K3.13 GEOLOGY

This appendix contains supplemental information on the affected environment for the following topic(s) related to:

- Geology-related field and desktop studies.
- Paleontological resources.

K3.13.1 Geology-Related Field and Desktop Studies

The geology-related findings presented in Section 3.13 and Section 4.13, Geology, were based on the review of field and office studies completed in the project area, including the following:

- Relevant existing literature and studies completed by the Applicant and others, including published geological reports and maps prepared by the US Geological Survey (USGS), Alaska Division of Geological and Geophysical Surveys and others (Knight Piésold 2011a, 2011d; Detterman and Reed 1973, 1980; Hamilton and Klieforth 2010; Nokleberg et al. 1994; Plafker et al. 1994; Wilson et al. 2012).
- Evaluation and interpretation of aerial photographs taken from aircraft, which can provide a good understanding of the surficial geological conditions (Knight Piésold 2011a, 2011d).
- Field reconnaissance studies, including helicopter and on-the-ground geologic mapping to verify the aerial photograph–related findings (Knight Piésold 2011a, 2011d).
- Offshore drill holes and bathymetry (depth of water) surveys to support the ferry transportation corridors and natural gas pipeline alternative–related studies (Knight Piésold 2011a, 2011d; GeoEngineers 2018a).
- In the mine study area:
  - More than 700 drill holes were completed in the mine study area using helicopter-portable drilling equipment (Section 3.13, Geology, Figure 3.15-3). About 500 of the drill holes were completed to understand the mineralogy, and the remaining drill holes supported civil engineering-related studies. Rock and soil samples were collected for detailed evaluation during and after the field work (Knight Piésold 2011a, 2011d, 2018 [borehole Geographical Information System location data and borehole log information received, report in progress by Knight Piésold]).
  - Excavation of more than 300 test pits in the mine study area that ranged in depth between about 1.5 to 3 meters, and were completed by a helicopter-portable excavation apparatus (Knight Piésold 2011a, 2011d).
  - Ground-based (versus from aircraft) geophysical surveys were completed with helicopter- and boat-portable instruments in the mine study and project area to understand the physical characteristics of the mineralized bedrock and near-shore sediments. These studies were non-invasive (did not include drilling or excavations), and relied on electronic sensors to map the geology. The geophysical studies included seismic reflection, infrared imagery, and induced polarization (Knight Piésold 2011a, 2011d).

K3.13.2 Paleontological Resources

K3.13.3 Alternative 1 – Applicant's Proposed Alternative

K3.13.3.1 Mine Site

Cretaceous age Kahiltna flysch sedimentary units are largely derived from eroded volcanic rocks, and are not likely to contain fossils. Other volcanic and intrusive igneous rocks in the mine site area are not suitable lithologies for fossil formation and preservation. Quaternary age glacial sediments at the mine site are unlikely to host fossils, and without measurable permafrost, significant findings of frozen Pleistocene age megafauna are not likely (Blodgett and Zhang 2018; Arctos 2018).

K3.13.3.2 Transportation Corridor

As with the mine site, the intrusive igneous and volcanic bedrock that spans most of the mine access transportation corridor is not an amenable lithology for fossil formation and preservation. Pleistocene age glacial sediments along the transportation corridor are unlikely to host fossils, and without the preserving effects of measurable permafrost, significant findings of Pleistocene age megafauna are not likely (Blodgett and Zhang 2018; Arctos 2018).

There are known paleontological resource sites at the southern terminus of the transportation corridor, where the road meets the port. Quaternary age beach deposits present in the area are locally fossiliferous, originating from erosion of nearby Jurassic age marine sedimentary rock (see Amakdedori port section below); therefore, fossils are likely present in that area (Detterman and Reed 1973). About 20 acres of the transportation corridor footprint is on Quaternary age beach deposits that could contain significant fossil resources. Additionally, the transportation corridor comes within 800 feet of the Talkeetna and Naknek formations, which have produced significant vertebrate paleontological resources (Wilson et al. 2012).

K3.13.3.3 Amakdedori Port

Jurassic age marine sedimentary rocks around the port site are host to numerous diverse marine invertebrate fossils. Fossil ammonites, brachiopods, cephalopods, and pelecypods are abundant in the Naknek and Talkeetna Formation members exposed in the bluff directly northeast of the port facility (Blodgett and Zhang 2018; Detterman and Reed 1973, 1980; Wilson et al. 2012). Cephalopod fossils eroded from nearby Jurassic age sedimentary rock have been found in the same beach deposits in the port facility footprint (Arctos 2018). Although these are common fossils, they are considered significant as sources of new data concerning Jurassic period evolutionary trends, species survival beyond Triassic period extinctions, and the global and regional development of Jurassic age marine biological communities (Sandy and Blodgett 2000). The Naknek Formation at other sites in the region contains vertebrate fossils from the Jurassic marine reptile *Megalneusaurus*, which represents the only find of this species in Alaska, and one of only two occurrences of this genus in North America (Blodgett et al. 1995; Weems and Blodgett 1996). Terrestrial vertebrate trackways have also been discovered in the Naknek Formation at other locales in the region (Blodgett et al. 1995). These findings demonstrate a potential for paleontological resources in the Amakdedori port footprint.

K3.13.4 Natural Gas Pipeline Corridor

The paleontological environment of the natural gas pipeline corridor is the same as that discussed above for the transportation corridor. Quaternary age sediments along both sides of Cook Inlet are unlikely to contain fossils, and without the preserving effect of measurable

permafrost, significant findings of Pleistocene age megafauna are not likely (Blodgett and Zhang 2018; Arctos 2018). In the offshore section of corridor, the shallow floor of Cook Inlet is filled with abundant sand, pebbles, cobbles, and boulders flushed into the inlet from young glacial deposits across the region; no fossil resources would be expected.

K3.13.4.1 Alternative 1 – Summer-Only Ferry Operations Variant

The paleontological environment for this variant is the same as for Alternative 1.

K3.13.4.2 Kokhanok East Ferry Terminal Variant

The paleontological environment for Alternative 1 scenarios are considered to be comparable to the proposed alternative based on the presence of similar substrate conditions; however, Jurassic, Triassic, and possibly older complex assemblages of metamorphosed volcanic and sedimentary rock associated with the Kokhanok Complex coincide with the Kokhanok east ferry terminal variant footprint. Based on the reported mix of lithologies of variable metamorphic grade, the presence or preservation of fossils in this discrete lithologic occurrence at the Kokhanok port site is considered low to unlikely.

K3.13.4.3 Alternative 1 – Pile-Supported Dock Variant

The paleontological environment for this variant is the same as for Alternative 1.

K3.13.4.4 Alternative 2 (North Road and Ferry and Downstream Dams and Alternative 3 (North Road Only)

The Diamond Point port footprint would be on volcanic and intrusive igneous bedrock. The north access road and/or pipeline segments of Alternative 2 and Alternative 3 (including the concentrate pipeline variant) is contiguously mapped as volcanic and intrusive igneous bedrock with interspersed segments, including Quaternary age glacial sediments (Wilson et al. 2015). Igneous substrates are not considered amenable for fossil preservation and formation. Similar to all other alternatives, interspersed Quaternary age glacial sediments are considered unlikely to host fossils.