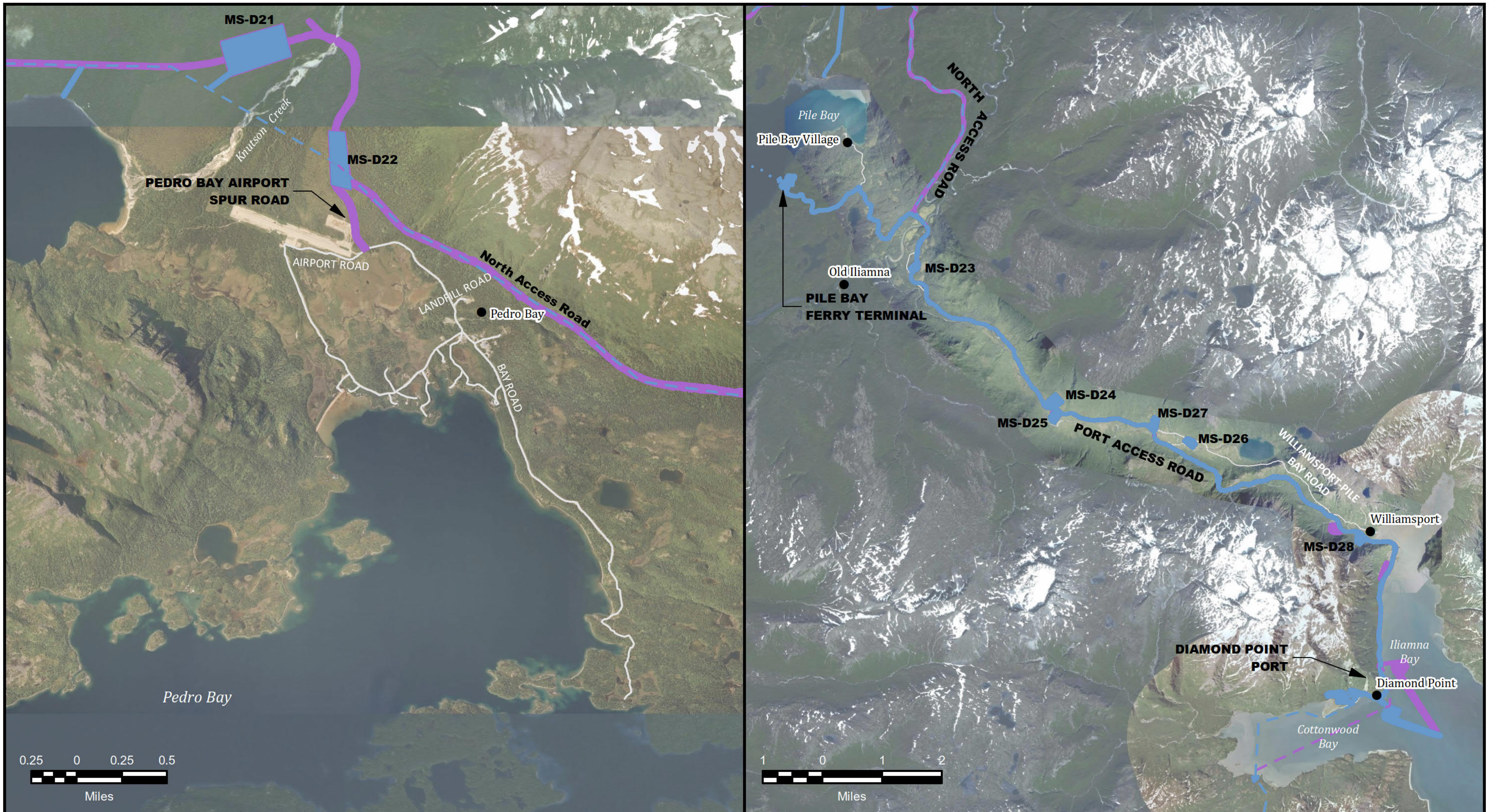
The Williamsport-Pile Bay Road is approximately 15 miles long, connecting Williamsport on Cook Inlet to Pile Bay on Iliamna Lake, and is maintained by the State (NOAA 2018c). This road had an average annual daily traffic count of 19 cars per day in 2017 (ADOT&PF 2018b); it is assumed that the average would be doubled (i.e., 38 cars per day) for the summer months, and would be zero for the winter months, because the road is only used between June and October (NOAA 2018c). It is also assumed that daily use would be higher at the beginning and end of the commercial fishing season. The road's current use is for transporting fishing vessels and heavy freight. Vessels less than 12 feet wide, 32 feet long, and 9.5 feet high may be hauled on the road. Approximately 50 fishing boats are transferred on the road annually, and approximately 22 barge loads of fuel and cargo were transported in 2009 (Kevin Waring and Associates 2011c). Tidal fluctuations in Cook Inlet and the potential for wet and flooded road conditions determine the accessibility and degree of drivability (e.g., Williamsport is very shallow, and boats can only be hauled out at a 17-foot or higher tide, after navigating through a channel. Weather often causes additional delays.) (Fast 2018; NOAA 2018c; USACE 1995). When the tide allows, one landing craft can deliver freight to Williamsport at a frequency of eight times per month; however, delivering fuel to communities by air is more economical. Fuel is also transported by barge up the Kvichak River from Bristol Bay, which takes more than a week and involves lightering (i.e., the process of transferring cargo between vessels of different sizes) through shallow areas. The Pile Bay port is undeveloped (DOWL 2016). In 2017, Airport Road in Pedro Bay experienced an average annual daily traffic count of 45 cars per day (ADOT&PF 2018b). The Williamsport-Pile Bay Road and Pedro Bay local roads are shown on Figure 3.12-2. The Diamond Point quarry port is approximately 3 miles from Williamsport in Iliamna Bay, but is not currently connected by road (DP 2018).

Current off-road surface transportation in the EIS analysis area for all alternatives includes travel to and from subsistence harvest areas and neighboring villages via ATV and snowmachine. This type of travel is easiest in the winter months, when the tundra, rivers, and lakes are frozen (Fall et al. 2006; Krieg et al. 2009). Additionally, snowmachines are used to access hunting areas for freshwater seals on Iliamna Lake (Van Lanen 2012). Known community subsistence harvest areas are discussed in Section 3.9, Subsistence.

No existing roads provide access to the Amakdedori port site. Subsistence activities occur in the area via surface and water transportation (see Section 3.9, Subsistence, for more information on subsistence activities near Amakdedori). The regional Comprehensive Economic Development Plan for the Bristol Bay Region (excluding the Bristol Bay Borough) prioritizes supporting transportation and infrastructure needs in the region to promote strong communities (BBNA 2019).

The natural gas pipeline would connect to the compressor station near Anchor Point, following Bourbon Avenue west until crossing the Sterling Highway. In 2017, this stretch of the Sterling Highway had annual average daily traffic volume of just under 3,000 vehicles (ADOT&PF 2018b). The Sterling Highway is the only major roadway connecting the city of Homer to the rest of the Kenai Peninsula and the Alaska road system (ADCCED 2017). According to the Alaska Highway Safety Office, the Sterling Highway had three fatal motor vehicle accidents in 2016, each resulting in one death; these fatal accidents all occurred in Soldotna. In 2017, there was one fatal accident resulting in one death in Clam Gulch (AHSO 2018).

There were no fatal motor vehicle accidents reported for 2016 and 2017 on any existing internal community roads that would be connected to the mine site or transportation corridor (AHSO 2018). Statewide, the Alaska Highway Safety Office reported that in 2017 there were 75 fatal crashes in Alaska totaling 79 fatalities. From 2016 to 2017, fatalities and fatal crashes decreased by 6 percent and 4 percent, respectively. In addition, fatal crashes related to alcohol dropped by 54 percent.



Sources: PLP 2020-RFI168;
PLP 2019-RFI153; ADOT&PF

US Army Corps of Engineers

Action Alternatives

- Ferry Routes
- Natural Gas Pipelines
- Alternative 1a
- Alternative 1
- Alternative 1 Kokhanok East Ferry Terminal Variant
- Alternative 2
- Alternative 2 Newhalen River North Crossing Variant
- Alternative 3

Other Features

- Existing Road Infrastructure

EXISTING ROADS: WILLIAMSPORT-PILE BAY ROAD AND PEDRO BAY

PEBBLE PROJECT EIS

FIGURE 3.12-2

3.12.2 Air Transportation

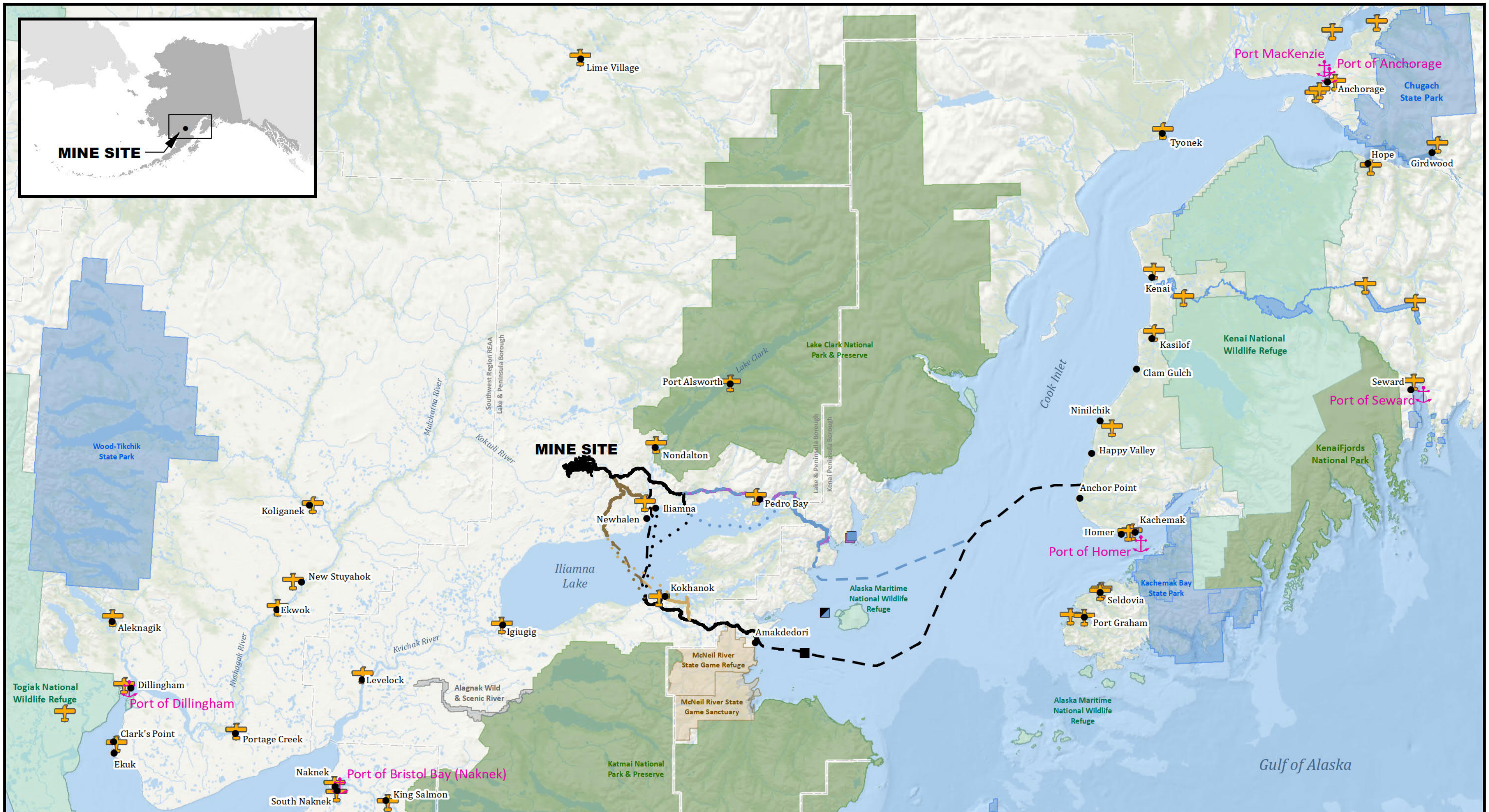
Passenger and cargo transport by aircraft is common for residents, visitors, and goods in the Bristol Bay region, on a regularly scheduled and charter basis. Small charter planes, run by private guide companies, also transport sport fishers and hunters to lodges around the Iliamna Lake and Lake Clark areas (Travel Alaska 2018). General flight paths from Anchorage to Bristol Bay and the Alaska Peninsula communities go over Iliamna or the project area if there is inclement weather over Iliamna Lake (FAA 2018; Ravn 2018) (see Appendix K3.12 for flight path descriptions and illustration).

Table 3.12-2 provides a summary of airports in the EIS analysis area that may be affected by a change in air traffic related to the project. Included in the table are nine airports west of Cook Inlet and three east of Cook Inlet. Regional airports are shown in Figure 3.12-3.

Table 3.12-2: Summary of Potentially Affected Airports

Airport	Owner	Use	Average Annual Operations[1]	Runway Surface	Runway Lighting	Based Aircraft
Dillingham Airport (DLG)	ADOT&PF Central Region	Public	50,735	Asphalt/grooved	HIRL	59
Iliamna Airport (ILI)	ADOT&PF Southcoast Region	Public	15,330	Asphalt/grooved Water	MIRL —	29
King Salmon Airport (AKN)	ADOT&PF Southcoast Region	Public	15,330	Asphalt/grooved, in poor condition Asphalt/grooved Water	HIRL MIRL —	39
Kokhanok Airport (9K2)	ADOT&PF Southcoast Region	Public	—	Gravel	MIRL	—
Nondalton Airport (5NN)	ADOT&PF Southcoast Region	Public	1,248	Gravel	MIRL	—
Pedro Bay Airport (4K0)	ADOT&PF Southcoast Region	Public	1,040	Gravel	MIRL	—
Igiugig Airport (IGG)	ADOT&PF Southcoast Region	Public	8,030	Gravel	MIRL	—
Port Alsworth Airport (TPO)	Glen Alsworth, SR	Private	1,300	Dirt/gravel	—	19
Wilder/Natwick LLC Airport (05K) (Port Alsworth)*	Wild Air, LLC	Private	Undetermined	Gravel	None	25
Ted Stevens Anchorage International Airport (ANC)	ADOT&PF	Public	261,705	Asphalt/concrete/grooved Asphalt/grooved Asphalt/grooved	HIRL HIRL HIRL	109
Kenai Municipal Airport (ENA)	City of Kenai	Public	39,055	Asphalt/grooved Gravel Water	HIRL None —	61
Homer Airport (HOM)	ADOT&PF Central Region	Public	48,180	Asphalt/aggregate friction Seal coat Water	HIRL —	93

Notes:
— = Not listed
[1]One operation is a takeoff or a landing
ADOT&PF = Alaska Department of Transportation and Public Facilities
HIRL=High-Intensity Runway Lighting
MIRL=Medium-Intensity Runway Lighting
Source: AirNav 2018, AirNav 2019



Sources: PLP 2020-RFI168;
PLP 2019-RFI153; ADNR

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20 0 20 40

Miles

Airport or Sea Plane Base

Ports

Action Alternatives

Lightering Locations

Ferry Routes

Natural Gas Pipelines

Alternative 1a

Alternative 1

Alternative 1 Kokhanok East Ferry Terminal Variant

Alternative 2

Alternative 3

Other Features

Borough Boundary

National Park

National Wildlife Refuge

Alaska State Park

Wild and Scenic River

State Game Refuge/Sanctuary

REGIONAL AIRPORTS AND PORTS

PEBBLE PROJECT EIS

FIGURE 3.12-3

3.12.3 Water Transportation

Streams or lakes are referred to as "navigable in fact" when they are used or have the possibility of being used in their ordinary condition for commerce where trade and travel are conducted (77 United States Code [USC] 557, 563). There are limited facilities for delivery of cargo and fuel and similar purposes in the EIS analysis area. Examples of commerce in the vicinity of the project include goods lightered from Iliamna to Nondalton by boat in the summer (Nondalton is not accessible by barge), fuel transported across Iliamna Lake to Kokhanok and Igiugig, and goods transported to Anchorage and Homer via Cook Inlet, in addition to commercial fishing and guided hunting, fishing, rafting, or sightseeing (Kevin Waring & Associates 2010b).

3.12.3.1 Mine Site

Some small watercraft use associated with recreational activities occurs on the Koktuli River downstream of the mine site. The closest "navigable in fact" waterbody is the South Fork Koktuli River.

3.12.3.2 Transportation Corridor

The Alternative 1a, Alternative 1, and Alternative 2 transportation corridors would connect the mine site with the Amakdedori or Diamond Point port primarily overland, with one section relying on a ferry crossing of Iliamna Lake.

Iliamna Lake is used year-round by community members to access subsistence harvest areas and resources around the lake, traveling via watercraft in open water and by snowmachine when ice conditions allow. For example, Kokhanok community members cross the lake to access resources near the community of Iliamna and near Lake Clark National Park and Preserve (Fall et al. 2006) (see Section 3.9, Subsistence, for more information on subsistence practices). There is a heavily used snowmachine route between the communities of Kokhanok and Iliamna across Iliamna Lake. The communities of Pedro Bay and Igiugig also traverse the length of the lake on snowmachine, hugging the shoreline (PLP 2018-RFI 088). Local sport fishing, hunting, and tourism industries also rely on the use of Iliamna Lake for transportation and natural resources (Fall et al. 2006) (see Section 3.5, Recreation, and Section 3.6, Commercial and Recreational Fisheries).

Iliamna Lake is also used for inter-village travel, via boat during the open water season, or via snowmachine as allowed by lake ice conditions. Ice coverage (thickness and extent) can vary across Iliamna Lake, which contributes to transportation access. Iliamna Lake ice conditions are described in Section 3.16, Surface Water Hydrology (PLP 2018-RFI 013).

Fuel and other supplies are delivered to Iliamna Lake communities via barge. The Williamsport-Pile Bay Road is used as portage for barges from Cook Inlet to Iliamna Lake. Several smaller rivers (e.g., Gibraltar River) and streams are used for recreation and subsistence. The Newhalen River is used for transportation, but it cannot accommodate barge traffic to transport goods to Nondalton (Kevin Waring and Associates 2010b).

3.12.3.3 Cook Inlet

Cook Inlet is home to commercial, subsistence, sport, and personal-use fisheries. Aquatic farming, research, and hatcheries are also permitted (ADF&G 2018h) (see Section 3.9, Subsistence, for more information on subsistence uses in Cook Inlet). Cook Inlet provides access to major ports in Alaska from primary shipping lanes in the northern Pacific. All alternatives would use those shipping routes to transport goods from the west coast of the United States and to transport concentrate to markets in Asia. Shipping routes are illustrated in Appendix K3.12.

Vessels operating in Cook Inlet range up to 840 feet long and include various cargo vessels, tank ships carrying petroleum products, tugs, passenger vessels, fishing vessels, fish processing vessels, mobile drilling rigs, government vessels, and dredges, which have typical speeds of up to 20 knots. The weather and conditions in Cook Inlet can create difficulty for vessels, because seasonal sea ice and sudden weather changes can occur (Eley 2012). Sea conditions in Cook Inlet and in the vicinity of the project are described in Section 3.16, Surface Water Hydrology.

The Cook Inlet Vessel Traffic Study (Eley 2012) and Risk Assessment (Nuka and Pearson 2015) state that in 2010, 80 percent of ship transits were made by 15 ships (to Homer, Nikiski, and Anchorage); there were 480 ship port calls total. The ships include state, national, and international owners (Eley 2012). Area ports are shown on Figure 3.12-3. The study summary is presented below:

> Each region of Cook Inlet (upper, middle and lower) experienced varying levels of activity based on the primary port and the types of vessels operating there. Kachemak Bay in lower Cook Inlet experienced the highest levels of activity in Cook Inlet, primarily due to ferry operations, or vessels awaiting a marine pilot, more favorable weather, or Coast Guard inspection. Middle Cook Inlet reflected tank ship movements in and around the Nikiski and Drift River oil terminals. Upper Cook Inlet activity was dominated by movement in and out of the Port of Anchorage. AIS [Automatic Identification System] data showed that the busiest times of year were the third quarter (July through September) followed by the second quarter (April through June) (Eley 2012).

Pilotage (i.e., the process of directing the movement of a ship by visual or electronic observations of recognizable landmarks) is required for all vessels traveling in Cook Inlet (unless exempt[1]), because navigation is affected by large tidal fluctuations, currents, winds, mud flats, ice flows, boulders, reefs, and shoals, which are not always detectable by echo sounder, lead lines, or by observing turbulence in the water (NOAA 2018c). Potential hazardous obstacles may also include shipwrecks, unconsolidated sediments, glacial deposits, and volcanic debris (BSEE 2018b). Navigating Cook Inlet in the winter months requires a separate set of guidelines set by the US Coast Guard (USCG), and vessels are subject to inspection by the USCG (NOAA 2018c).

Western Cook Inlet has more debris than eastern Cook Inlet and experiences larger ice pans in the winter. In Kamishak Bay, there are scattered reefs within a few feet of the water surface, many are visible at low tide. Local knowledge is recommended for navigation of this area, especially for lower Kamishak Bay (known as the Kamishak Gap) near the Douglas River, where rip tides, currents, and strong west winds combine with the underwater obstructions of reefs, ledges, and mudflats, making navigation more challenging.

The Amakdedori port site for Alternative 1a and Alternative 1 would be on a beach in Kamishak Bay. Amakdedori can be safely approached just north of Amakdedori Creek, although rocky outcroppings exist near shore and large reefs offshore. Winds in this area can pick up after mid-August to produce larger swells (NOAA 2018c). Regional and local wave climate, tides, currents, and storm surge are described in Section 3.16, Surface Water Hydrology.

The seabed from Amakdedori to about 5.6 miles offshore gently slopes to a depth of 60 feet, with Amakdedori Creek's alluvial fan reaching almost 1,000 feet offshore. Rocky outcrops occur about 2 miles north of the mouth of Amakdedori Creek (PLP 2018-RFI 039).

The Diamond Point port site for Alternative 2 and Alternative 3 would be in Iliamna Bay north of the entrance to Cottonwood Bay. The site for Alternative 2 is currently being developed as a quarry. The bay shoals gradually from 36 feet in the entrance north of White Gull Island to 6 feet

[1] Examples of vessels exempt from pilot requirements in Cook Inlet include fishing vessels, most vessels under 65 feet, and US-registered pleasure craft.

in the entrance to Cottonwood Bay. Iliamna Bay can be approached between North Head and White Gull Island, although care must be taken to avoid a reef. Iliamna Bay has several suitable temporary anchorages (NOAA 2018c).

At the end of the eastern arm of Iliamna Bay is Williamsport, the eastern portage point for passage to Iliamna Lake. The depth of Iliamna Bay is 36 to 48 feet, although Williamsport is shallow and usable only at higher tides, as discussed above. Upper Cook Inlet ice drifts to this area in the winter (NOAA 2018c). The National Oceanic and Atmospheric Administration (NOAA) acoustic wave profiler recorded wave height data from 2010 to 2012 outside of Iliamna Bay.

The lightering location for Alternative 2 and Alternative 3 would be in Iniskin Bay. Safe anchorages in this area can be dependent on season and wind. Although sometimes windy, Iniskin Bay is considered secure for anchorage of medium-sized vessels on the western side of Cook Inlet in any weather. Fishing vessels 4,000 tons or less currently use this bay for anchorage. Reefs and shoals near the water surface exist in this bay (NOAA 2018c). Sea ice conditions at Amakdedori, Diamond Point, and Lightering Location A are described in Section 3.16, Surface Water Hydrology.

Based on the available data for geography, wave climate, bathymetry, and ice coverage, access to Amakdedori or Diamond Point may be limited due to periods of high wave activity and/or ice conditions in Kamishak and Iliamna bays.

3.12.4 Navigation

Federal jurisdiction of navigation includes waters that are subject to tidal influence, are currently used, were used in the past, or could be used in the future to transport interstate or foreign commerce (e.g., transportation of goods and fuel, guided fishing or rafting, oil and gas production) (33 Code of Federal Regulations [CFR] Part 329.4). Section 10 of the Rivers and Harbors Act of 1899 requires authorization from the US Army Corps of Engineers (USACE) for the construction of any structure in, under, or over any navigable waters of the US (NWUS). NWUS require a Section 10 permit if the structure or work affects the course, location, or condition of the waterbody, and applies to any dredging or disposal of dredged materials, excavation, filling, rechannelization, or any other modification of a NWUS. The General Bridge Act of 1946, as amended, and the Rivers and Harbors Act, as amended, require the location and plans of bridges and causeways across the NWUS be submitted to and approved by the Secretary of Homeland Security (delegated to the USCG) prior to construction. Table 3.12-3 lists the federally navigable waters in the EIS analysis area.

Figure 3.12-4 illustrates the navigable waterways in the EIS analysis area. The navigable waterbodies are listed in Table 3.12-3. The Iliamna River and the Pile River are considered navigable by the State of Alaska (ADNR 2018b); the ADNR Division of Mining, Land, and Water determines navigable waters for the state.

3.12.4.1 Mine Site

The mine site is not accessible by navigable waters, although some navigable waters are hydrologically connected to the area, such as the Kvichak and Nushagak rivers. The closest navigable water with facilities to accommodate vessel traffic is Iliamna Lake.

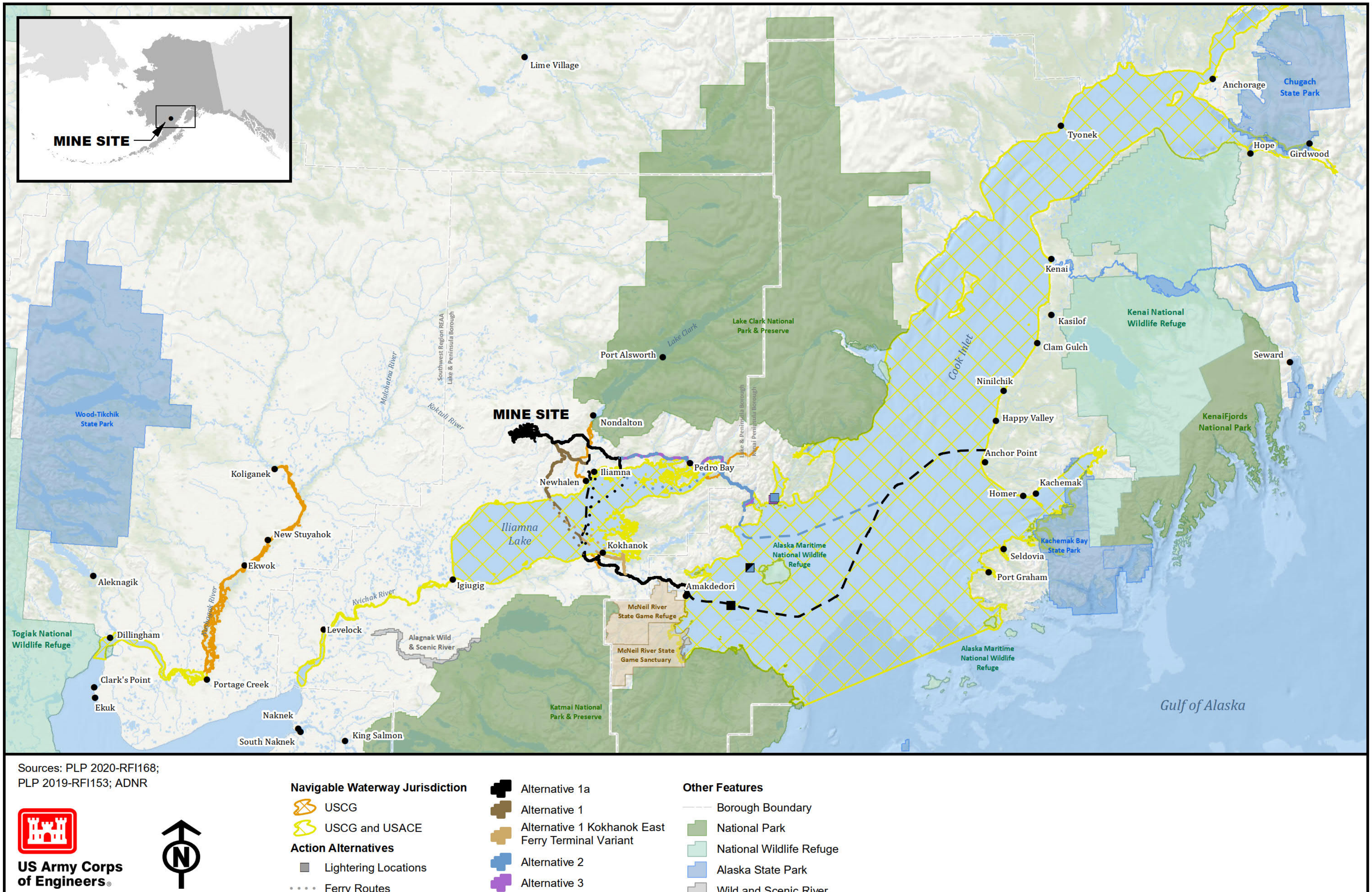
3.12.4.2 Transportation Corridor

The Alternative 1a, Alternative 1, and Alternative 2 transportation corridors would connect the mine site with the Amakdedori or Diamond Point port primarily overland, with one section relying on a ferry crossing of Iliamna Lake.

Table 3.12-3: Navigable Waters of the US

Waterway	Agencies with Authority	Limit of Navigability	Existing Structures/Facililities
Cook Inlet	USACE/USCG BOEM/BSEE	All waters subject to tidal influence Alaska OCS (Cook Inlet)	Communication cables Oil and gas infrastructure—platforms, pipelines, exploration drilling (BOEM/BSEE in OCS Cook Inlet Waters) Municipal and commercial docks Navigation aids
Iliamna Lake	USACE/USCG	Entire waterway	Public dock in Iliamna Small boat ramp in Igiugig Boat landing in Pedro Bay Several private docks
Iliamna River	USCG	Entire waterway	Bridge on the Williamsport-Pile Bay Road
Kvichak River	USACE/USCG	Mouth to and including Iliamna Lake	Beach landing and riverfront dock in Levelock
Gibraltar River	USCG	Undetermined	Unknown
Newhalen River	USCG	Entire waterway	Beach landing in Newhalen, small-boat launch along Newhalen River Road
Nushagak River	USACE/USCG	USACE—from mouth of Wood River USCG—Mouth to the Village of Koliganek	N/A

Notes:
BOEM = Bureau of Ocean Energy Management
BSEE = Bureau of Safety and Environmental Enforcement
OCS = Outer Continental Shelf
USACE = US Army Corps of Engineers
USCG = US Coast Guard
Source: USCG 2012, 2020; USACE 2018b; Kevin Waring & Associates 2010b, 2011b



NAVIGABLE WATERWAYS

PEBBLE PROJECT EIS

FIGURE 3.12-4

Iliamna Lake is considered navigable by USACE, USCG, and the State of Alaska, and is used year-round by community members to access subsistence harvest areas, resources, and other villages around the lake, traveling via watercraft in open water and via snowmachine when ice conditions allow. Historically, barges have traveled from Bristol Bay up the Kvichak River to Iliamna Lake, delivering goods at the Iliamna barge landing for the communities of the area; however, low water levels and river shoals in some years make this route limited to shallow-draft vessels, or infeasible. No other navigable waterways in the transportation corridor are used to transport goods commercially. Other commerce on the lake includes the transport of commercial fishing vessels from Pile Bay to Bristol Bay, recreational navigation, and guided sport fishing (Kevin Waring and Associates 2010b).

3.12.4.3 Cook Inlet

All alternatives would use a port on Cook Inlet to transport supplies to and from the mine site. Cook Inlet is used for commercial, subsistence, sport, and personal-use fishing, as well as oil and gas exploration and extraction, transportation of goods, cruise ships, aquatic farming, research, and hatcheries (ADF&G 2018h).

Alternative 1a and Alternative 1 would use Amakdedori Creek as a port location. There are no port structures currently in this area.

The Diamond Point port site for Alternative 2 and Alternative 3 would be in Iliamna Bay, north of the entrance to Cottonwood Bay. At the end of the eastern arm of Iliamna Bay is the port of Williamsport, the eastern portage point for passage to Iliamna Lake. The current use of Williamsport as a port is discussed above.

The lightering location for Alternative 2 and Alternative 3 would also be in Iniskin Bay. Iniskin Bay is considered secure for anchorage of medium-sized vessels on the western side of Cook Inlet in any weather. Fishing vessels 4,000 tons or less currently use this bay for anchorage (NOAA 2018c).

3.13 GEOLOGY

3.13.1 Introduction

This section describes the baseline geology of the project area. Information provided here is based on field and desktop studies conducted for the project area by the applicant and others from 1985 to the present, as described in Appendix K3.13. Paleontological resources are also addressed in Appendix K3.13. Other sections that directly correspond to the geology discussion are Section 3.14, Soils; Section 3.15, Geohazards and Seismic Conditions; and Section 3.17, Groundwater Hydrology.

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 EIS analysis area is the same as the project area for this resource.

A definition for many technical terms applied in this section can be found in the glossary, available online on the project website (https://pebbleprojecteis.com/overview/glossary).

3.13.2 Regional Setting

The project area is approximately 250 miles northwest of the Alaska-Aleutian megathrust, where the Pacific tectonic plate subducts (i.e., sinks) beneath the North American plate. Section 3.15, Geohazards and Seismic Conditions, describes the tectonic setting, seismicity, faults, and volcanic activity. Tectonic activity at the plate boundary is the cause of the region's seismicity and volcanic activity and has promoted the growth of the Alaska landmass through the accretion of crustal blocks called terranes. Tectonic plate boundaries shifted throughout the Mesozoic (245 to 65 million years ago). These shifts produced igneous intrusives (magma) of Late Cretaceous age (about 90 million years old) responsible for the mineralization of the Pebble deposit (PLP 2011a).

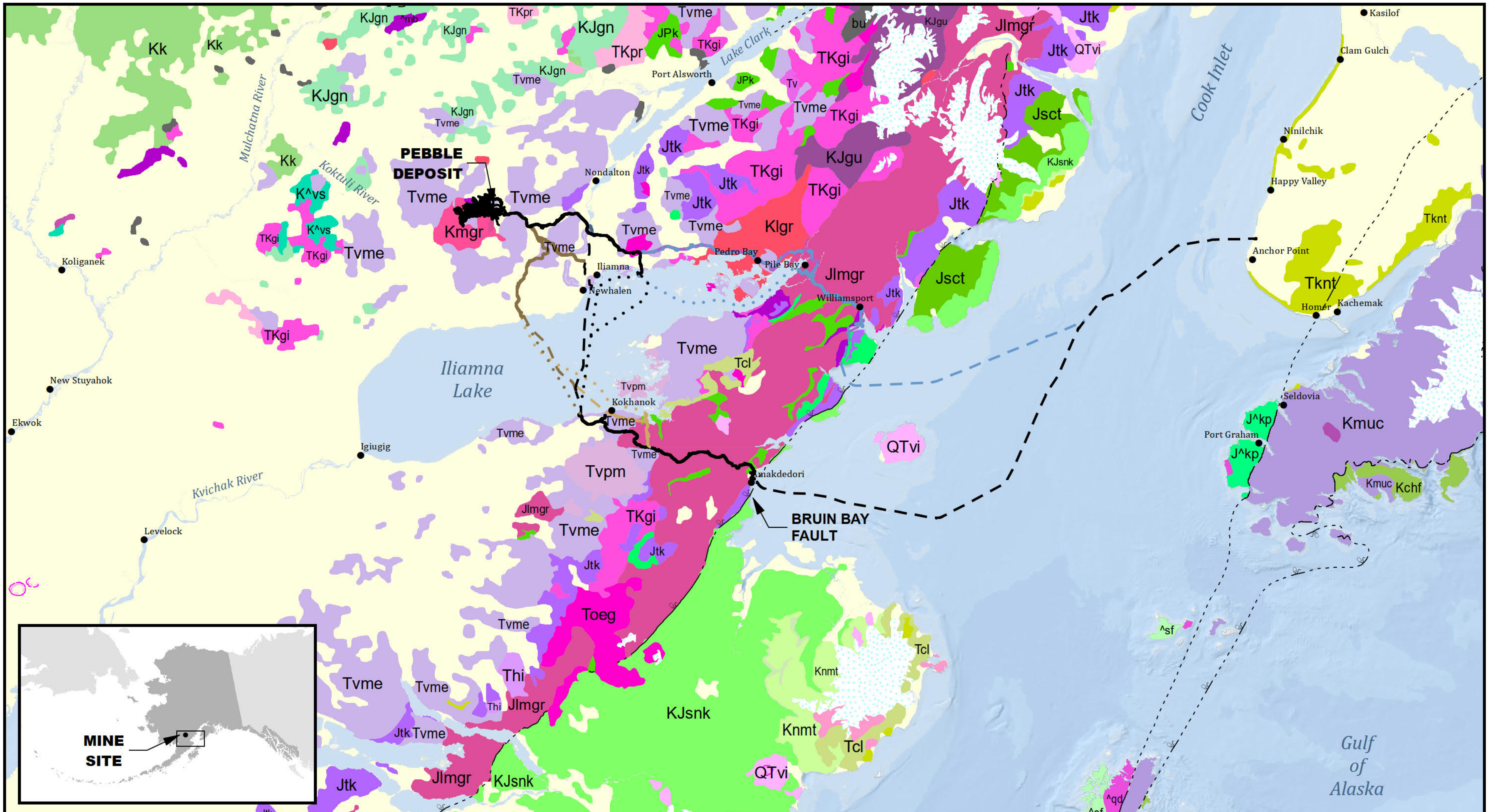
Over the last 2.6 million years (i.e., Quaternary), glaciers have repeatedly advanced over the landscape, causing erosion of glacial valleys, rounding landforms of hills and mountains, and depositing, which reworked materials throughout the region. The unconsolidated sediments occur in the valleys between bedrock hills and mountains. No glaciers exist in the project area.

3.13.3 Geologic Overview of the EIS Analysis Area

The geology of the mine site generally consists of bedrock hills with thin or no unconsolidated sediment with overburden in the wide valleys (Hamilton and Klieforth 2010). Overburden in this area is composed of glacial, glaciofluvial, and alluvial sediments. Iliamna Lake is in a basin generally filled with glacial sediments of Quaternary age that are exposed southwest, west, and north of the lake with occasional bedrock outcrops. The area between Iliamna Lake and Cook Inlet generally consists of exposed or near-surface bedrock, with limited sediments overlying the bedrock at the lower elevations (Wilson et al. 2015) (Figure 3.13-1).

The geologic structure of the project area is broadly defined by the northeast- to southwest-trending Bruin Bay Fault (Figure 3.13-1) (see Section 3.15, Geohazards and Seismic Conditions).

Extensive surficial glacial deposits, similar to those near Iliamna Lake, overlie the southwestern portion of the Kenai Peninsula (Detterman and Reed 1973). There is no known permafrost in the project area, including the areas of all alternatives and variants (see Section 3.14, Soils, for a discussion of permafrost).



Sources: PLP 2020-RFI168;
PLP 2019-RFI153; Wilson et al. 2015

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Action Alternatives

- Ferry Routes
- Natural Gas Pipelines
- Alternative 1a
- Alternative 1
- Alternative 1 Kokhanok East Ferry Terminal Variant
- Alternative 2
- Alternative 2 Newhalen River North Crossing Variant
- Alternative 3

Note: The complete legend describing the map units is provided in Wilson et al. 2015.

PEBBLE PROJECT AREA GEOLOGY

PEBBLE PROJECT EIS

FIGURE 3.13-1

3.13.4 Alternative 1a

3.13.4.1 Mine Site

Unconsolidated sediments (overburden) in the mine site consist of glacial till, outwash, alluvium, alluvial fan and deltaic deposits, and glaciolacustrine (glacial lake) deposits (Figure 3.13-2). Sediment grain sizes vary from silt, sands, and gravels to boulders. Overburden ranges in thickness from a few feet to about 165 feet (Detterman and Reed 1973; Knight Piésold et al. 2011a).

When glaciers were present, lakes formed where glacial ice blocked the major drainage basins (Hamilton and Klieforth 2010), resulting in deposition of lacustrine deposits. Glacial lake deposits are mapped in the eastern half of the open pit area, extending south of Frying Pan Lake, and in the area of water treatment plant #1 discharge-south (Figure 3.13-2). The lake deposits are composed of stratified (layered) to weakly stratified silts, sands, and fine gravels, and display poorly drained surface morphology (Hamilton and Klieforth 2010). Glacial meltwater channels and a moraine ridges are also present (Figure 3.13-2).

Colluvium and felsenmeer occur along the flanks of Kaskanak Mountain, including the footprint of the bulk tailings storage facility (TSF) and on slopes surrounding the mine site. Solifluction lobes composed mostly of silt are present on isolated lower slopes in the mine site, including the footprint of the pyritic TSF (Knight Piésold et al. 2011a). Thin, organic soils less than 1 foot thick cover the mine site and are often intermixed with sands and gravels (Hamilton and Klieforth 2010) (see Section 3.14, Soils).

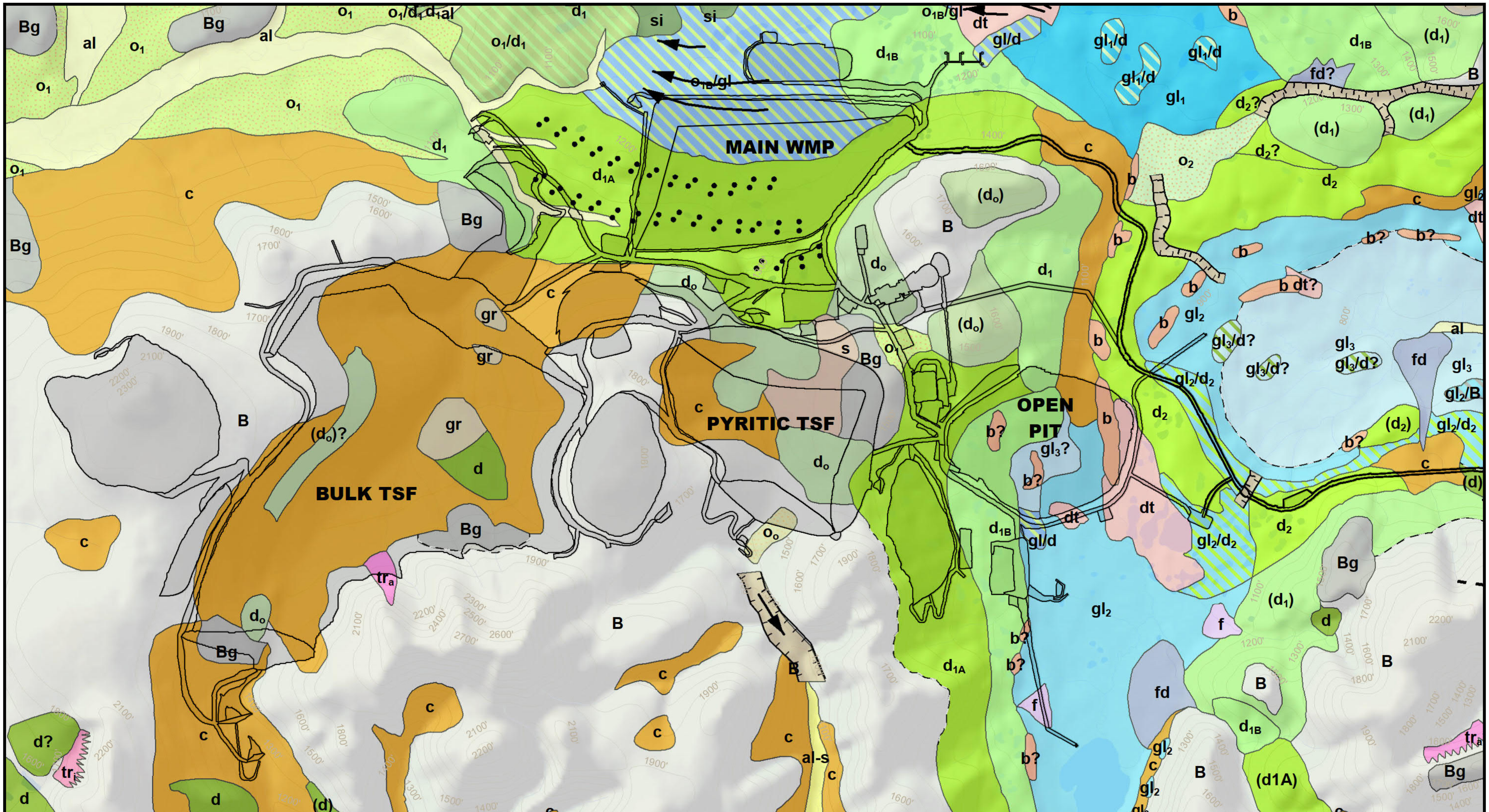
Bedrock occurs at the higher elevations (above about 1,400 feet above mean sea level) in the mine site area (Figure 3.13-2). The bedrock geologic map (Figure 3.13-3) shows the mine site's complex bedrock geology and is described below.

Mine Site Bedrock Geology and Mineralization of the Pebble Deposit

The mine site bedrock geology is complex (Figure 3.13-3). Much of the bedrock in and around the open pit area is a type of Mesozoic sedimentary rock derived from eroded andesitic volcanic rock (Kahiltna flysch). Tertiary (Paleogene and Neogene, about 65 to 2.6 million years old) volcanic and sedimentary rocks outcrop at higher elevations on the southern end of the bulk TSF and in the southeastern corner of the mine site area. A variety of Cretaceous (about 145 to 65 million years old) intrusive rocks outcrop in the mine site, including the granodiorite of the Kaskanak batholith, which outcrops in the western portion of the mine site (Knight Piésold et al. 2011a) (Figure 3.13-3).

Other diverse magmas intruded in the flysch in a north-northeast-trending belt throughout the Cretaceous and were then folded by tectonic forces (Nokleberg et al. 1994). The mineralization that formed the Pebble deposit was likely caused by these diverse magma intrusions that comprise the rock in the open pit area (Knight Piésold et al. 2011a).

Offshoots of the magma injected into joints and fractures in the surrounding sedimentary bedrock, heating the rock and causing hot fluids to circulate in a large magmatic-hydrothermal system. The hot fluids carried dissolved metals from the magma, including copper, gold, and molybdenum. As the fluids cooled, the metals and associated sulfide minerals (such as iron sulfide [pyrite]) precipitated in the surrounding rock, concentrated in metal-rich quartz veins. These rocks make up the Pebble deposit, a copper, gold, molybdenum porphyry system.



Sources: PLP 2019-RFI153; Hamilton and Klieforth 2010

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Alternative 1a

Surficial Geology Linear Features

- - - Contact

Crest of moraine ridge

Drainage Channel

Fault

Meltwater channel

Surficial Geology Map Units

Alluvian
al, al-s

Bedrock, undifferentiated
B

Bedrock, glaciated
Bg

Beach deposits
b, b?

Colluvium
c

Glacial drift
d, d?, d1, d1A, d1B, d2, d2?, do, (d), (d1), (d1A), (d2), (do), (do)?

Deltaic deposits
dt, dt?

Fan deposits
f

Fan-delta deposits
fd, fd?

Glacial-lake deposits
gl/d, gl1, gl1/d, gl2, gl2/B, gl2/d2, gl3, gl3/d?, gl3?

Gravel
gr

Glacial outwash
o1, o1/d1, o1B/gl, o2, oo

Solifluction deposits
s

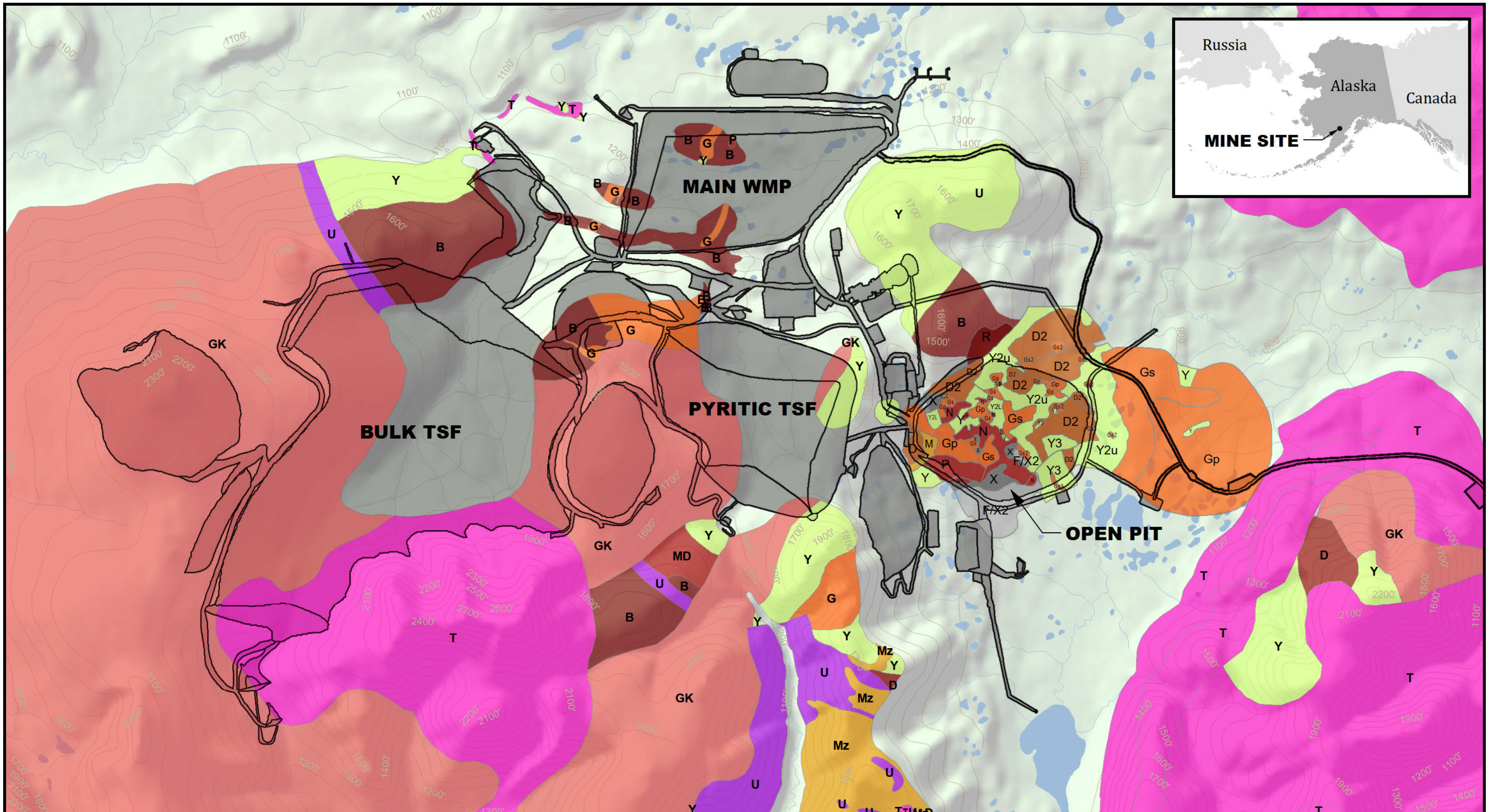
Silt, ice-rich
si

Talus rubble
tra, tri

MINE SITE SURFICIAL GEOLOGY

PEBBLE PROJECT EIS

FIGURE 3.13-2



Sources: PLP 2019-RFI153;
Knight Piesold 2011d

US Army Corps of Engineers

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Miles

Alternative 1a

Bedrock Geology

- F/X2; Fault breccia
- X; Intrusion breccia
- Y, Y2L, Y2u, Y3; Mesozoic andesitic sedimentary flysch
- C; Mesozoic conglomerate
- M, Mz; Cretaceous monzonite
- G, Gp, Gs2, Gs3, Gs; Cretaceous quartz monzodiorite, granodiorite sill
- D, D2; Diorite sill
- GK; Cretaceous granodiorite (Kaskanask batholith)
- MD, N, P; Cretaceous monzodiorite
- D; Cretaceous diorite
- B; Mesozoic basalt and gabbro
- R; Gabbro
- U; Cretaceous pyroxenite
- T; Tertiary volcanic and sedimentary rocks

MINE SITE BEDROCK GEOLOGY

PEBBLE PROJECT EIS

FIGURE 3.13-3

Table 3.13-1 presents the estimated deposit resource for copper, gold, and molybdenum; and compares the total deposit to the amount that would be mined over the 20-year lifespan of the project (PLP 2018d). The project would mine approximately 10 percent of the total estimated Pebble deposit resource.

Table 3.13-1: Estimated Pebble Deposit Resource (Measured, Indicated, and Inferred)

Resource	Total Deposit		20-Year Open Pit	
	Weight	Grade	Weight	Grade
Copper	81.5 Blb	0.34%	7.4 Blb	0.29%
Gold	107.3 MMoz	0.31 g/t	12.1 MMoz	0.27 g/t
Molybdenum	5.64 Blb	234 ppm	398 MMlb	154 ppm

Notes:
Blb: billion pounds
g/t: grams per ton
MMlb: million pounds
MMoz: million ounces
ppm: parts per million
Source: PLP 2018d

Construction Materials

Material to construct the embankments would be sourced from quarries A, B, and C, with granodiorite rock at these locations. Granodiorite is a competent (e.g., strong and resistant) rock that is suitable for use as rockfill. Construction would also use the overburden removed from the open pit area that is determined to be suitable as rockfill (Figure 3.13-3).

3.13.4.2 Transportation Corridor

Roads

Bedrock and surficial geology vary somewhat across the transportation corridor (see Chapter 2, Alternatives), but is generally composed of the same rock types and overburden present at the mine site, without the diverse magmatic intrusions that resulted in the mineralization of the Pebble deposit. Few bedrock exposures exist north of Iliamna Lake, and glacial sediments cover most of the terrain (Detterman and Reed 1973, 1980).

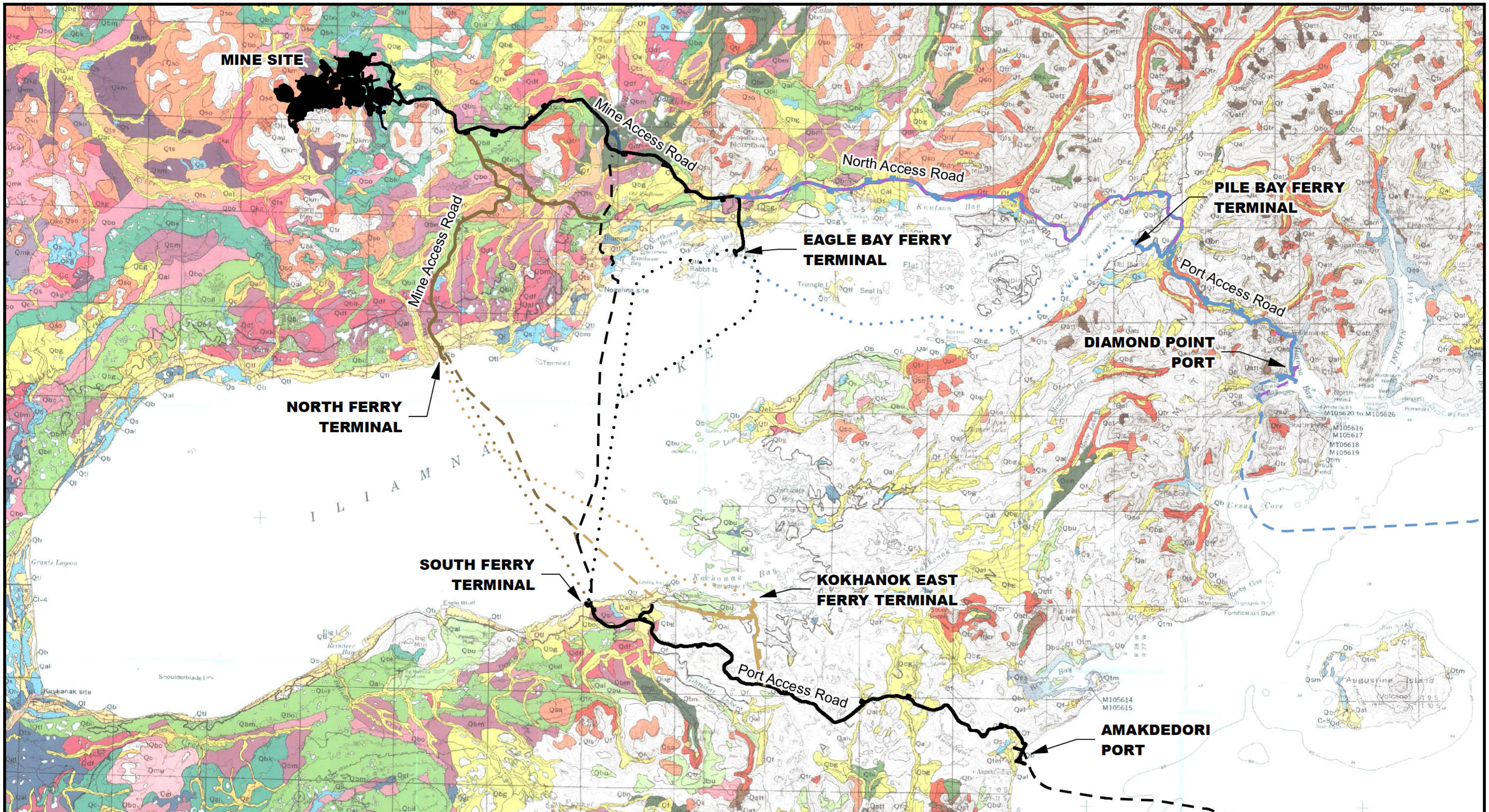
Near the Amakdedori port site, the transportation corridor would be on outcrops of Jurassic (200 to 145 million years ago) metamorphic rock and marine sedimentary rock that are locally abundant in marine invertebrate fossils (Detterman and Reed 1980; Wilson et al. 2015).

From the port to the south ferry terminal, the port access road would traverse Tertiary (Paleogene and Neogene) volcanic rocks, similar to those north of the lake; and Jurassic intrusive bedrock outcrops at higher elevations, with sparse surficial deposits (Figure 3.13-4) (Detterman and Reed 1973, 1980; Wilson et al. 2015).

Geology of the transportation corridor from the Eagle Bay ferry terminal to the mine site is composed of bedrock overlain by glacial moraine, beach deposits, solifluction, stream channels, and terrace deposits (Figure 3.13-4) (Detterman and Reed 1973).

Ferry Terminals

The Eagle Bay ferry terminal would be underlain by glacial deposits (Detterman and Reed 1973, 1980). The south ferry terminal would be underlain by Tertiary (Paleogene and Neogene) volcanic rock near the shoreline, and by Pleistocene terrace deposits farther upslope (Detterman and Reed 1973, 1980).



Sources: PLP 2020-RFI168; PLP 2019-RFI153; Detterman and Reed 1973

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Action Alternatives

- Ferry Routes
- Natural Gas Pipelines
- Alternative 1a
- Alternative 1
- Alternative 1 Kokhanok East Ferry Terminal Variant
- Alternative 2
- Alternative 2 Newhalen River North Crossing Variant
- Alternative 3

Geology

- Bedrock
- Holocene Glacial Moraine and Drift
- Outwash
- Beach and Eolian Deposits
- Mass Wasting Deposits
- Alluvium
- Estuary and Lake Deposits
- Pleistocene Glacial Moraine and Drift

SURFICIAL GEOLOGY OF TRANSPORTATION CORRIDORS

PEBBLE PROJECT EIS

FIGURE 3.13-4

Construction Material Sources

Material sites along the transportation corridor would supply earthen materials (e.g., rock, gravel) for construction and maintenance of the transportation corridor. Material sites of bedrock would likely require blasting along the mine access road west of the Newhalen River and from the south ferry terminal to Amakdedori port (Figure 3.13-5). The remaining material sites would likely be developed in surficial glacial deposits and could be excavated without blasting (Detterman and Reed 1973; Hamilton and Klieforth 2010). Appendix K2, Alternatives, provides figures depicting the material sites.

3.13.4.3 Amakdedori Port

The footprint of Amakdedori port would be on marine terrace and beach deposits consisting of sand, pebbles, and cobbles (Detterman and Reed 1973). Alluvial fan-delta deposits from Amakdedori Creek extend about 1,000 feet offshore into Kamishak Bay (PLP 2018-RFI 039). Seafloor sediment at and around the Amakdedori port site is primarily composed of subtidal gravel and beach complex, with sub-bottom sediments consisting primarily of fine silty sand, occasional coarse gravel and shell fragments, and a fines content ranging from 14 to 19 percent (GeoEngineers 2018a).

Bedrock is not exposed in the port footprint, but is exposed in the bluffs to the northeast, and consists of Jurassic igneous and metamorphic rock, and fossiliferous marine sedimentary rocks (Detterman and Reed 1973, 1980; Wilson et al. 2015).

Rock to be used in construction of the port would be supplied from material site (MS) MS-A08 (PLP 2018-RFI 035). MS-A08 is in an area of thin or absent surficial deposits underlain by bedrock (Detterman and Reed 1973).

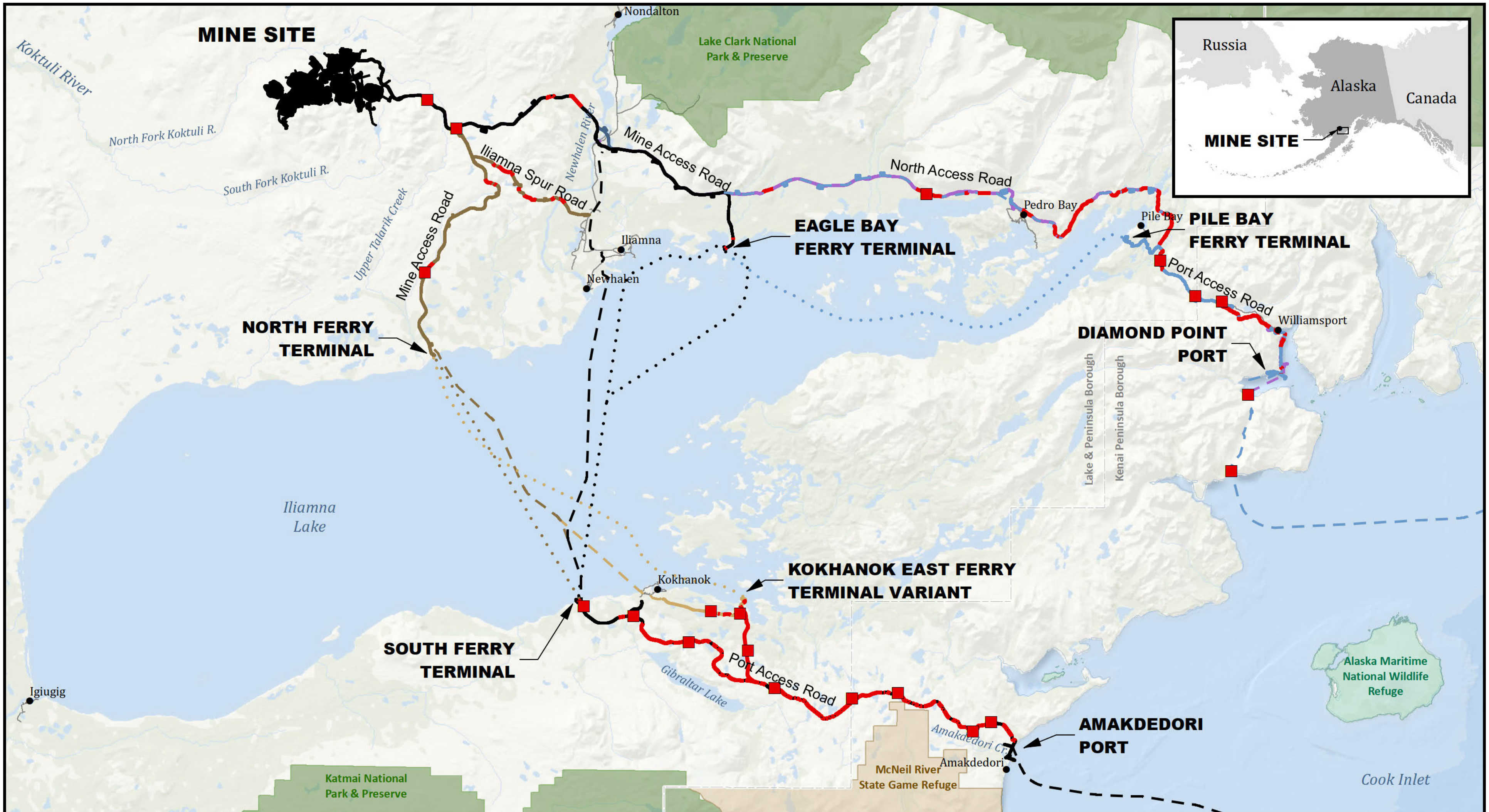
3.13.4.4 Natural Gas Pipeline Corridor

Surficial deposits along the Kenai Peninsula segment of the pipeline corridor include Quaternary glacial outwash sediments and minor alluvial deposits (Wilson et al. 2015). Bedrock on the Kenai Peninsula segment is almost entirely buried by deep glacial deposits, but limited outcrops in the lower bluffs along Cook Inlet reveal late Tertiary (Neogene) estuarine and non-marine sedimentary bedrock (Wilson et al. 2015). No material sites would be required on the Kenai Peninsula portion of the pipeline route (PLP 2018-RFI 035).

The Cook Inlet pipeline segment from the Kenai Peninsula to Amakdedori port crosses a relatively shallow sedimentary basin filled with actively migrating, sand- to boulder-sized material. Materials consist of stratified glaciofluvial, glaciomarine, and marine sediments (BOEM 2016a). The seafloor gradient is generally less than 10 degrees and contains sedimentary features such as ripples and wave forms, dunes, compound and complex bedforms, and scours. Boulder fields, lineaments, spur features, and outcropping rock were reported by IntecSea (2019) (Figure 3.13-6). Section 3.18, Water and Sediment Quality, describes the seafloor sediments and sediment distribution in the area of Cook Inlet that includes the pipeline corridors for Alternative 1a and other action alternatives. Seafloor sediment distribution is shown in Figure 3.18-9 (see Section 3.18, Water and Sediment Quality).

The geology along the natural gas pipeline corridor from Amakdedori port to the south ferry terminal is the same as described above for the transportation corridor.

The pipeline corridor crosses Iliamna Lake from the south ferry terminal west of Kokhanok to landfall just east of Newhalen on the north shore. Geology beneath Iliamna Lake is buried bedrock overlain by glacial and alluvial sediments. The substrate of the lake is described in Section 3.18, Water and Sediment Quality.



Sources: PLP 2020-RFI168; PLP 2019-RFI153; PLP 2019-RFI084a; ADNR

US Army Corps of Engineers

5 0 5 10

Miles

Bedrock Blasting Intervals

- Material Site
- Transportation Corridor

Action Alternatives

- Ferry Routes
- Natural Gas Pipelines
- Alternative 1a
- Alternative 1
- Alternative 1 Kokhanok East Ferry Terminal Variant
- Alternative 2
- Alternative 2 Newhalen River North Crossing Variant
- Alternative 3

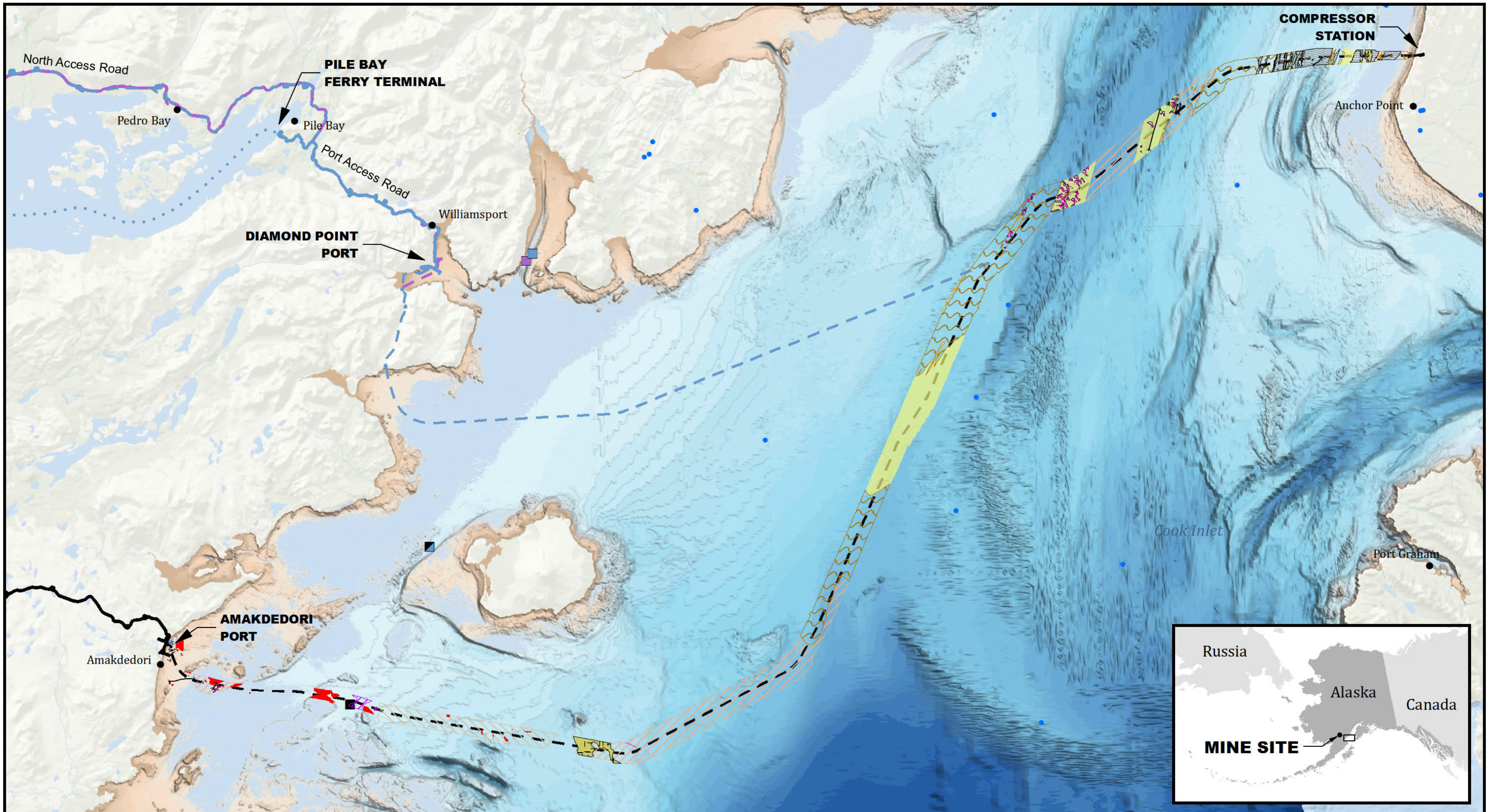
Other Features

- Local Roads
- Borough Boundary
- National Park
- National Wildlife Refuge
- State Game Refuge/Sanctuary

BEDROCK BLASTING INTERVALS

PEBBLE PROJECT EIS

FIGURE 3.13-5



Sources: PLP 2020-RFI168; PLP 2019-RFI153; IntecSea 2019

US Army Corps of Engineers

5 0 5 10
Miles

Geologic Features

- Wells
- Lineation
- Ridge Axis
- Spur
- Dune Crest
- Potential Shallow Gas
- Area of Possible Diffuse Shallow Gas
- Boulder Field
- Ripples
- Waves
- Compound Bedforms
- Dunes
- Complex Bedforms
- Scour
- Outcropping Rock
- Outcropping Strata

Action Alternatives

- Lightering Locations
- Ferry Routes
- Natural Gas Pipelines
- Alternative 1a
- Alternative 2
- Alternative 3

SEABED GEOLOGIC FEATURES IN THE VICINITY OF THE COOK INLET PIPELINE CORRIDOR

PEBBLE PROJECT EIS

FIGURE 3.13-6

Along the pipeline-only (no associated road) segment from the north shore of Iliamna Lake to the Newhalen River crossing, buried bedrock would be mostly the same Tertiary (Paleogene and Neogene) volcanic rock present in the mine site, overlain by Quaternary deposits including glacial and alluvial deposits and sand at the pipeline landfall near Newhalen.

Geology from the Newhalen River crossing to the mine is the same as described above under transportation corridor—bedrock overlain by Quaternary sediments.

3.13.5 Alternative 1

This section describes the geology relative to Alternative 1 and variants.

3.13.5.1 Mine Site

The geology and material sites at the mine site would be the same as those for Alternative 1a.

3.13.5.2 Transportation Corridor

Roads

From Amakdedori port to the south ferry terminal, the geology would be the same as Alternative 1a. Along the mine access road from the north ferry terminal to the mine site, the buried bedrock would be mostly the same Tertiary (Paleogene and Neogene) volcanic rock present in the mine site. The entire Iliamna spur road would be underlain by Quaternary glacial deposits, with no apparent exposed bedrock (Detterman and Reed 1973, 1980).

Ferry Terminals

Geology at the south ferry terminal would be the same as Alternative 1a. The north ferry terminal would be underlain by Pleistocene glacial deposits consisting mostly of sand.

Construction Material Sources

Materials sites are generally described under Alternative 1a. For Alternative 1, blasting would be required at some material sites on the mine access road north of the north ferry terminal, along Iliamna spur road, and along the south ferry terminal to Amakdedori, as described for Alternative 1a (Figure 3.13-5).

3.13.5.3 Amakdedori Port

The geology at Amakdedori port would be the same as Alternative 1a.

3.13.5.4 Natural Gas Pipeline Corridor

The surficial and bedrock geology of the natural gas pipeline corridor from the Kenai Peninsula to Amakdedori port and the south ferry terminal would be the same as described for Alternative 1a. The geology of the pipeline corridor across Iliamna Lake would be similar to Alternative 1a. The geology of the pipeline corridor from the north ferry terminal to the mine site is the same as described for the transportation corridor.

Construction material sources for the natural gas pipeline corridor would be the same as those identified for the transportation corridor between the mine site and Amakdedori port.

3.13.5.5 Alternative 1—Summer-Only Ferry Operations Variant

The Summer-Only Ferry Operations Variant is not relevant to the geology affected environment and is therefore not addressed in this section.

3.13.5.6 Alternative 1—Kokhanok East Ferry Terminal Variant

The Kokhanok east ferry terminal would be underlain by Quaternary beach deposits near the Iliamna Lake shoreline, and by Tertiary (Paleogene and Neogene) volcanic bedrock farther upslope (Detterman and Reed 1973, 1980).

3.13.5.7 Alternative 1—Pile-Supported Dock Variant

Marine sediments at the Amakdedori port site that are relevant to the Pile-Supported Dock Variant are the same as those addressed above for the port.

3.13.6 Alternative 2—North Road and Ferry with Downstream Dams

3.13.6.1 Mine Site

The geology and material sites at the mine site would be the same as those for Alternative 1a.

3.13.6.2 Transportation Corridor

Roads

Geology of the transportation corridor between the mine site and the Eagle Bay ferry terminal would be the same as Alternative 1a.

From the Pile Bay ferry terminal to Williamsport, the transportation corridor would largely follow the existing road underlain by Jurassic igneous rock and Quaternary alluvium, talus, and rubble deposits (Detterman and Reed 1980; Wilson et al. 2015).

From Williamsport to Diamond Point port, the road would cross a slope underlain by Jurassic to Triassic (251 to 200 million years old) igneous volcanic rock, intrusive granodiorite and quartz monzonite, and slightly metamorphosed basaltic flows and sedimentary rocks (Detterman and Reed 1980; Wilson et al. 2015).

Ferry Terminals

The geology at the Eagle Bay ferry terminal would be the same as Alternative 1a. The Pile Bay ferry terminal area would be on Jurassic igneous rocks and possibly isolated glacial beach deposits (Detterman and Reed 1973, 1980).

Construction Material Sources

Material sources for construction of the transportation corridor from the mine site to the Eagle Bay ferry terminal would be supplied by material sites in mostly glacial deposits (Detterman and Reed 1973). Construction of the transportation corridor between Williamsport and Diamond Point might also use bedrock that would be removed (excavated or drilled/blasted) to support construction of the roadbed (Detterman and Reed 1980; Wilson et al. 2015).

3.13.6.3 Diamond Point Port

The geology of Diamond Point port is mapped as Jurassic igneous intrusive rocks (Detterman and Reed 1980; Wilson et al. 2015). Construction of a port facility at Diamond Point would likely require drilling and blasting.

3.13.6.4 Natural Gas Pipeline Corridor

The pipeline would originate on the Kenai Peninsula as described for Alternative 1a, cross beneath Cook Inlet, and make landfall on the shore of Ursus Cove. The corridor would then follow a possible geological bedding and/or linear structural feature that is largely overlain by glacial deposits between Ursus Cove and Cottonwood Bay. Then the corridor crosses Cottonwood Bay to Diamond Point. Cretaceous to Jurassic igneous and volcanic rocks are mapped in the bedding/ structural feature between Ursus Cove and Cottonwood Bay (Detterman and Reed 1973, 1980).

In Cook Inlet, the Alternative 2 pipeline segment would diverge from the Alternative 1a route about midway from Anchor Point to the west across the inlet; it would be routed north of Augustine Island then north to the landfall on the shore of Ursus Cove. The lease sale (Lease Sale 244) area described in BOEM (2016a) includes the area of the Alternative 2 pipeline corridor that diverges from the Alternative 1a pipeline corridor. Based on the description of geology for this area in BOEM (2016a), the seafloor sedimentary deposits are similar to those described for the Alternative 1a pipeline corridor and include fine- to medium-grained sand sculptured into bedforms. Sediment distribution is shown in Figure 3.18-9 (see Section 3.18, Water and Sediment Quality). Based on bathymetric features and geologic trends, scattered areas of outcropping rock may occur at the seafloor in the vicinity of Augustine Volcano and Ursus Cove (Figure 3.16-6).

Between Cottonwood Bay and Pile Bay, the geology of the pipeline corridor is the same as the geology of the transportation corridor. From Pile Bay to near Pedro Bay, the corridor is underlain by mostly Cretaceous to Jurassic igneous rocks (Detterman and Reed 1973, 1980).

From Pedro Bay to the western portion of Knutson Bay, the geology mostly consists of surficial glacial deposits and bedrock similar to those found near Pedro Bay. From Knutson Bay to the mine site, the geology consists of surficial glacial deposits similar to the geology of Alternative 1a from the Eagle Bay ferry terminal to the mine site (Detterman and Reed 1973, 1980).

3.13.7 Alternative 2—Summer-Only Ferry Operations Variant

The Summer-Only Ferry Operations Variant is not relevant to geology affected environment and is therefore not addressed in this section.

3.13.7.1 Alternative 2—Pile-Supported Dock Variant

Marine sediments at the Amakdedori port site that are relevant to the Pile-Supported Dock Variant are addressed above under Alternative 1, Amakdedori port.

3.13.7.2 Alternative 2—Newhalen River North Crossing Variant

The geology of the Newhalen River North Crossing Variant would be similar to the south crossing under Alternative 1a.

3.13.8 Alternative 3—North Road Only

3.13.8.1 Mine Site

The geology and construction materials would be the same as those for Alternative 1a.

3.13.8.2 Transportation Corridor

The geology of the road from the mine site to near the western portion of Knutson Bay consists of surficial glacial deposits, similar to the geology of the Alternative 2 transportation corridor to the Eagle Bay ferry terminal (Figure 3.13-4). From Knutson Bay to Pedro Bay, the geology mostly consists of surficial glacial deposits and then bedrock, including Cretaceous and Jurassic igneous rocks.

From Pedro Bay to Pile Bay, the geology consists of Cretaceous and Jurassic intrusive igneous rocks. From the Pile Bay to the Diamond Point port site, the transportation corridor would largely follow the existing road, as described under Alternative 2 (Detterman and Reed 1973, 1980).

3.13.8.3 Diamond Point Port

The geology and construction material sources for the Diamond Point port site (north of Diamond Point) would be similar to Alternative 2, except the Alternative 3 location is essentially all bedrock composed of Cretaceous and Jurassic igneous rock.

3.13.8.4 Natural Gas Pipeline Corridor

The geology and construction material sources would be similar to those for Alternative 2. The pipeline landfall under Alternative 3 would be north of Diamond Point.

3.13.8.5 Alternative 3—Concentrate Pipeline Variant

The concentrate pipeline corridor from the mine site to the port would follow the same alignment as for Alternative 3; therefore, the geology would be the same.

3.14 SOILS

This section describes the soil types in the project area, and evaluates project disturbance/ removal, susceptibility to erosion, and soil chemical quality. In addition, soil conditions such as permafrost and soil impairment from contaminated sites are briefly addressed in this section. Descriptions of unconsolidated overburden at the mine site and other project components are provided in Section 3.13, Geology; and Section 3.15, Geohazards and Seismic Conditions. 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.

3.14.1 De Minimis/Insignificant Soil Conditions

Some soil conditions that may be important in other areas of Alaska have minimal presence in the project area, as described below.

3.14.1.1 Permafrost

Permafrost is soil that is permanently frozen. This condition can cause problems during development because changes to the overlying vegetation can cause a thermal disturbance to this condition, resulting in melting and erosion.

To date, investigations in the project area (including all project components) have not reported widespread permafrost. Small patches of permafrost may occur in the project area; however, occurrence is presumed to be relict permafrost from prior glacial periods (Knight Piésold 2011b). Recorded variations in ground temperature at depth in the mine site study area do not support the presence of permafrost, based on measured mean annual ground temperatures above freezing (39.1 degrees Fahrenheit [°F]). Recorded groundwater temperatures from the deposit area were also above freezing throughout the year. Although such conditions do not preclude the occurrence of small localized areas of permafrost, current conditions do not support permafrost development or wide-spread occurrence. Additional technical discussion regarding potential permafrost occurrence in the study area is provided in Appendix K3.14.

3.14.1.2 Soil Impairments

A review was conducted of the Alaska Department of Environmental Conservation (ADEC) Contaminated Sites Program database (ADEC 2018d), which lists known contaminated sites and leaking underground storage tanks throughout Alaska. The database provides information regarding the type of contaminant released to the environment, the type(s) of media (e.g., air, water, soil, and rock) affected by the contaminant, the potential responsible party for the documented release, and the location where the release occurred. No contaminated site records coincided with or were in proximity to the project footprint.

3.14.2 Alternative 1a

3.14.2.1 Mine Site

Available Soil Information

Available literature directly associated with the mine site and transportation corridor components for all alternatives is limited to the US Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS; formerly known as the Soil Conservation Service) 2016 Soil Survey

Geographic Database (SSURGO) for the Bristol Bay-Northern Alaska Peninsula, North and Bordering Areas (NRCS 2019), and the Exploratory Soil Survey of Alaska (ESS) (Rieger et al. 1979). Literature provided by the NRCS generally covers a variety of baseline soil data intended to assist in land resource planning and management, including classifications based on soil taxonomy, drainage, slopes, vegetative growth potential, and suitability for various land uses and development.

The ESS is not sufficient for site-specific interpretation, but is useful as a general soils map. Although some soils information provided in the ESS does not translate directly to current classification system standards, comparative equivalent soil type estimates can be made. Technical information regarding soil types in the project footprint is provided in Appendix K3.14.

Soil Types

Soils at the mine site are generally acidic, gravelly, and formed from volcanic source rocks. Most of the mine site area (approximately 69 percent) is associated with soil map unit D36MTG that consists of hilly to steep terrain that supports vegetation such as alder, grasses, or low shrubs in a thin surface cover of decomposed plant material and organic silt loam. Shallow surface materials overlie gravelly silt loam mixtures which are underlain by extremely stony loam mixtures and bedrock (25 to 67 inches). Approximately 25 percent of the mine site area is associated soil map unit D36HIL that consists of hills and plains landscape. Typical profile characteristics for these soils include a thin surface layer of moderately decomposed plant material and highly organic silt loam over sandy and silty loam mixtures. Approximately 6 percent of the mine site area is associated with soil map unit D36HIJ that consists of highly organic soil conditions associated with a plains landscape. Typical profile characteristics for these soils include peat and mucky peat over very fine sandy loam mixtures. Physical properties and detailed descriptions of soil types and distribution present at the mine site are provided in Appendix K3.14.

Erosion

Erosion resulting from surface and subsurface soil disturbances would be attributed to both wind and hydraulic processes. Numerous conditions can influence a soil's susceptibility to wind and hydraulic erosion. Such conditions include weather (e.g., wind, precipitation), season (e.g., ground freeze), soil type (e.g., texture and cohesion), slope angle and length, vegetative cover, and severity of disturbance. In most circumstances, soil disturbances and subsequent exposure would accelerate erosion by wind and water. Finer-grained soil types such as silt and sand are generally more susceptible to erosion than gravels and coarser material. Flowing water over ground surfaces results in hydraulic erosion that also removes and transports soils. Possible consequences of erosion include sediment loading in surface water runoff, and alteration of soil profile characteristics and ecological communities. Downslope movement of surface materials from other slope instability processes (e.g., landslides, solifluction) is addressed in Section 3.15, Geohazards and Seismic Conditions.

With the exception of the limited occurrence of organic-rich soils associated with nearly level topographic conditions, soils at the mine site are generally well drained to moderately well drained with no ponding or flooding. Soils associated with the most prevalent soil map unit (D36MTG) are the least susceptible to the hydraulic erosion process; however, prevalent silt and sandy loam mixtures associated with soil map units D36JIL and D36HIL are more susceptible to sheet and rill erosion from water. The variability in hydraulic erosion potential for these soil types would be influenced by the conditions described above (e.g., slope, weather, and severity of disturbance). Furthermore, soils at the mine site are considered to have a moderate to low susceptibility for wind erosion potential.

Soil Chemistry

A baseline soil chemistry description is provided for the mine site to compare anticipated effects resulting from the deposition of fugitive dust from sources of concern. Fugitive dust sources of concern at the mine site include mining operations; material (e.g., rock) storage, processing, and handling (including concentrate); tailings storage; and repurposing materials derived from the mine site (e.g., aggregates).

The baseline soil chemistry evaluation is exclusive to the mine site. Further evaluation of limited upland soil chemistry baseline data for the transportation corridor and natural gas pipeline corridor was not conducted because neither of these components is considered to have mechanisms or chemical sources that could result in adverse impacts to soil (see Section 4.14, Soils). Furthermore, the limited upland soil chemistry data for the transportation corridor and natural gas pipeline corridor are chemically consistent with those described for the mine site study area (SLR et al. 2011a).

To establish baseline soil chemistry conditions at the mine site, more than 200 shallow surface soil samples (i.e., less than 0.5 foot below ground surface) were collected from a total of 117 locations (SLR et al. 2011a). The samples were analyzed to determine the variability in naturally occurring constituents (NOCs), which included trace elements, hydrocarbons, total carbon, cyanide, sodium, and ions. Sample analytical results and more detailed discussion are provided in Appendix K3.14.

All trace elements (mostly metals) evaluated were detected in some of the surface samples. Although reported concentrations of most NOCs were generally low and consistent with undeveloped areas of Bristol Bay drainages, analytical results of some sample locations reported elevated NOCs at levels considered elevated in literature. Variations across up to 16 different landform types and seven different habitat types reportedly influence the ranges of elemental concentrations throughout the study area (SLR et al. 2011a).

Iron and aluminum are the most abundant elements reported throughout the mine site study area surface soils, followed by calcium and magnesium. Concentrations of other trace elements are substantially lower. Trace elements with the lowest average concentrations include mercury and silver. The relative distribution of trace elements in the mine site study area surface soils is generally consistent with those reported across the US, based on published US Geological Survey (USGS) evaluations. Comparison of co-located shallow subsurface soil sample results (18 inches in depth) reported similar relative and mean concentrations of trace elements; however, less variability among sample locations was observed (where present). Notable deviations include those associated with bismuth and mercury. The mean concentration of bismuth in surface soil is approximately 13 times greater than concentrations for deeper soils. The mean concentration of mercury in surface soils is almost two times greater than concentrations for subsurface soil (SLR et al. 2011a).

Because arsenic, copper, and lead are considered key trace elements associated with the deposit, additional depth-based and temporal (i.e., yearly) statistical tests were performed to identify differences. The statistical tests identified no significant[1] differences in depth-based or temporal variables (SLR et al. 2011a).

[1] The term "significant" is used correctly as it applies to statistical testing, p-value.

3.14.2.2 Transportation Corridor and Amakdedori Port

Soil Types

Because almost all of the land-based portions of the natural gas pipeline corridor on the western side of Cook Inlet would be buried in the roadbed of the transportation corridor, soil types for both the transportation corridor and natural gas pipeline corridor for all alternatives are collectively described in this section, in addition to those present at the Amakdedori port site. This discussion also includes the pipeline-only segment for Alternative 1a, from Iliamna Lake near Newhalen to the mine access road.

Soil descriptions available through SSURGO for the transportation corridor are limited to areas in proximity to the mine site. Soil map units and corresponding acreages associated with these portions of transportation corridor for all alternatives are as follows:

- D36MTG Western Maritime Mountains—approximately 87 acres
- D36HIL Western Maritime Glaciated Hills and Plains—approximately 82 acres
- D36HIJ Western Maritime Eolian Plains, Sloping—approximately 9 acres

Based on soil-type descriptions provided in the ESS, approximately 60 percent of the soil types associated with the transportation corridor footprint are the same as those described for the mine site. Most of the remaining acreage consists of varying sand, silt, and clay mixtures (i.e., loam) over shallow bedrock or gravel till materials. The soils are generally well-drained and occur in variable terrain, of which hilly and mountainous terrain and shallow bedrock are most prevalent south of Iliamna Lake along the port access road. A limited occurrence (13.5 acres) of poorly drained organic-rich muskeg soils also coincides with the transportation corridor. Soil type distribution and additional details are provided in Appendix K3.14.

The Amakdedori port site is generally level and includes upland (shore-based) soil types that transition seaward to intertidal dunes and a gravel-lined shoreline. ESS soil types associated with the Amakdedori port site and immediate area are limited to loamy upland soils with hilly to steep associations.

Erosion

The ESS does not provide wind and water erosion descriptors (i.e., suitability ratings) for all soil types; where present, they are limited to unique physical conditions or soil types. None were listed for map units corresponding to the transportation corridor; however, generalized inferences regarding susceptibility to erosion can be made assuming surface cover would be removed or disturbed. Similar to soil erosion susceptibility descriptions provided for the mine site, silt and sandy loam mixtures would be most susceptible to erosional processes depending on slope gradients, weather, and severity of disturbance in the transportation corridor.

Finer-grained loamy soils over shallow bedrock in hilly or steep terrain are considered to be most susceptible to erosional processes in the transportation corridor (including the Amakdedori port site). This is attributed to the erosional susceptibility of finer-grained materials that overlie bedrock conditions that are generally resistant to erosional processes, and potentially facilitate overland flow. Comparatively increased surface water flow velocities associated with hilly to steep terrain would likely increase the susceptibility of soils to erosion. Soils associated with nearly level terrain are likely the least susceptible to hydraulic erosion in the transportation corridor.

Soil Chemistry

A baseline soil chemistry description is provided for portions of the transportation corridor for comparative evaluation of the same suite of analyses for shallow surface soil samples collected in the mine site study area. Sample analytical results and additional discussion are provided in Appendix K3.14.

Seventeen baseline surface soil samples were collected from Bristol Bay drainage uplands along the transportation corridor route that most approximates the north access road associated with Alternative 3—North Road Only. Six (of 17 total) baseline soil sample locations coincide with the transportation corridor associated with Alternative 1a from the mine site to the Eagle Bay ferry terminal and are also representative of the northern pipeline-only segment from Iliamna Lake to the mine access road.

The hierarchy of trace element mean concentration trends were similar to those in the mine site study area; however, in all circumstances, trace element mean concentrations were lower. Comparisons of trace element values to those documented at the mine site indicate less mineral-rich soil conditions in the transportation corridor. Mean concentrations of iron (8,986 milligrams per kilogram [mg/kg]) and aluminum (8,281 mg/kg) were the highest, followed by calcium (2,491 mg/kg), magnesium (977 mg/kg), and potassium (238 mg/kg). The hierarchy is reportedly consistent with a variety of soil types (SLR et al. 2011a). Although Coefficient of Variation (CV) ranges for trace elements in the transportation corridor were greater than the mine site, the average CV for all trace elements was substantially less (SLR et al. 2011a).

Because only one sample was collected and analyzed for Diesel Range Organics (DRO), Residual Range Organics (RRO), and Total Organic Carbon (TOC), no comparison of mean values to the mine site study area was conducted. Reported concentrations of DRO, RRO, and TOC were 1,520 mg/kg, 9,220 mg/kg, and 18.20 percent, respectively. The elevated concentrations are representative of naturally occurring organic presence in a moist tundra/shrub habitat type.

3.14.2.3 Natural Gas Pipeline Corridor

Soil Types

Because the natural gas pipeline on the eastern side of Cook Inlet would predominantly incorporate existing infrastructure, potential soil disturbances directly associated with the project would be limited to the horizontal directional drilling (HDD) work area and compressor station area. The most detailed resource for soil data in this area is the USDA NRCS Soil Survey of Western Kenai Peninsula Area, Alaska. Available NRCS data for the area include a land capability classification, which provides a general suitability index for agriculture or farming (USDA 2005). Soils in the footprint are considered to have severe limitations for these purposes.

Two detailed soil map units coincide with approximately 6 acres of pipeline footprint ground disturbance on the eastern side of Cook Inlet. The soils consist of silt and sand mixtures (i.e., silt loam). Additional details for soils associated with the pipeline infrastructure on the eastern side of Cook Inlet are provided in Appendix K3.14 along with descriptions of all soil types associated with project alternatives and variants. This includes soil types for pipeline-only segments on the western side of Cook Inlet, which also correspond to those associated with transportation infrastructure (i.e., no soil types unique to pipeline-only segments).

Erosion

Soils in the pipeline infrastructure footprint on the eastern side of Cook Inlet predominantly consist of silt and sand mixtures (i.e., silt loam) along slope angles ranging from 0 to 4 percent. The soil is poorly to well-drained, with no flooding or ponding. The soils have a severe susceptibility to wind erosion, assuming disturbance and removal of surface cover, and a “slight” water erosion hazard.

Soil Chemistry

Soil chemistry information for the pipeline corridor on the northern side of Iliamna Lake is addressed above, including the transportation corridor associated with Alternative 1a from the mine site to the Eagle Bay ferry terminal, which is also representative of the northern pipeline-only segment from Iliamna Lake near Newhalen to the mine access road.

3.14.3 Alternative 1

3.14.3.1 Mine Site

Soil types, erosion, and soil chemistry at the mine site would be the same as those under Alternative 1a.

3.14.3.2 Transportation Corridor and Amakdedori Port

The soil, erosion, and soil chemistry for the transportation corridor would be similar to Alternative 1a. Soil characteristics at Amakdedori port would be the same as those under Alternative 1a.

3.14.3.3 Natural Gas Pipeline Corridor

The soil, erosion, and soil chemistry tor the pipeline corridor would be the same between Amakdedori port and the south ferry terminal at Kokhanok as those under Alternative 1a, and similar to Alternative 1a on the northern side of Iliamna Lake.

3.14.3.4 Alternative 1—Summer-Only Ferry Operations Variant

The Summer-Only Ferry Operations Variant would necessitate additional project footprint to store and manage concentrate (see Chapter 2, Alternatives). The soils descriptions provided in this section address the locations where surface soils may be affected by increased project footprint.

3.14.3.5 Alternative 1—Kokhanok East Ferry Terminal Variant

This area is east of the south ferry terminal site. Soil conditions at the south ferry terminal include soils that are common to the transportation corridor, but are exclusive to (13.5 acres) varying sand, silt, and clay mixtures (i.e., loam) over shallow bedrock or gravelly glacial till materials.

3.14.3.6 Alternative 1—Pile-Supported Dock Variant

This variant would not cause change in the land footprint of Alternative 1; therefore, soils are the same as those described under Alternative 1.

3.14.4 Alternative 2—North Road and Ferry with Downstream Dams

3.14.4.1 Mine Site

The downstream dams would necessitate increased project footprint. Soils in the mine site area, described above under Alternative 1a, address the locations where surface soils may be affected by increased project footprint.

3.14.4.2 Transportation Corridor and Diamond Point Port

This section addresses the road and pipeline corridor from the mine site to Diamond Point port site.

Soil Types

The soil types along the transportation corridor from the mine site to Eagle Bay ferry terminal are the same as those under Alternative 1a.

Approximately one-half of the transportation corridor footprint and Eagle Bay ferry terminal under Alternative 2 consist of the same ESS soil types as those described for the mine site under Alternative 1a. Approximately one-third of the Alternative 2 transportation corridor footprint and Pile Bay ferry terminal footprint consist of well-drained soils on foot slopes associated with hilly to steep terrain. The shallow soils are formed in silty volcanic ash (10 to 24 inches thick) overlying very gravelly glacial till. The appreciable presence of variable silt and sandy loam soil mixtures throughout the corridor would be anticipated. Based on generalized ESS descriptions, the remaining area in the transportation corridor consists of rough mountainous land along steep rocky slopes overlying shallow bedrock and boulder-sized rock fragments. Less than 1 percent of the total footprint consists of silty loess (20 to 40 inches) over gravelly glacial till to fibrous organic soils in depressions. These soils are associated with level or nearly level terrain and range from well-drained to very poorly drained soils. Additional soil type details are provided in Appendix K3.14.

Erosion

Soils associated with nearly level terrain are likely the least susceptible to hydraulic erosion in the transportation corridor. Soils considered most susceptible to erosion include those with finer-grained textures (e.g., volcanic ash, silt and sandy loam mixtures) that are associated with hilly to steep terrain. This is attributed to the erosional susceptibility of finer-grained materials and comparatively increased surface water flow velocities associated with hilly to steep terrain.

Coarse-grained soil textures or shallow bedrock in rough mountainous terrain should not preclude the potential for erosion susceptibility or location-specific conditions where erosion may be comparatively greater. Enhanced design or stabilization measures may be required on a case-by-case basis to mitigate steep side slopes, cross-slope toe-cuts, or slope failure. Erosion associated with potential high-energy environments in mountainous terrain includes, but is not limited to, increased surface water runoff flow velocities, up- or down-slope failure (e.g., slumping, washout), or impacts to infrastructure from natural process (e.g., landslides). Because the ESS is broadly based and is not intended to be used for site-specific information, general terrain conditions (e.g., topography) are considered in Section 4.14, Soils.

Soil Chemistry

Soil chemistry information for the natural gas pipeline corridor on the northern side of Iliamna Lake is addressed above.

3.14.4.3 Natural Gas Pipeline Corridor

This section addresses the overland portion of the natural gas pipeline corridor (Diamond Point to 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 5.5 miles of uplands pipeline along this segment coincide with shallow bedrock and coarse soil textures (e.g., boulder and cobble) in rough mountainous terrain; however, it is likely that appreciable gravel/sand-bearing colluvium is present along the valley floor. The pipeline from the port would follow a shared road corridor towards the Pile Bay ferry terminal.

3.14.4.4 Alternative 2—Summer-Only Ferry Operations Variant

Baseline soil characteristics are the same as described under this variant in Alternative 1.

3.14.4.5 Alternative 2—Pile-Supported Dock Variant

This variant would not cause change in the land footprint of Alternative 2; therefore, soils are the same as described under Alternative 2.

3.14.5 Alternative 3—North Road Only

The occurrence and distribution of soil types and terrain under Alternative 3 are generally the same as Alternative 2. The primary difference between Alternative 2 and Alternative 3 is a shared overland transportation and pipeline infrastructure under Alternative 3, and absence of ferry terminal infrastructure.

3.14.5.1 Alternative 3—Concentrate Pipeline Variant

The concentrate pipeline under this variant would follow the same corridor as the north road and natural gas pipeline corridor. The soil characteristics are the same as described for the north access road corridor for Alternative 3.

3.15 GEOHAZARDS AND SEISMIC CONDITIONS

This section provides information currently available regarding seismic and other geological hazards (geohazards) in the vicinity of the project. Geohazards include tectonic processes (e.g., earthquakes, volcanoes), surficial or geomorphological processes (e.g., landslides) and other hazards (e.g., ice effects, erosion, tsunamis). Regional-scale descriptions of the geohazards are presented in this section, enhanced with local information gathered from geotechnical engineering studies where available. The project area is in a region of active tectonic processes, and the potential for multiple types of geohazards across the project area depends on location, topography, natural materials present, and proximity to hazard sources. The Environmental Impact Statement (EIS) analysis area for geohazards ranges from the immediate vicinity of the project footprint for each alternative (e.g., slope instability) to regional areas with geohazards that could affect project facilities from long distances (e.g., earthquakes, volcanoes).

3.15.1 Earthquakes

3.15.1.1 Active Faults

The project is in a tectonically active region of southern Alaska near the subduction zone between the Pacific and North American plates. Both shallow crustal earthquakes and deeper earthquakes associated with the subduction zone megathrust affect this region. A description of the regional tectonic setting is provided in Section 3.13, Geology.

In general, faults that have demonstrated geologic displacement and earthquakes during the Holocene epoch (the last 11,000 years) are considered to be active, and have potential for future movement. Evidence for fault activity might include offset surface features (such as stream channels), sag ponds along a fault, surface vegetation changes, lineaments depicted by remote sensing data, and subsurface seismicity (earthquake record) aligned with a certain fault. In the absence of surficial evidence, subsurface seismicity could indicate the presence of an active buried fault such as a low-angle blind thrust.

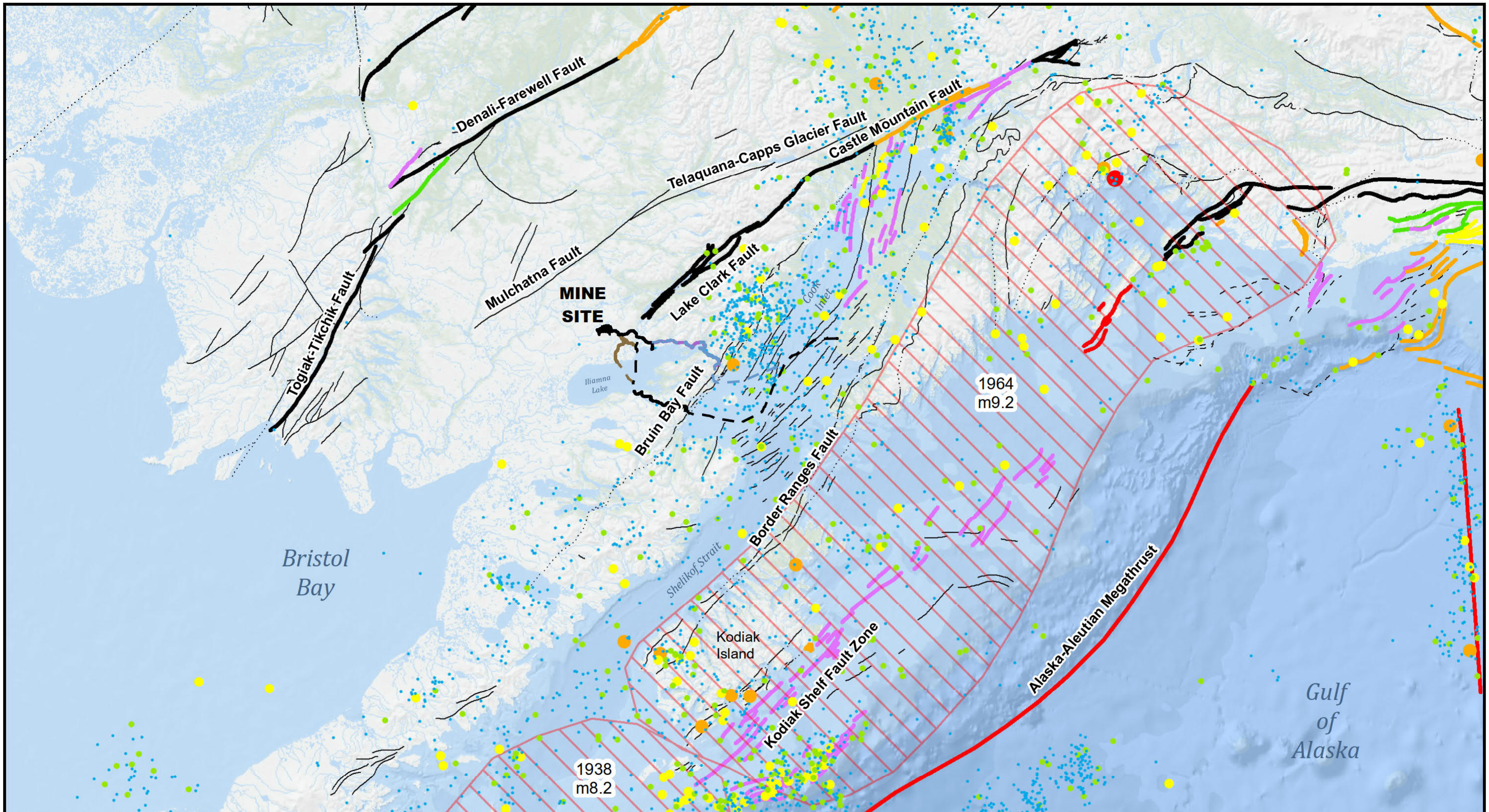
Earthquake hazards generally increase with the magnitude (M) of the event, proximity to the site, and fault length. The likelihood of fault movement is typically described in terms of average recurrence interval or return period (i.e., how often the fault is expected to generate a large earthquake based on field evidence and past seismic record). This is described below under "Ground Shaking," and in Section 4.15, Geohazards and Seismic Conditions, and Appendix K4.15 as applied to project facilities. Active and suspected or potentially active faults in the project area are shown on Figure 3.15-1, and include the following:

- The closest active surface fault to the project area is the northeast-trending Lake Clark-Castle Mountain Fault, which has been mapped at the surface to about 14 miles northeast of the mine site at the western end of Lake Clark (Haeussler and Saltus 2004). This fault exhibits evidence of Holocene (about 11,700 years ago to present) activity in the Susitna Valley area, where it is considered capable of a maximum earthquake of M7.1 (Wesson et al. 2007); however, the fault shows no evidence of activity younger than Late Pleistocene (about 126,000 to 11,700 years ago) along the Lake Clark segment southwest of Tyonek (Koehler and Reger 2011). Past studies have suggested the fault may extend farther southwest of Lake Clark based on regional aeromagnetic and gravity data. Several extensions or splays of the fault have been postulated to be as close as 6 miles from the mine site, where the fault is interpreted to dissipate into multiple strands around the Kaskanak batholith, which may have acted as a buttress to continuation of the fault as a single major strand

(SRK 2008; Knight Piésold 2019d; Rankin 2009; PLP 2019-RFI 139) (Figure 3.15-2). However, field studies in this area have not found evidence of Holocene fault activity on any of the potential splays (Hamilton and Klieforth 2010; Koehler 2010; Koehler and Reger 2011; Haeussler and Waythomas 2011; Knight Piésold 2015a), suggesting they could be erosion and deposition features that perhaps follow weak zones along old fault lines, but are not necessarily active faults. This conclusion is further supported by a review of Light Detection and Ranging (LiDAR) data collected in 2004 in the vicinity of the mine site, which show that no lineaments were observed in surficial deposits that suggest possible fault-related movement southwest of the previously mapped termination point of the Lake Clark fault (AECOM 2018m). Other field studies have shown evidence of repeated paleo-liquefaction events in Holocene to late-Pleistocene surficial deposits southwest of the mine site (Higman and Riordan 2019; PLP 2019-RFI 139), which could suggest earthquake activity on either a buried Lake Clark fault extension, or deeper subduction-related seismicity. Based on the body of evidence to date, Koehler and Carver (2018) conclude that the Lake Clark fault could be active, but with a very low slip rate; the fault remains poorly characterized.

- The Alaska-Aleutian Megathrust, associated with the subduction zone of the Pacific Plate beneath the North American Plate, is responsible for some of the largest earthquakes globally, including the 1964 M9.2 Great Alaskan (Good Friday) Earthquake and 1938 M8.3 Alaska Peninsula earthquake. The megathrust lies at the seafloor more than 200 miles southeast of the project area, and dips northwest beneath the project area. Its 30-mile zone of seismicity ranges from 20 to 50 miles deep beneath the eastern end of the natural gas pipeline corridor to about 90 to 120 miles deep near the mine site (Plafker et al. 1994; Knight Piésold 2015a). The Kodiak and Prince William Sound areas of the megathrust are considered capable of a maximum M9.2 earthquake every 650 years (Wesson et al. 2007).
- Intraslab faults associated with the deeper part of the subduction zone are considered capable of earthquakes in the range of M7+ (Wesson et al. 2007). These are generally of smaller magnitude and occur at greater depth than megathrust earthquakes. Figure K4.15-8 and Figure K4.15-9 show the distribution of earthquakes associated with both megathrust and intraslab faulting. The M7.1 earthquake that struck the Anchorage area on November 30, 2018 was an intraslab event with numerous aftershocks that continue to the present time. Recent large intraslab earthquakes in the Alaska Peninsula and Kodiak area ranged from M6.6 to M7.1, and the largest intraslab earthquake recorded in Alaska was a M7.9 in the western Aleutians (Knight Piésold 2019d).
- The Denali-Farewell Fault, about 120 miles northwest of the project area, was the source of the 2002 M7.9 Denali earthquake that originated along the central part of the fault in Interior Alaska. The westernmost extension of this fault system, called the Togiak-Tikchik Fault, about 140 miles west of the mine site, exhibits evidence of mid-Quaternary activity. Although evidence of Holocene activity along the western part of the fault is limited compared to that of Interior Alaska, it is considered capable of generating large earthquakes in the range of M7.5 to M8.0 (BGC 2011; Knight Piésold 2015a).
- The Telaquana-Capps Glacier and Mulchatna faults are about 40 miles north and northwest of the mine site, respectively (Haeussler and Saltus 2004; Gillis et al. 2009). Evidence of Holocene activity along these faults has not been established. If active, they are considered capable of maximum earthquakes in the range of M6.0 to M7.0 (Knight Piésold 2015a).

- The Bruin Bay Fault extends along the western shore of Cook Inlet near the Amakdedori and Diamond Point port sites. Although the surface expression of the Bruin Bay Fault shows no evidence of movement since the Neogene (about 24 to 1.8 million years ago) (Detterman et al. 1975), this fault is near an area of seismicity north of Iniskin Bay where several deep, small to moderate earthquakes occurred up to M7.3 in 1943 (Stevens and Craw 2003). Several faults and lineaments trending sub-parallel to the Bruin Bay Fault have been mapped in bedrock west of the Bruin Bay Fault along drainages northeast of Iliamna Lake, such as the Iliamna and Pile Bay rivers. These do not exhibit offset of Quaternary deposits (Detterman and Reed 1980; Nelson et al. 1983).
- Several fault-cored folds in Upper Cook Inlet show evidence of Quaternary activity and possible bending of the seafloor. The closest of these lies about 130 miles east of the mine site and 10 miles north of the eastern end of the pipeline corridor. These structures are considered capable of generating earthquakes up to M6.8 (Haeussler et al. 2000). Recent activity has not been documented on similar folds and faults in Lower Cook Inlet near the Amakdedori port and natural gas pipeline corridor underwater crossing (Haeussler and Saltus 2011; Koehler et al. 2012).
- The Kodiak Shelf fault zone, composed of a series of northeast-trending faults, lies in the upper plate of the subduction zone. These faults, about 120 miles southeast of the closest project components, show geomorphic evidence of Holocene activity, and are considered capable of earthquakes up to M7.5 (Wesson et al. 2007; Carver et al. 2008).
- The level of activity on the Border Ranges Fault, extending northeast through Kodiak Island and Kenai Peninsula, is controversial, and evidence is limited (Stevens and Craw 2004). Although it has not exhibited definitive surficial evidence of movement since the Paleogene to early Neogene (about 65 to 24 million years ago with no record of younger activity) (Plafker et al. 1994), it extends through an area with extensive Pleistocene glaciation that may have removed or buried evidence. MacKevett and Plafker (1974) have suggested that ground breakage near the fault during the 1964 earthquake was related to a buried inferred trace of the fault. It contains a 3- to 6-mile shear zone that is considered by some to be capable of a future earthquake in the range of M7.0 (Knight Piésold 2015a; Suleimani et al. 2005).
- Several faults have been mapped at the mine site that offset bedrock only, with no evidence of Holocene activity (see Figure 3.17-11). These faults are interpreted to have been active between 90 and 40 million years ago (Cretaceous to Paleogene), before a change in tectonic plate direction caused long strike-slip faults such as the Lake Clark-Castle Mountain and Denali faults to develop. There is no direct relationship between these faults and the Lake Clark fault zone or its splays (SRK 2008; PLP 2019-RFI 139).
- Shallow crustal faults can be capable of background earthquakes even in the absence of associated historical seismicity. Studies suggest that earthquakes as large as M6.5 could occur at relatively shallow depths and not result in significant surface evidence (dePolo 1994; Knight Piésold 2019b).



Sources: PLP 2020-RFI168; PLP 2019-RFI153; USGS 2020a; Koehler 2013; Haeussler and Saltus 2004; Plafker et al. 1994

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Earthquake Magnitude 1900 - 2019

- 4.0 - 4.9
- 5.0 - 5.9
- 6.0 - 6.9
- 7.0 - 7.9
- 8.0 +
- Rupture Zone of Megathrust Earthquake

Fault Activity (Age of Most Recent Surface Deformation)

- Historical, <150 yrs
- Latest Pleistocene and Holocene, <15,000 yrs
- Latest Quaternary, <130,000 yrs
- Mid-Quaternary, <750,000 yrs
- Quaternary, <1,600,000 yrs
- Questionable, Class B
- Pre-Quaternary Fault

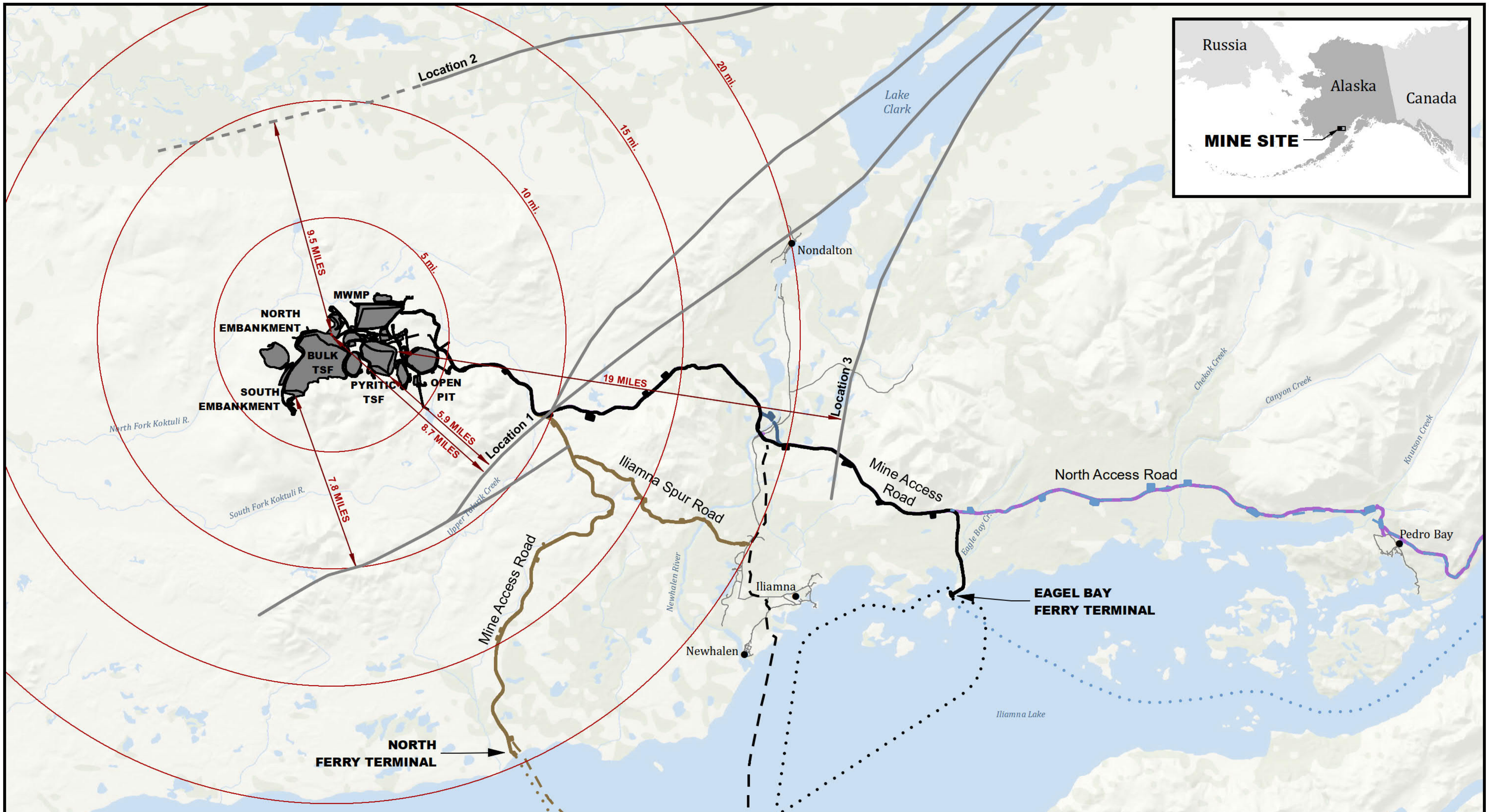
Action Alternatives

- Natural Gas Pipelines
- Alternative 1a
- Alternative 1
- Alternative 2
- Alternative 3

EARTHQUAKES AND ACTIVE FAULTS

PEBBLE PROJECT EIS

FIGURE 3.15-1



Sources: PLP 2020-RFI168; PLP 2019-RFI153;
PLP 2019-RFI139; Knight Piesold (2019d)

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Possible Fault Extension
Hypothetical Extension

Action Alternatives

Ferry Routes
Natural Gas Pipelines
Alternative 1a
Alternative 1
Alternative 2
Alternative 2 Newhalen River North Crossing Variant
Alternative 3

Other Features

Local Roads

POSSIBLE EXTENSIONS OF LAKE CLARK FAULT NEAR MINE SITE

PEBBLE PROJECT EIS

FIGURE 3.15-2

3.15.1.2 Ground Shaking

Earthquake-induced ground shaking is typically expressed in terms of peak ground acceleration (pga), measured as a fraction of gravity (g), with a probability of exceeding a certain level over a specific period of time in the future. For example, a pga of 0.1g in bedrock is considered the approximate threshold at which damage occurs in buildings that are not specially constructed to withstand earthquakes (Arnold 2006). An earthquake with a 10 percent probability of exceedance in 50 years (about a 500-year return period) is the most common event used in building codes for seismic design (e.g., Gould 2003). Larger, more infrequent seismic events, such as those between a 2,500-year return period earthquake (a 2 percent probability of exceedance in 50 years) and a 10,000-year event or maximum credible earthquake (MCE), are typically used for design of critical structures such as dams (ADNR 2017a; CDA 2014).

Ground shaking prediction in Alaska has been studied both regionally by the US Geological Survey (USGS) (Wesson et al. 2007) and for the project area by Knight Piésold (2011c, 2015a, 2018c, 2019d). Based on published USGS data for the 2,500-year event, Figure 3.15-3 depicts a general trend from high ground shaking near the subduction zone offshore of Kodiak to less ground shaking farther inland. Predicted ground shaking for the 2,500-year event ranges from a pga of about 0.3g near the mine site to 0.6g at the eastern end of the natural gas pipeline corridor. In comparison, predicted ground shaking for a smaller 500-year earthquake ranges from about 0.2g near the mine site to 0.4g at the eastern end of the natural gas pipeline corridor (Wesson et al. 2007). Site-specific seismic hazard analyses conducted for project facilities are discussed in Section 4.15, Geohazards and Seismic Conditions, and Appendix K4.15.

3.15.1.3 Liquefaction

Liquefaction is an earthquake-caused phenomenon that reduces the strength and stiffness of a soil by ground shaking. Where the groundwater table is near surface, or the ground is otherwise saturated, the pore space between soil particles containing water can increase (i.e., increase pore pressure), changing the physical character of the landform and weakening the natural material; in essence, the ground temporarily behaves like a liquid. Liquefaction generally affects unconsolidated, fine-grained sand and silt deposits in lowland areas. The susceptibility of an area to liquefaction is a consideration in design and construction in earthquake-prone areas because the loss of strength of the foundational material can cause structural damage. The potential for liquefaction from ground shaking at the mine site is less for features built where bedrock is near the surface, than in lowland areas underlain by unconsolidated material. A more detailed explanation of liquefaction and implications for the depth of liquefaction in tailings deposits are provided in Appendix K3.15. Locations in the project area believed to be susceptible to liquefaction are described below.

Areas susceptible to liquefaction are typically found along rivers, streams, lake and marine shorelines, and in areas with relatively shallow groundwater. Lateral spread of liquefied soil can occur on gentle slopes or in areas near a free face, such as an incised river channel. Section 3.18, Water and Sediment Quality, provides a description of sediment types in areas of the project that could be subject to liquefaction. These include portions of the mine site with shallow groundwater and fine-grained soils, such as the glacial lake deposits in the eastern part of the mine site (see Section 3.13, Geology), and in project facilities that contain fine-grained saturated tailings (bulk and pyritic tailings storage facilities [TSFs]). Wide stream crossings along the road and pipeline corridors and marine sediment at port sites that contain predominantly sand and silt, such as along the northern portion of the mine access road, protected bays in Iliamna Lake, and Cottonwood and Iliamna bays in Cook Inlet, may be subject to liquefaction.

Sediments with high gravel content are less likely to liquefy. These include beach and lake terrace deposits at the Alternative 1 north ferry terminal, high-energy stream crossings along the port access road and north road route (Alternative 2—North Road and Ferry with Downstream Dams, and Alternative 3—North Road Only) (PLP 2018-RFI 036), and nearshore Kamishak Bay. Marine cores extending up to 3 feet below the seafloor in the Amakdedori dock area contained primarily silty fine to coarse sand with about 20 to 40 percent gravel content (PLP 2018-RFI 039; Intecsea 2019). Likewise, areas underlain by bedrock, such as the Eagle Bay ferry terminal (Alternative 1a) and the incised bedrock and cobble/boulder substrates described at the Newhalen and Gibraltar river crossings (PLP 2020d, e), are not likely to liquefy.

3.15.2 Geotechnical Conditions

Subsurface geotechnical conditions form the basis of foundation design and stability analysis of major structures such as dams, buildings, tanks, facilities, bridges, docks, and fills. Geotechnical conditions important to the analysis of potential geohazard effects on the project are summarized below, including discussion of features (e.g., roads and port sites) described in alternatives and related environmental impacts.

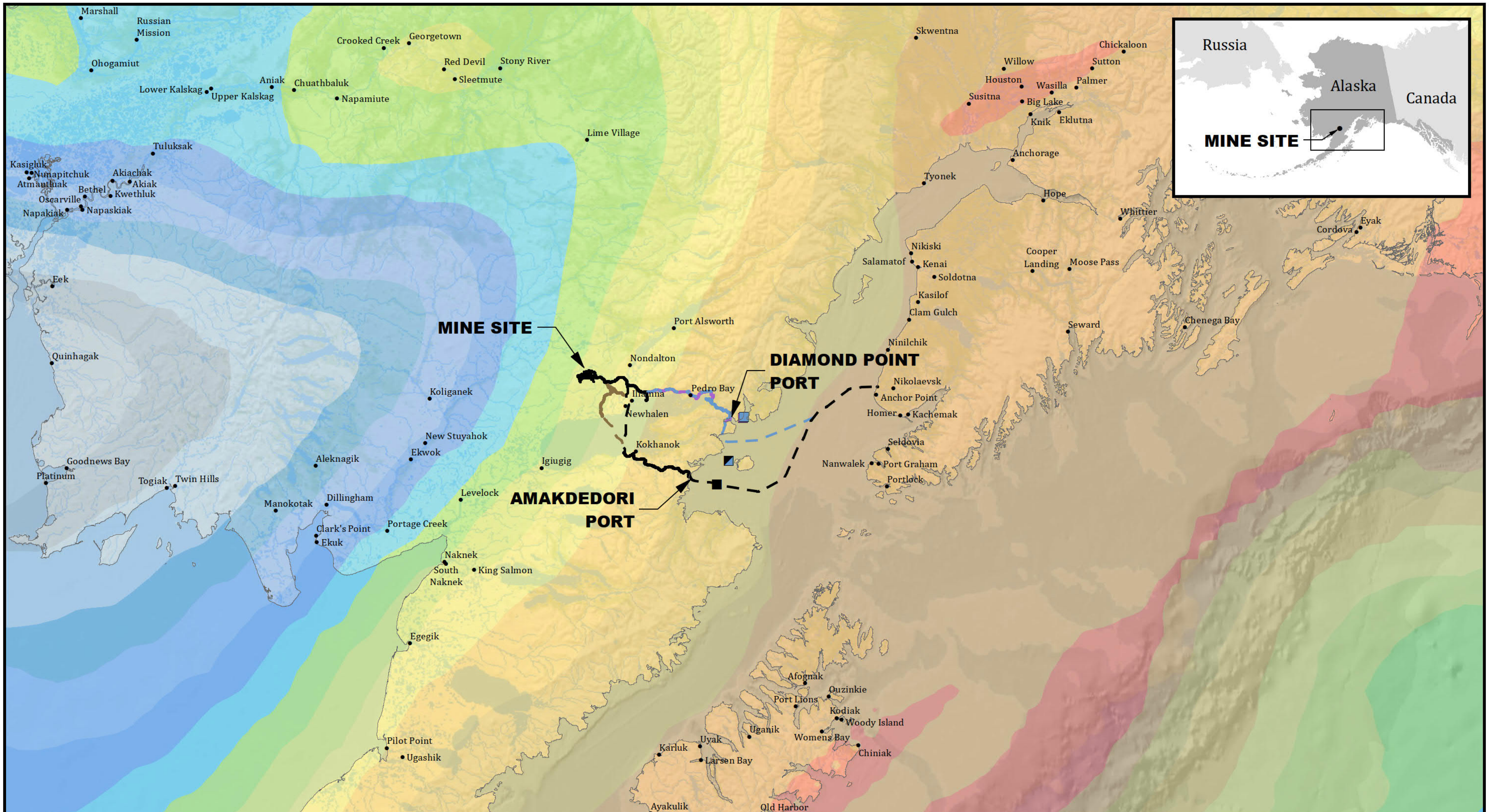
3.15.2.1 Mine Site

Geotechnical data from site-wide geologic reconnaissance and mapping, drill holes, test pits, and geophysical (seismic) surveys were collected at the mine site between 2004 and 2018 (Hamilton and Klieforth 2010; Knight Piésold 2011c; PLP 2013a; PLP 2018-RFI 014; PLP 2019-RFI 014b). Knight Piésold (2011a) divided the mine site into several study areas based on geomorphology and watershed divisions for the purposes of baseline characterization. These areas are listed in Appendix K3.15, along with the number of drill holes, test pits, and seismic survey lines beneath locations of major facilities in each area. As discussed in Section 3.14, Soils, permafrost has not been encountered at the mine site. Geotechnical data locations, the mine site footprint, and depths to moderately weathered bedrock are shown on Figure 3.15-4, as provided in PLP 2018-RFI 014) for 2018 drillholes, and in Knight Piésold (2011c: Appendix 6B and PLP 2019-RFI 014b) for earlier drill holes. In some cases, these depths are below the base of overburden due to the presence of a highly weathered zone in upper bedrock characterized by intense fracturing and frost disturbance (Knight Piésold 2018a).

A summary of geotechnical conditions in each of the mine areas is provided below. A more detailed description of drill holes beneath major embankments is provided in Appendix K4.15, Geohazards and Seismic Conditions, as pertains to potential weak foundation zones.

- **North Fork Koktuli (NFK) West—**Most of the data collected in this north-draining watershed, which contains the bulk TSF, are in the northern part of the watershed, with fewer data points beneath the southern part of the bulk TSF. Overburden deposits consist of frost-shattered angular boulders, glacial drift, and colluvium containing mostly sand and gravel with varying amounts of silt and peat in the valley bottom. Overburden overlies sedimentary, volcanic, or intrusive bedrock in this area. Depths to bedrock are variable; ranging from 3 to 135 feet. Bedrock quality, measured using a Rock Mass Rating (RMR) system on a scale of 0 to 100, with higher numbers representing stronger rock quality (Bieniawski 1989), ranges from 35 to 66 (i.e., poor to good). Weathered bedrock tends to be deeper in the southern part of this area than the northern part.

- **NFK East—**Field investigations in this north-draining watershed that would contain the pyritic TSF and associated seepage collection ponds indicate that depth to bedrock ranges from 3 feet on hilltops to 255 feet in the valley. In the NFK East, bedrock is generally more fractured and has deeper weathering than beneath the bulk TSF area in NFK west. Overburden consists of sand and gravel with variable amounts of silt.
- **NFK North—**This area contains seepage and sediment ponds downstream of the bulk TSF main embankment and the main water management pond (WMP). Overburden consists mainly of alluvial and morainal gravel and sand deposits with glacial lake deposits mapped in the northern half of the main WMP footprint, and morainal ridges in the southern half (Hamilton and Klieforth 2010). Depths to bedrock range from 4 feet to more than 150 feet. Bedrock in this area consists of basalt with RMRs from 52 to 65 (i.e., fair to good).
- **Pit Area—**Geotechnical data in the area of the open pit and rim indicate the presence of overburden consisting of varying mixtures of gravel, sand, silt, and clay of glacial origin, with occasional peat. Depths to bedrock range from about 25 to 150 feet (Knight Piésold 2011c, Figure 6-9). Bedrock types consist primarily of volcanic and sedimentary rock, with average RMRs ranging from 45 to 55 (fair).
- **Bulk TSF South—**The northern portion of this south-flowing watershed contains the footprints of the bulk TSF southern embankment and associated seepage and sediment ponds. Previous investigations indicate depths to bedrock ranging from about 2 to 160 feet, with thicker overburden deposits in the valley bottom consisting of primarily sand and gravel with variable amounts of fines. Bedrock is of similar type and quality to the southern part of NFK west.
- **South of Pit Area—**The northern end of this south-flowing tributary, which drains towards Frying Pan Lake, contains the open pit WMP, pit overburden stockpile, and sediment ponds related to these facilities. Depths to bedrock range from about 25 feet on lower slopes up to 185 feet in the valley. Overburden consists of mostly silty sand and gravel glacial deposits with peat and glacial lake deposits in the valley bottom (Hamilton and Klieforth 2010; Knight Piésold 2011c).



Sources: PLP 2020-RFI168; PLP 2019-RFI153; Wesson et al. 2007

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Action Alternatives

- Lightering Locations
- Natural Gas Pipelines
- Alternative 1a
- Alternative 1
- Alternative 2
- Alternative 3

Peak Ground Acceleration (% g [1])

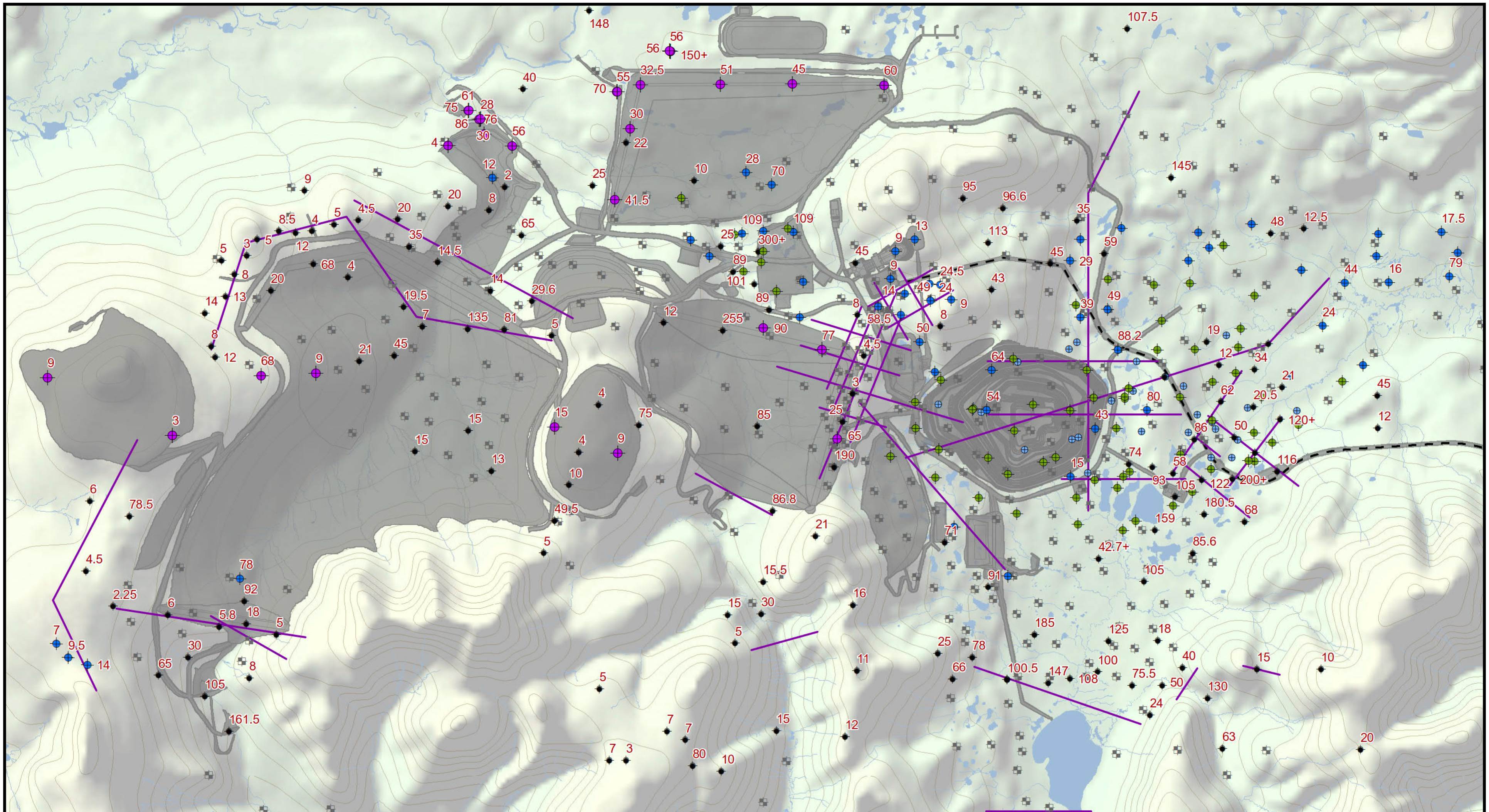
5 - 6	9 - 11	17 - 21	32 - 40	61 - 76
6 - 7	11 - 14	21 - 26	40 - 49	76 - 94
7 - 9	14 - 17	26 - 32	49 - 61	94 - 117

1. Ground shaking expressed as the probability of exceeding a certain amount of peak ground acceleration (PGA), measured in % of gravity (g), over a 2,500-year time period (return period), which is equivalent to a 2% probability of exceedance in 50 years.

SEISMIC HAZARD MAP

PEBBLE PROJECT EIS

FIGURE 3.15-3



Sources: PLP 2019-RFI153; Knight Piesold (KP) 2011c; PLP 2013a; PLP 2018 - RFI 014

Note: 1. For 2004-2008 drillholes, denotes depth to bedrock from KP (2011c) Appendix 6B; for 2010-2018 drillholes, denotes depth to moderately weathered bedrock in KP (2011h, 2012b) and PLP (2018-RFI014; 2019-RFI014b).

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Geotechnical Investigations

- 2004 to 2008 Geotechnical Drillhole
- 2010 to 2012 Geotechnical Drillhole
- 2011 to 2012 Sonic Drillhole
- 2018 Geotechnical Drillhole
- Oriented Geotechnical Drillhole
- Test Pit
- Seismic Line
- 96 Depth to Bedrock (feet)[1]

Alternative 1a

- Natural Gas Pipeline
- Mine Site/Transportation

Other Features

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

GEOTECHNICAL DATA COVERAGE AND DEPTH TO BEDROCK

PEBBLE PROJECT EIS

FIGURE 3.15-4

3.15.2.2 Other Project Components

Surficial deposits, near-surface soils, and stream substrates along the transportation corridor are described in Section 3.13, Geology; Section 3.14, Soils; and Section 3.18, Water and Sediment Quality, respectively. Geotechnical conditions along the northern part of the mine access road would be similar to those described above for the mine site.

Zonge (2017) geophysical data suggest that overburden ranges from 50 to 100 feet thick in the onshore Amakdedori port area. Topographic and stratigraphic relationships in Amakdedori Valley indicate that alluvium, alluvial fan, and beach deposits fill a bedrock-sided valley about 2 miles across between Chenik Mountain to the south, and Peak “1996” to the north. These deposits may extend below sea level in the port area, where valley fill and nearshore delta fan material have been deposited towards the east and southeast, following trends of deepening bathymetric contours between Augustine Island and Douglas Reef (NOAA 2015; PLP 2018-RFI 039).

Geophysical survey data and marine vibracores in the Amakdedori dock area have encountered numerous boulders on the seafloor, likely derived from sloughing of rocky cliffs and ice-raft movement, silty sand and gravel in the subsurface to 3 feet below mudline (maximum depth of core penetration), and possible shallow bedrock about 20 to 30 feet below mudline, likely extending from outcrops to the north (PLP 2018-RFI 039, 2019b, 2020-RFI 160; Terrasond 2019).

Surficial deposits mapped beneath the footprint of the Alternative 2 Diamond Point port site consist of thin alluvial fan deposits on top of shallow bedrock (Detterman and Reed 1973). Offshore deposits in the Diamond Point area, and along the road corridor between Diamond Point and Williamsport, consist primarily of silt and fine sand, with extensive mudflats, buried alluvial gravels, and loose sands in the upper reaches of Cottonwood and Iliamna bays (Knight Piésold 2011f; USACE 2011b). Surficial deposits at the Alternative 3 port facilities are expected to consist of consist of similar material backed by steep bedrock cliffs and rockfall deposits. Subsurface sediments in Iliamna Bay are expected to be composed of more than 70 percent fines, with the remainder sand and gravel. Geophysical data indicate that bedrock in the vicinity of the Alternative 3 dredge channel and dock occurs at a depth of greater than 100 feet (PLP 2020d). Scattered boulders lie on the mudflats, and extensive reefs, shoals, and offshore rocks occur near the entrance to the bays (see Figure 3.18-7) (Pentec Environmental/Hart Crowser and SLR 2011). A combination of marine siltation and tectonic uplift is raising the seafloor near Williamsport at a rate of about 0.3 inch per year (ADNR 2014a).

Site-specific geotechnical information is not available for the eastern landfall pipeline section that is planned to be installed by horizontal directional drilling (HDD) beneath Cook Inlet bluff. The coastal bluff is about 230 feet high at this location; has a relatively steep slope angle of about 1.4H:1V; and is composed primarily of Pleistocene glacial deposits (Reger and Petrik 1993; Karlstrom 1964). A stratigraphic section of the bluff 2 miles south of the pipeline landfall contains sand and gravel with occasional boulders overlying a 50-foot-thick glaciolacustrine clay-silt unit (Reger and Petrik 1993). Perched groundwater is known to seep out of the bluff above similar fine-grained units along eastern Cook Inlet. Neogene sedimentary rocks of the Beluga Formation are exposed in the lower sea cliff several miles further to the south and may underlie glacial deposits at the pipeline landfall in the depth of the HDD. These rocks consist of weakly indurated, interbedded sandstone, siltstone, and shale with thin layers of coal (Reger and Petrik 1993). The potential for slope stability impacts on the project from these deposits is provided in Section 4.15, Geohazards and Seismic Conditions.

3.15.3 Unstable Slopes

Unstable slopes typically occur under combined conditions of steep terrain, heavy precipitation, and certain types of surficial deposits, weathered bedrock, or weak stratified layers. Slope failure can also be triggered by earthquakes. Increased precipitation due to climate change is predicted to occur as rain and snow in the Iliamna Lake and Cook Inlet areas over the next few decades (SNAP 2019), which could locally increase the risk of landslides and avalanches.

Mine Site—The terrain and geomorphology of the mine site consists primarily of gently rolling hills with rounded exposed bedrock hilltops and valleys of glacial deposits with low-angle slopes and mostly low potential for slope instability. Surficial deposits that have the potential to produce unstable slopes occur sporadically around the mine site, and include the following (Hamilton and Klieforth 2010):

- Colluvium, consisting of rock rubble and debris with fines deposited at the base of slopes, may be subject to frost creep and gradual mass wasting slope processes related to freeze-thaw activity (solifluction). These deposits have been mapped throughout much of the bulk TSF footprint: on slopes adjacent to the bulk TSF south embankment, beneath the southern sediment pond, on the western side of the pyritic TSF, beneath several overburden and growth media stockpiles, and in the northeastern corner of the pit area.
- Solifluction deposits, consisting of moderately sloped sheets of stony and organic silt, are subject to gradual downslope movement related to freeze-thaw action. These have been mapped on the eastern side of the pyritic TSF footprint.
- Active talus rubble deposits have been mapped on the northern slope of Kaskanak Mountain (southeastern slope of the bulk TSF).

Transportation Corridors and Port Sites—Small areas of colluvium, solifluction, and steep alluvial fan deposits have been mapped along the western portion of the mine access road alternatives and Iliamna spur road. These occur at the following locations:

- About 2 miles east of the mine site and about 6 miles east of the mine site on the northern side of Koktuli Mountain, both of which are along the portion of the road corridor common to all alternatives
- Near the Iliamna spur road junction of Alternative 1
- Between 3 and 6 miles west of the Newhalen River crossing and along the southern flank of Roadhouse Mountain north of Eagle Bay, which both apply to Alternative 1a, Alternative 2, and Alternative 3 (Detterman and Reed 1973; Hamilton and Klieforth 2010)

Steep alluvial fan, talus, and landslide deposits occur in incised valleys crossed by the eastern portion of Alternative 2 and Alternative 3, along the lake front south of Knutson Mountain, and at the head of Lonesome Bay. The steep slopes and valleys between Pile Bay and Williamsport are well known for landslide and avalanche risks. Talus deposits have been mapped on the south side of Williams Creek near Williamsport (Detterman and Reed 1973). Rockfall is evident along the steep coastal slopes between Williamsport and Diamond Point (INL 2019). Steep alluvial fan deposits have also been mapped at the southern end of the port access road alternatives: about 1 mile north of the Amakdedori port site, and beneath some of the shore-based facilities of the Alternative 2 Diamond Point port site (Figure 3.13-4) (Detterman and Reed 1973).

Pipeline Corridor—Factors that contribute to unstable coastal bluffs near the pipeline landfall on the eastern side of Cook Inlet are described above under “Other Project Components.” The bluffs in this area have a history of erosion problems caused by wave action, tidal currents, groundwater seepage, and overland flow. Bluff retreat estimates range from 0.3 to 0.5 foot per year in lower Cook Inlet near Kachemak Bay, to as much as 3 feet per year near the town of Kenai (Adams et al. 2007; USACE 2007a). The bluffs have experienced gullying, periodic landsliding, and debris flows following major storms (Reger and Petrik 1993; USACE 2008). In particular, a recent arcuate landslide scar on the northern side of the eastern end of the pipeline route is visible on the aerial photograph in Figure 3.17-16. This feature lies within 100 feet of both the Sterling Highway and the pipeline route.

The 1964 Great Alaskan Earthquake caused numerous landslides, rockslides, debris flows, soil slumps, and avalanches along the shoreline of Cook Inlet and slopes of Kodiak Island. The earthquake also caused translational landslides, tension cracks, and earth fissures on the top of bluffs, and rotational slides in Neogene sedimentary rocks, such as those that outcrop along the eastern coast of Cook Inlet (Plafker and Kachadoorian 1966; Waller 1966).

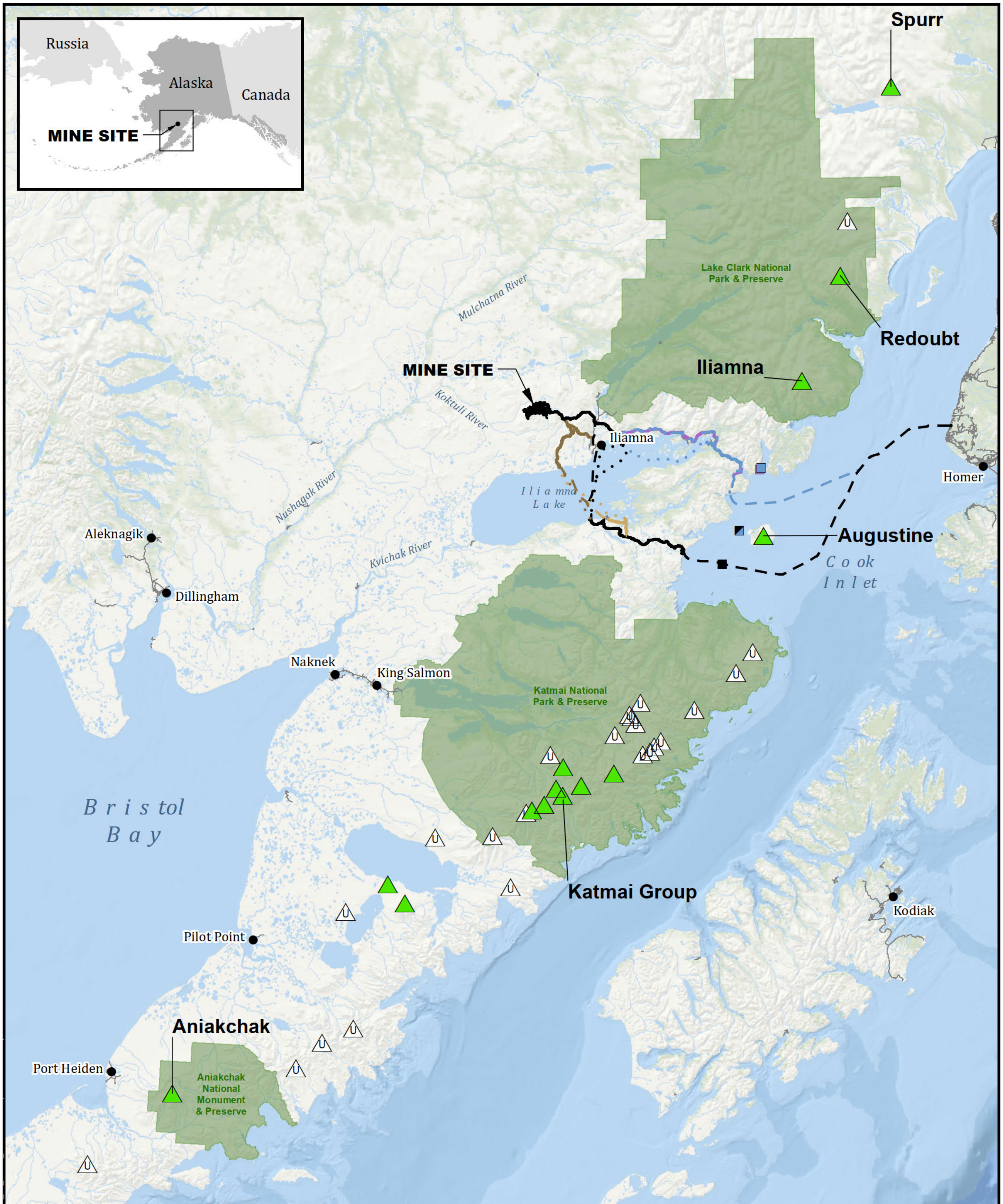
3.15.4 Volcanoes

Alaska contains more than 50 volcanoes considered to be historically active, having erupted in the last few hundred years (Alaska Volcano Observatory [AVO] 2018a). Several are about 100 miles from proposed project infrastructure (Figure 3.15-5), including Mount Augustine, 20 miles east of the Amakdedori port site; Mount Iliamna and Mount Redoubt volcanoes, north of the project area; and a cluster of volcanoes on the northern Alaska Peninsula.

Mount Augustine volcano is the most historically active volcano in the Cook Inlet region. It has erupted seven times since the late 1700s, averaging one eruption every 35 years, and was last active in 2015 (Miller et al. 1998). Past eruptions of Mount Augustine caused ashfall accumulations of up to 0.25 inch on the Alaska and Kenai peninsulas; floating rafts of pumice that interfered with boat traffic in Cook Inlet; and ash clouds that disrupted air travel for hundreds of miles (Waythomas and Waitt 1998). Volcanic debris flows into Cook Inlet are known to occur with an average recurrence interval of about 150 to 200 years (Begét and Kienle 1992). It is estimated that 12 to 14 have reached the sea in the last 2,000 years, with flow paths extending in all directions around the volcano (Figure 3.15-6). Derived from the collapse of summit lava domes and flows, these debris flows consist of rock debris, gravel, sand, and silt (Waitt et al. 1996; Waythomas et al. 2006). Outcropping rock likely associated with Mount Augustine has been mapped at the seafloor between Augustine Island and Amakdedori port site (Intecsea 2019).

Mount Redoubt and Mount Iliamna volcanoes were recently active. Mount Redoubt has had three major eruptions in the last 100 years, the most recent of which (2015) created significant ash plumes that disrupted air traffic on and off for months, and trace amounts of ashfall in Southcentral Alaska communities. Mount Iliamna is mainly known for active steam vents and avalanches related to seismic activity (AVO 2018a). It had a small eruption in 2016.

The Katmai group of seven volcanoes on the northern Alaska Peninsula includes three that have experienced historical eruptions (Katmai, Novarupta, and Trident), and four that are primarily known for steaming fumaroles (Snowy, Griggs, Martin, and Mageik) (AVO 2018a). The largest historical eruption in this group occurred at Katmai and Novarupta in 1912, resulting in deposition of approximately 1 foot of ash in Kodiak, 100 miles away (Fenner 1920). Trident’s last eruption began in 1953, producing ballistic blocks about 2 miles away from the vent, and intermittent ash clouds over a period of 21 years (AVO 2018a).



Sources: PLP 2020-RFI168; PLP 2019-RFI153; AVO 2018

Active Volcanos

- Active Historically, Monitored by AVO
- Active Historically or Within Holocene, Not Monitored by AVO

Action Alternatives

- Lightering Locations
- Ferry Routes
- Natural Gas Pipelines
- Alternative 1a
- Alternative 1
- Alternative 1 Kokhanok East Ferry Terminal Variant
- Alternative 2
- Alternative 3

US Army Corps of Engineers

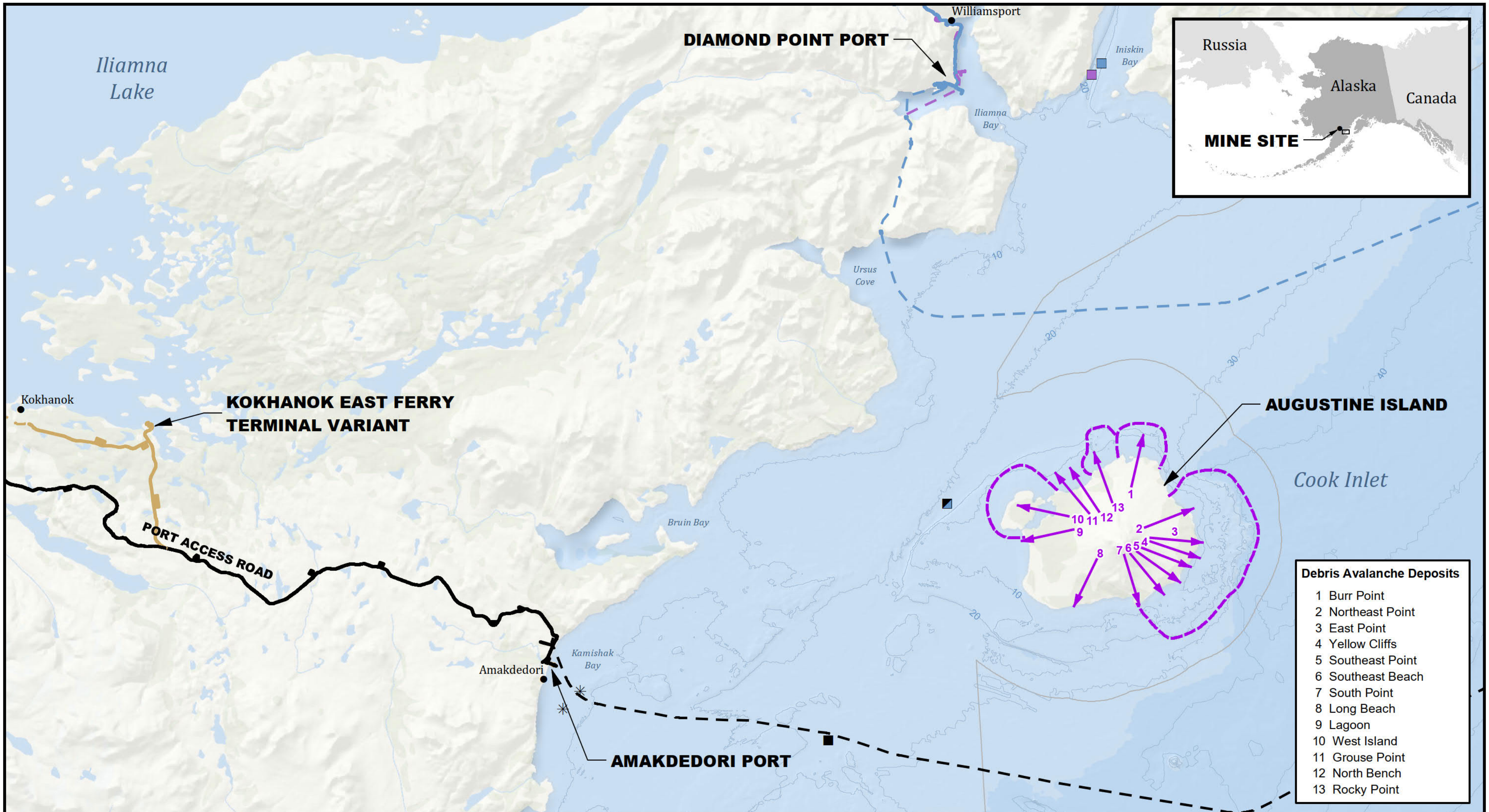
15 0 15 30

Miles

ACTIVE VOLCANOES

PEBBLE PROJECT EIS

FIGURE 3.15-5



Sources: PLP 2020-RFI168;
PLP 2019-RFI153; Waythomas et al. 2006

US Army Corps of Engineers

3 0 3 6
Miles

Approximate offshore extent of debris-avalanche deposits

Approximate drbris avalanche flow path

Action Alternatives

Lighted Navigation Buoys

Lightering Locations

Natural Gas Pipelines

Alternative 1a

Alternative 1 Kokhanok East Ferry Terminal Variant

Alternative 2

Alternative 3

Other Features

Bathymetric Contour (meters)

Three Nautical Mile Line

HISTORICAL DEBRIS AVALANCHES ON AUGUSTINE ISLAND

PEBBLE PROJECT EIS

FIGURE 3.15-6

3.15.5 Tsunamis, Seiches, and Coastal Hazards

A tsunami is a sea wave that results from large-scale seafloor displacement caused by a large earthquake or major submarine slide. A seiche is a series of standing waves in a fully or partially enclosed body of water caused by earthquakes or landslides (Kabiri-Samani 2013).

Lower Cook Inlet has the potential for tsunamis and related coastal geohazards from seismic events. Impacts from tsunamis are dependent on bathymetry, coastline configuration, and tidal interactions. The 1964 Great Alaskan Earthquake generated numerous tsunami waves, including several that destroyed the harbor at Kodiak (Plafker and Kachadoorian 1966). Recent tsunami modeling by American Society of Civil Engineers (ASCE) (2017b) predicts a runup elevation of 28.5 feet above mean high water (MHW) for a 2,500-year return period event at high tide at the Amakdedori port site. This is equivalent to a runup elevation of roughly 42 feet mean lower low water (MLLW)[1]. Lower tsunami runup elevations are predicted for the Alternative 2 Diamond Point port site (22 to 25 feet MHW, or 36 to 39 feet MLLW[2]), the Alternative 3 dock site (24 to 27 feet MHW, or 38 to 41 feet MLLW), and the eastern end of the pipeline on Kenai Peninsula (18.6 feet MHW, or about 36 feet MLLW) (ASCE 2017b, 2018b). Higher runup elevations are predicted for the Alternative 3 port site located further north in Iliamna Bay (31 to 33 feet MHW, or 45 to 47 feet MLLW) (ASCE 2018b).

Older tsunami modeling by Crawford (1987) provides information on smaller, more frequent tsunamis that could occur. For example, wave height predictions for 100- to 500-year return period events (combined with high tide) are estimated to be 12 to 23 feet above mean sea level (amsl) (about 19 to 30 feet MLLW[3]) in the Amakdedori area of Kamishak Bay, and 13 to 15 feet amsl (21 to 23 feet MLLW) near the eastern end of the pipeline on Kenai Peninsula.

Volcanic eruptions can also produce tsunamis from catastrophic dome collapses and rapidly moving pyroclastic flows entering the sea (Allen 1994; Armes 1996; Waythomas and Neal 1998; Waythomas et al. 2009; AVO 2018a). One of the debris avalanches at Mount Augustine created West Island on the western side of Augustine Island 300 to 500 years ago (Figure 3.15-6). Based on numerical modeling of this deposit by Waythomas et al. (2006), it is estimated that a tsunami with a maximum wave amplitude of about 30 to 55 feet may have struck the mainland shore south of Ursus Cove, reaching about 10 feet near the Amakdedori port site. A secondary 60-foot wave may have occurred near West Island during this event. (For context, maximum wind-generated storm waves in lower Cook Inlet can reach 40 feet.) The 1883 eruption of Mount Augustine produced a debris avalanche–generated wave that affected areas up to 55 feet above high tide on the northern side of the island, and 23 feet above high tide on Kenai Peninsula (Begét et al. 2008). Numerical modeling suggests that this event may have produced a tsunami in the range of 5 to 20 feet near Diamond Point and the mouth of Iniskin Bay. These events are estimated to have been capable of transporting gravel- to cobble-sized sediment in northern Kamishak Bay, Ursus Cove, and Iliamna Bay (Waythomas et al. 2006).

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[1] MHW is estimated to be in the range of 13 to 14 feet MLLW at Amakdedori, based on an interpolation of tide gage data from Iniskin Bay (Pentec/Hart Crowser and SLR 2011; Hart Crowser 2015a), northern Shelikof Strait, and southern Kenai Peninsula (NOAA 2018f; PLP 2019-RFI 112). A site-specific MHW for Amakdedori would be determined from ongoing field data collection (PLP 2019-RFI 112).
[2] MHW is 13.8 feet MLLW at Diamond Point (Iniskin Bay) and 17.6 feet MLLW at Anchor Point (Pentec/Hart Crowser and SLR 2011; Hart Crowser 2015a; NOAA 2018f).
[3] Mean sea level (MSL) is estimated to be about 7.3 to 7.4 feet MLLW at Amakdedori, based on an interpolation of tide gage data from Iniskin Bay and northern Shelikof Strait (Pentec/Hart Crowser and SLR 2011; Hart Crowser 2015a; NOAA 2018f); MSL is 8.2 feet MLLW at Anchor Point (NOAA 2018f).

The occurrence of seiches and tsunamis in large lakes in the region has not been documented, and their occurrence in Iliamna Lake during past large earthquakes is unknown (PLP 2018-RFI 013). During the 1964 Great Alaskan and 2002 Denali earthquakes, seiches several feet high occurred in the intracoastal waterways of Southeast Alaska, and in a number of lakes and reservoirs in the contiguous 48 states (McGarr et al. 1968; Barberopoulou et al. 2004; CBJ 2018). Modeling of an earthquake-induced landslide into Bradley Lake in Southcentral Alaska predicted that a 10-foot wave would occur (Stone and Webster 1987); Bradley Lake is in a similar seismic zone but is much smaller than Iliamna Lake. Coastal planning in Southeast Alaska anticipates that seiches up to 20 feet high could occur from large distant earthquakes originating in Southcentral Alaska (Community and Systems Analysis [CASA] 1982). For context, storm-driven waves on Iliamna Lake have been documented as high as 6 feet in the community of Iliamna, where they have caused shoreline erosion and damage to the dock and boats (USACE 2009a). The likelihood of seiches and tsunamis to occur in Iliamna Lake is further addressed in Section 4.15, Geohazards and Seismic Conditions.

The 1964 Great Alaskan Earthquake generated additional coastal hazards in Cook Inlet, such as tectonic uplift and subsidence, ground fissuring, and submarine landslides, which destroyed the Homer Harbor breakwater. Vertical uplift was on the order of 1 to 2 feet along the western shore of lower Cook Inlet, and subsidence in the range of 0.5 foot to 4 feet along the eastern shore of lower Cook Inlet (Foster and Karlstrom 1967). Ground cracking, liquefaction, and local subsidence up to several feet occurred in saturated beach and alluvial deposits around Kodiak Island, along Cook Inlet shorelines, and around large lakes in the area (Plafker and Kachadoorian 1966). Along the western shore of Cook Inlet, stream mouths were drowned and narrow beaches experienced vigorous erosion at bluff faces (Stanley 1968).

Other coastal and marine hazards in lower Cook Inlet include large sand waves (large deposits of moving sand forming shallows), scour features (areas where the seabed is being eroded), and boulders on the seafloor (BSEE 2018; Intecsea 2019). The boulders originate from coastal bluff slumping or as glacial erratics, and can be ice-rafted along shore during winter, causing potential navigation hazards. Boulders and rocky shallows have been mapped along the coast 1 to 2 miles north and south of the mouth of Amakdedori Creek (PLP 2018-RFI 039) and extend offshore in an east-trending ridge from 1 to 5 miles due east of the creek. Rocky areas and boulders are common on mudflats in the upper reaches of Cottonwood and Iliamna bays (Pentec Environmental/Hart Crowser and SLR 2011). Reconnaissance geophysical surveys indicate the presence of rocks and boulders on the seabed and buried in shallow sediment in the vicinity of Diamond Point, reaching a maximum density near the mouth of Iliamna Bay (PLP 2018-RFI 063). Boulders are common along the eastern Cook Inlet shoreline near the pipeline landfall (NOAA 2015; Intecsea 2019). Rocky lakebed areas are also known to occur in Iliamna Lake (PLP 2019-RFI 071b).