

3.1 GEOLOGY AND PALEONTOLOGY

SYNOPSIS

EXISTING CONDITION SUMMARY

This section presents information available regarding the physiography, bedrock geology, surficial geology, aggregate resources, and paleontological resources within the areas affected by the three project components: Mine Site, Transportation Corridor, and Pipeline. The EIS Analysis Area encompasses seven physiographic sub-provinces spread across Southwest and Southcentral Alaska and the Aleutian Island Chain. Regional descriptions of these resources are presented, followed by local descriptions, and enhanced with information gathered from project geotechnical studies.

EXPECTED EFFECTS SUMMARY

Alternative 1 - No Action

This alternative is representative of existing conditions. No project-related impacts to geological and paleontological resources would occur under this alternative.

Alternative 2 - Donlin Gold's Proposed Action

Mineral Resources: Under the proposed action, impacts to mineral, rock aggregate, and gravel resources at the Mine Site, Transportation Corridor, and Pipeline would vary in intensity depending on the type of project activity. For example, grading of bedrock would result in changes in the resource character that may not be measurable or noticeable. Blasting and resource removal, landform changes, and widespread aggregate resource utilization would result in acute or obvious changes in the resource character. Project activities would result in the alteration of the following:

- *Mineralized bedrock and waste rock:* roughly 3.7 billion tons across 7,000 acres for ore extraction at the Mine Site, with topographic changes up to about 600 feet;
- *Rock aggregate:* extraction of 5.6 million cy across 900 acres from material sites, and cuts along roughly 90 miles of roads and pipeline right-of-way (ROW); and
- *Gravel resources and surficial deposits:* about 50 million tons of overburden moved and reused for reclamation across about 9,000 acres at the Mine Site; 4.6 million cubic yards (cy) of gravel resources extracted from material sites; alteration of surficial deposits along 340 miles of roads and pipeline ROW; and 2,800 acres of material sites and pipeline infrastructure.

Most effects would include landscape changes and reduction in mineral/aggregate resources that would not be anticipated to return to previous levels even if actions that caused the impacts were to cease. Effects would be mostly limited to areas within the various facility footprints. Most rock and gravel aggregate resources impacted are usual or ordinary resources that are not considered depleted, although the ore-containing bedrock at the mine is a rare economic resource.

Paleontological Resources: Impacts would vary in intensity, depending on the actual presence and location of fossils. Most effects would be to usual or ordinary resources (formations with little fossil potential) that are not depleted. However, impacts may affect depleted resources where the potential is elevated for dinosaur fossils in Kuskokwim Group rocks or vertebrate fossils in Pleistocene deposits. The total volumes and acreages of potential fossil-bearing rock that could be affected by project activities would be similar to those summarized for bedrock and gravel resources. Fossils across the EIS Analysis Area could include abundant invertebrates, or potentially depleted resources such as dinosaur tracks or Pleistocene mammals.

Alternative 3A - LNG Powered Trucks

The effects of this alternative on mineral and paleontological resources would be very similar to the effects of Alternative 2. There would be about 20 fewer acres of ground disturbance and landform alterations at the Bethel and Dutch harbor fueling facilities.

Alternative 3B - Diesel Pipeline

The effects of this alternative on mineral and paleontological resources would be very similar to the effects of Alternative 2. There would be about 20 fewer acres of ground disturbance and landform alterations at the mine and transportation facilities, and about 1,400 acres more ground disturbance and extraction of surficial geologic resources along the extended pipeline ROW.

Alternative 4 - Birch Tree Crossing (BTC) Port

The BTC Road would utilize about 11 million cy more rock and gravel aggregate, and cause landform changes across about 900 more acres, than the Angyaruaq (Jungjuk) Road under Alternative 2. There would be a net increase in the probability of potential effects on paleontological resources under Alternative 4 due to the higher number of bedrock rock material sites along the BTC Road. However, the reduction on upper river barge travel under Alternative 4 would reduce potential effects on vertebrate fossils along the river corridor.

Alternative 5A - Dry Stack Tailings

The effects of this alternative on mineral and paleontological resources would be very similar to the effects of Alternative 2. The final elevation of the dry stack would be 50 to 150 feet higher than the existing ridge south of the TSF. There would be about a 12 percent increase in the amount of bedrock excavation and aggregate needed for the main and upper dry stack tailings dams than under Alternative 2.

Alternative 6A - Dalzell Gorge Route

The effects of this alternative on mineral and paleontological resources would be very similar to the effects of Alternative 2. There would be about three fewer material sites covering about 130 acres less than Alternative 2.

3.1.1 REGULATORY CONTEXT

3.1.1.1 MATERIALS SITES

“Materials” are defined as any substance from the ground that may be utilized as part of mine construction, but are not economically mineralized or part of the mineral claim itself. Examples would include sand, gravel, riprap, soil, rock, and any other similar substance. These materials might be used for construction of roads, pads for performing work, shoreline protection, etc. Use and placement of these resources is governed by a variety of state and federal laws and regulations.

A portion of the pipeline route would run through Kenai Peninsula borough (KPB). Use of the gravel would be covered under KPB Code of Ordinances, Chapter 21.29, which regulates materials extraction, processing, and excavation below the water table.

Alaska Statute [AS] 38.05.550-565 and 11 AAC 71 would govern borrow materials not located within the boundary of the millsite lease or a road ROW. Each site would require a Development Plan that addresses the handling of timber and slash, a bond, and a Reclamation Plan. Coverage under the Alaska Pollutant Discharge Elimination System (APDES) Multi-Sector General Permit may be required, as well as Excavation Dewatering General Permit. These general permits are administered by the Alaska Department of Environmental Conservation (ADEC). These permits control both the discharge of stormwater, and dewatering effluent.

Additional permits would be required from Alaska Department of Natural Resources (ADNR), including a Temporary Water Use Permit, and a material sale application if the pit is on state land.

The Bureau of Land Management (BLM) sells the materials from their land at not less than fair market value, as determined by appraisal. Regulations governing contracts and permits for mineral materials are contained in Title 43, Code of Federal Regulations, Subparts 3601, 3602, 3603, and 3604. Mineral resources used for the project would be sold to the proponent as a minerals material sale. BLM typically considers addressing the need for mineral materials after other options on non-BLM-managed lands are fully explored.

3.1.1.2 PALEONTOLOGY

Paleontology is a multi-disciplinary science that combines elements of geology, biology, geochemistry, and physics in an effort to understand past life on earth. Paleontological resources, more commonly known as fossils, are the remains, traces, or imprints of ancient animals and plants preserved in sediment and rock. Paleontological resources include mineralized, partially mineralized, and non-mineralized bones, skeletal material and invertebrate remains, and also skin imprints, footprints and tracks, as well as plant macro- and microfossils that have the potential of yielding important information about the history of life on earth.

Significant paleontological resources can be used to:

- document the presence, geographic distribution, and range of now-extinct organisms;
- study the evolutionary relationships among extinct organisms, and their relationships to modern groups;

- reconstruct ancient environments, climate change, and paleoecological relationships;
- provide indices for relative geologic dating;
- provide indices to determine the relationship of stratigraphic units at local, regional, continental and global scales;
- understand tectonic movements of land masses and ocean basins through time;
- study patterns and processes of evolution, extinction, and speciation;
- identify causes and effects of global environmental and climate change; and
- understand faunal and floral responses to global environmental and climate change.

It is important to note that the list above is not all-inclusive of the potential significant scientific contributions of the fossil record. Thorough, detailed documentation of the fossil record has the potential to answer other important contemporary or future scientific research questions.

These are non-renewable resources of scientific value that, on state and federal lands, are protected by state and federal laws. No state or federal laws protect paleontological resources on private lands. Federal laws protecting paleontological resources include:

- The Paleontological Resources Preservation Act of 2009;
- Antiquities Act of 1906; Archaeological Resources Protection Act of 1979;
- Federal Land Policy and Management Act of 1976 (as amended 1998).

Specific provisions for federal land-managing agencies reinforce policies regarding the collection and curation of significant paleontological resources. The BLM assesses potential impacts to paleontological resources under the Federal Land Policy and Management Act (FLPMA) and the National Environmental Policy Act (NEPA), and provides guidance for predicting, assessing, evaluating, and mitigating paleontological resources (BLM 1998). This is done by utilizing Instruction Memorandum No. 2016-124, the Potential Fossil Yield Classification (PFYC) system (BLM 2016), and the Handbook H-8270-1 (General Procedural Guidance for Paleontological Resource Management) Chapter III (Assessment & Mitigation) (BLM 1998).

The FLPMA defines significant fossils as: unique, rare or particularly well preserved; an unusual assemblage of common fossils; being of high scientific interest; or providing important new data concerning:

- evolutionary trends;
- development of biological communities;
- interaction between or among organisms;
- unusual or spectacular circumstances in life history; or
- anatomical structure.

For the purpose of this analysis, and in accordance with existing BLM policy (BLM H-8270-1; BLM IM 2009-011), scientifically significant paleontological resources are defined as vertebrate fossils that are identifiable to taxon and/or element, noteworthy occurrences of invertebrate and plant fossils, and vertebrate trackways.

The State of Alaska protects fossils on state lands under the Alaska Historic Preservation Act (AS 41.35), which explicitly includes paleontological materials in its definition of “historic, prehistoric, and archaeological resources,” and requires the ADNR to locate, identify, and preserve information on paleontological resources. In accordance with the federal and state regulations, exact locations of paleontological resources are restricted and exempt from federal and state Freedom of Information laws.

Potential Fossil Yield Classification (PFYC) System

Potential paleontological resource impacts tend to be determined at the geologic unit level (unlike cultural resources which are managed at the site level). Since fossils are typically encased in bedrock, sediments, or in the case of Alaska, permafrost, potential paleontological resource impacts are determined at the geologic unit level. Field surveys which employ surface inspections or shallow subsurface testing in unconsolidated sediments (such as cultural resource field surveys) have limited utility in determining the presence or absence of paleontological resources. The BLM’s Potential Fossil Yield Classification (PFYC) system ranks geologic units by their potential for containing significant paleontological resources and is the primary means for assessing potential impacts to paleontological resources.

As discussed in BLM IM 2016-124 (BLM 2016) which describes the PFYC, occurrences of paleontological resources are closely tied to the geologic units (i.e., formations, members, or beds) that contain them. The probability for finding paleontological resources can be broadly predicted from the geologic units present at or near the surface. Therefore, geologic mapping can be used for assessing the potential for the occurrence of paleontological resources. However, it is impossible to predict the specific types of fossils that will be found or their exact locations in a geologic formation.

Using the PFYC system, geologic units are classified based on the relative abundance of vertebrate fossils or scientifically significant invertebrate or plant fossils and their sensitivity to adverse impacts, with a higher class number indicating a higher potential. This classification is applied to the geologic formation, member, or other distinguishable unit, preferably at the most detailed mappable level. It is not intended to be applied to specific paleontological localities or small areas within units. Although significant localities may occasionally occur in a geologic unit, a few widely scattered important fossils or localities do not necessarily indicate a higher class; instead, the relative abundance of significant localities is intended to be the major determinant for the class assignment (BLM 2016).

The PFYC system is meant to provide baseline guidance for predicting, assessing, and mitigating paleontological resources. The classification should be considered at an intermediate point in the analysis, and should be used to assist in determining the need for further mitigation assessment or actions.

The descriptions for the classes below are written to serve as guidelines rather than as strict definitions. Knowledge of the geology and the paleontological potential for individual units or preservation conditions should be considered when determining the appropriate class assignment. Assignments are best made by collaboration between land managers and knowledgeable researchers.

The PFYC system rates geologic units according to their likelihood for containing recognizable fossil remains as follows (from BLM 2016):

Class 1 – Very Low: Geologic units that are not likely to contain recognizable fossil remains.

- Units that are igneous or metamorphic, excluding reworked volcanic ash units.
- Units that are Precambrian in age or older.

Management concern for paleontological resources in Class 1 units is usually negligible or not applicable. The occurrence of significant fossils is nonexistent or extremely rare. Assessment or mitigation is usually unnecessary. The probability for impacting any fossils is negligible.

Class 2 – Low: Sedimentary geologic units that are not likely to contain vertebrate fossils or scientifically significant non-vertebrate fossils.

- Field surveys have verified that significant paleontological resources are not present or are very rare.
- Units are generally younger than 10,000 years before present.
- Recent aeolian deposits.
- Sediments that exhibit significant physical and chemical changes (i.e., diagenetic alteration).

Management concern for paleontological resources in Class 2 units is generally low. Localities containing important resources may exist, but would be rare and would not influence the classification. Assessment or mitigation is usually unnecessary except in rare or isolated circumstances. The probability for impacting vertebrate fossils or scientifically significant invertebrate or plant fossils is low. Class 2 localities would be managed on a case-by-case basis. An assignment of Class 2 may not trigger further analysis unless paleontological resources are known or found to exist. However, standard stipulations should be put in place prior to authorizing any land use action in order to accommodate unanticipated discoveries.

Class 3 – Moderate: Sedimentary geologic units where fossil content varies in significance, abundance, and predictable occurrence; or sedimentary units of unknown fossil potential

- Marine in origin with sporadic known occurrences of paleontological resources.
- Paleontological resources may occur intermittently, but abundance is known to be low.
- Units may contain significant paleontological resources, but these occurrences are widely scattered.
- The potential for an unauthorized land use to impact a significant paleontological resource is known to be low-to-moderate.

Management concerns for paleontological resources are moderate because the existence of significant paleontological resources is known to be low. Common invertebrate or plant fossils may be found in the area, and opportunities may exist for casual collecting. Paleontological mitigation strategies will be proposed based on the nature of the proposed activity.

This classification includes units of moderate or infrequent occurrence of paleontological resources. Management considerations cover a broad range of options that may include record searches, pre-disturbance surveys, monitoring, mitigation, or avoidance. Surface-disturbing activities may require assessment by a qualified paleontologist to determine whether significant

paleontological resources occur in the area of a proposed action, and whether the action could affect the paleontological resources

Class 4 – High: Geologic units that are known to contain a high occurrence of significant fossils. Units assigned to Class 4 typically have the following characteristics:

- Significant paleontological resources have been documented, but may vary in occurrence and predictability.
- Surface disturbing activities may adversely affect paleontological resources.
- Rare or uncommon fossils, including invertebrate (such as soft body preservation) or unusual plant fossils, may be present.
- Illegal collecting activities may impact some areas.

Management concern for paleontological resources in Class 4 is moderate to high, depending on the proposed action. Paleontological mitigation strategies will depend on the nature of the proposed activity, but field assessment by a qualified paleontologist is normally needed to assess local conditions.

The probability for impacting significant paleontological resources is moderate to high, and is dependent on the proposed action. Mitigation plans must consider the nature of the proposed disturbance, such as removal or penetration of protective surface alluvium or soils, potential for future accelerated erosion, or increased ease of access that could result in looting. Detailed field assessment is normally required and on-site monitoring or spot-checking may be necessary during land disturbing activities. In some cases avoidance of known paleontological resources may be necessary.

Class 5 – Very High: Highly fossiliferous geologic units that consistently and predictably produce significant paleontological resources. Units assigned Class 5 have some or all of the following characteristics:

- Significant paleontological resources have been documented and occur consistently.
- Paleontological resources are highly susceptible to adverse impacts from surface disturbing activities.
- Unit is frequently the focus of illegal collecting activities.

Management concern for paleontological resources in Class 5 areas is high to very high. A field survey by a qualified paleontologist is almost always needed. The probability for impacting significant paleontological resources is high. The area should be assessed prior to land tenure adjustments. Pre-work surveys are usually needed and on-site monitoring may be necessary during land use activities. The area should be assessed prior to land tenure adjustments. Pre-work surveys are usually needed and on-site monitoring may be necessary during land use activities. Avoidance or resource preservation through controlled access, designation of areas of avoidance, or special management designations should be considered.

Class U – Unknown: Geologic units that cannot receive an informed PFYC assignment. Characteristics of Class U may include:

- Geological units may exhibit features or preservational conditions that suggest significant paleontological resources could be present, but little information about the actual paleontological resources of the unit or area is known.
- Geological units represented on a map are based on lithologic character or basis of origin, but have not been studied in detail.
- Scientific literature does not exist or does not reveal the nature of paleontological resources.
- Reports of paleontological resources are anecdotal or have not been verified.
- Area or geologic unit is poorly or under-studied.

Until a provisional assignment is made, geologic units that have an unknown potential have medium to high management concerns. Lacking other information, field surveys are normally necessary, especially prior to authorizing a ground-disturbing activity. An assignment of “Unknown” may indicate the unit or area is poorly studied, and field surveys are needed to verify the presence or absence of paleontological resources. Literature searches or consultation with professional colleagues may allow an unknown unit to be provisionally assigned to another Class, but the geological unit should be formally assigned to a Class after adequate survey and research is performed to make an informed determination.

Class W – Water: Includes any surface area that is mapped as water.

Class I – Ice: Includes any area that is mapped as ice or snow.

Project Area PFYC

The fossil potential of the Mine Site, mine facilities, and pipeline route was evaluated using the PFYC system described above. A general PFYC assignment conducted for Alaska in 2010 by the BLM regional paleontologist included geologic units present in portions of the project area (Armstrong 2010). The PFYC assessment also utilized recent paleontological surveys and inventories conducted specifically for the project (Druckenmiller et al. 2013; Jacobus and Druckenmiller 2013; Reuther et al. 2014), as well as information derived from the paleontological site database maintained by the State of Alaska Office of History and Archaeology (OHA) Alaska Heritage Resource Survey (AHRS), the Arctos Database, and the Alaska Paleontological Database (Zhang and Blodgett 2017), published scientific literature, and geologic maps and museum records.

3.1.2 AFFECTED ENVIRONMENT

This section presents information available regarding the physiography, bedrock geology, surficial geology, aggregate resources, and paleontological resources within the areas affected by the three project components: Mine Site (Section 3.1.2.1), Transportation Corridor (Section 3.1.2.2), and Pipeline (Section 3.1.2.3). The EIS Analysis Area encompasses seven physiographic sub-provinces spread across Southwest and Southcentral Alaska and the Aleutian Island Chain. Regional descriptions of the geological resources are presented below, based on state and federal government research, and related thematic studies as presented in scientific journals. These are followed by local descriptions, enhanced with information gathered from project geotechnical studies, where available.

3.1.2.1 MINE SITE

Geologic features associated with the mine site area are discussed in the sections below. The vegetation found in the area of the Mine Site is discussed in Section 3.10, Vegetation, including a discussion of ecoregions in Section 3.10.2.1. Permafrost is discussed in Section 3.2, Soils. Surface water and river systems are discussed in Section 3.5, Surface Water Hydrology.

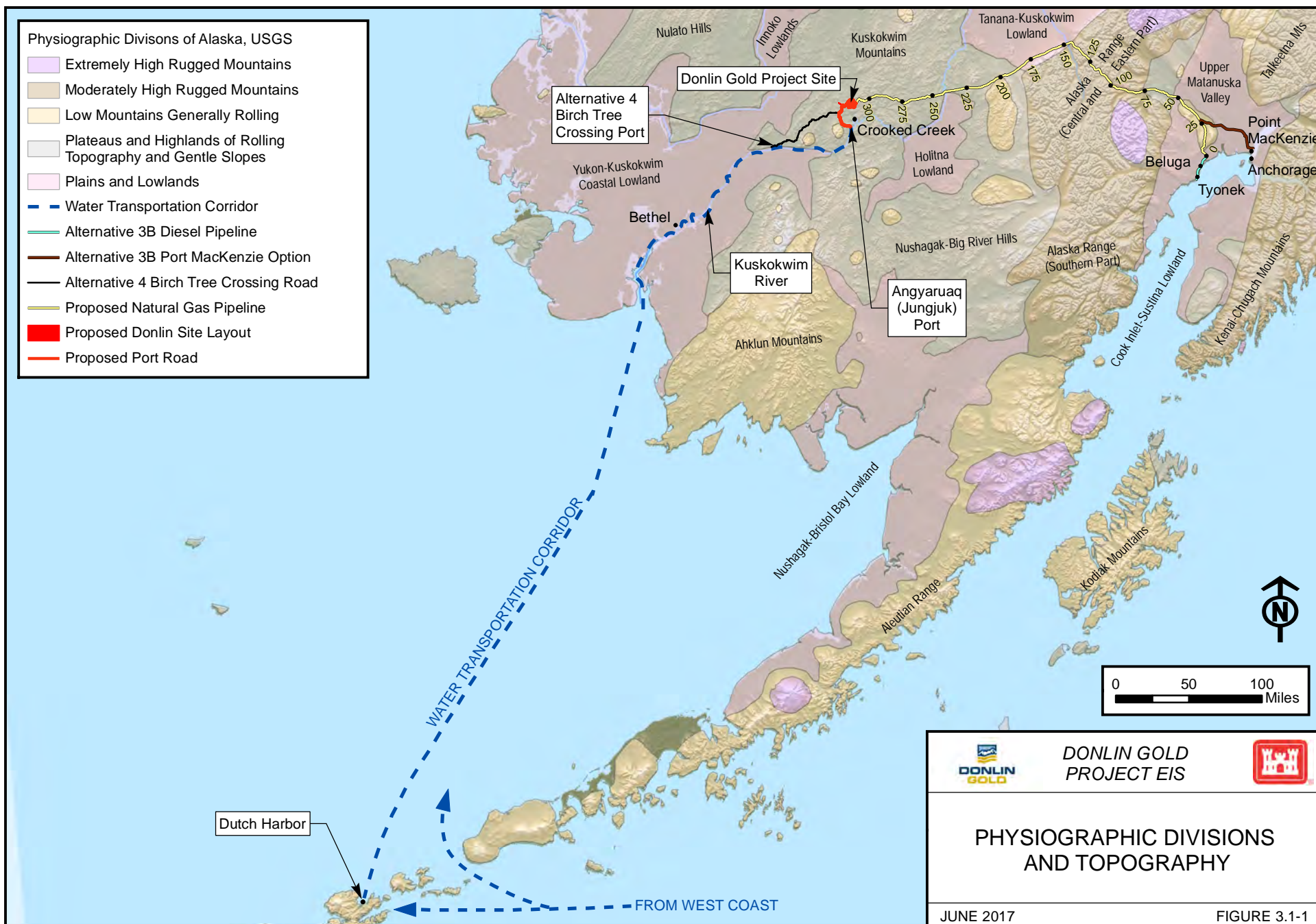
3.1.2.1.1 PHYSIOGRAPHY

The area of and surrounding the Mine Site includes rounded mountains, occasional oxbow and thaw lakes, and creek drainages leading to the Kuskokwim River. Specifically, the Mine Site lies within the Kuskokwim Mountains physiographic sub-province of the larger Uplands and Lowlands Western Alaska province of the Intermontane Plateaus physiographic division (Figure 3.1-1) (Wahrhaftig 1965, 1994). The Kuskokwim Mountains, which trend northeast, consist of rounded mountaintops with elevations up to about 2,000 feet. Lookout Mountain, located approximately one mile northeast of the proposed mine facilities, reaches an elevation of 2,146 feet, and Anaconda Ridge, located within the Mine Site, has an elevation of 2,112 feet. The primary drainages of the Kuskokwim Mountains physiographic province are the Yukon and Kuskokwim rivers that discharge into Norton Sound and Kuskokwim Bay, respectively. Glacial landforms have been recognized in the higher elevations of the range (Meyer 1985; Kline and Bundtzen 1986). Oxbow and thaw lakes occasionally occur in the valleys of this province (Wahrhaftig 1965).

The Mine Site lies within a northeast-trending ridge predominantly drained by west-flowing tributaries to Crooked Creek, which discharges into the Kuskokwim River approximately 10 miles to the south. The Mine Site physical footprint encompasses an area of approximately 25 square miles. The proposed ore processing footprint is bounded to the northeast by Quartz Gulch, to the northwest by Donlin Creek, to the west by Crooked Creek, to the south by Crevice Creek, and to the east by Anaconda Ridge (Figure 2.3-1). The top of the proposed excavated pit lies at an elevation of approximately 1,400 feet, and is bounded to the south by American Creek and to the north by a ridge between Lewis and Queen gulches. American Creek and Queen Gulch flow westward and discharge into Crooked Creek. The proposed waste rock facility lies to the southeast of the proposed pit within the upper reaches of American Creek. The proposed Tailings Storage facility (TSF) lies south of the waste rock facility within the Anaconda Creek drainage.

3.1.2.1.2 BEDROCK GEOLOGY

Geology of the project can be broken into two areas of study: the bedrock geology, and the surficial geology. The bedrock is defined as the solid (consolidated) rock of the earth's surface. As this rock weathered over time it breaks apart (becomes unconsolidated) and forms soils and loose rock. These materials are discussed as surficial geology (Section 3.1.2.1.3).



Regional Bedrock Geology

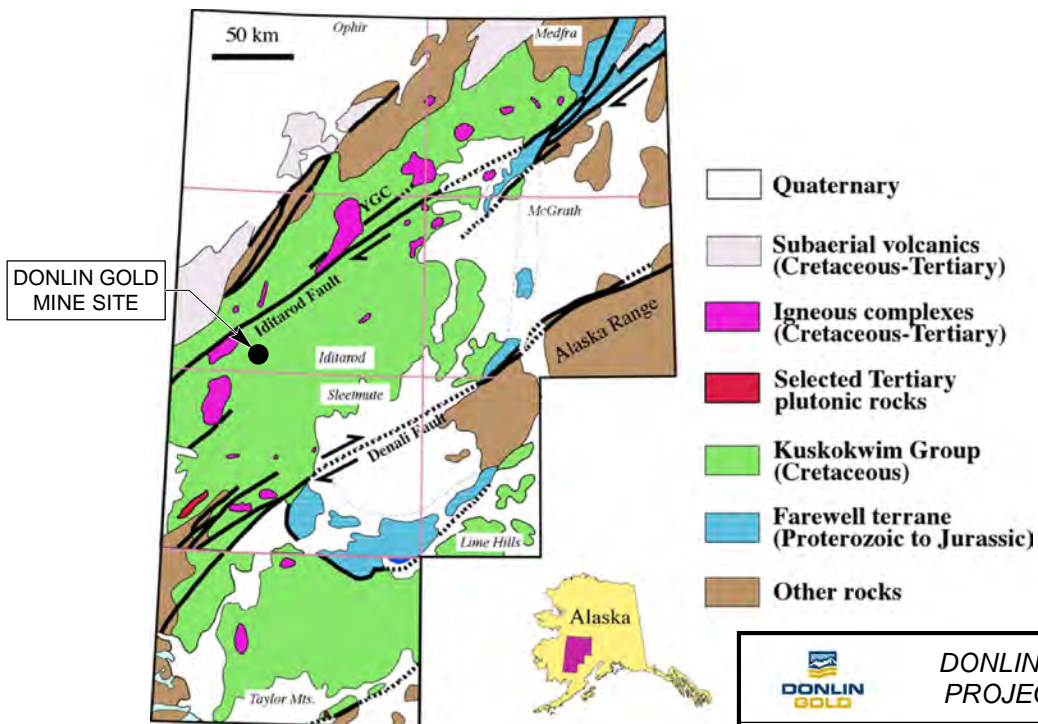
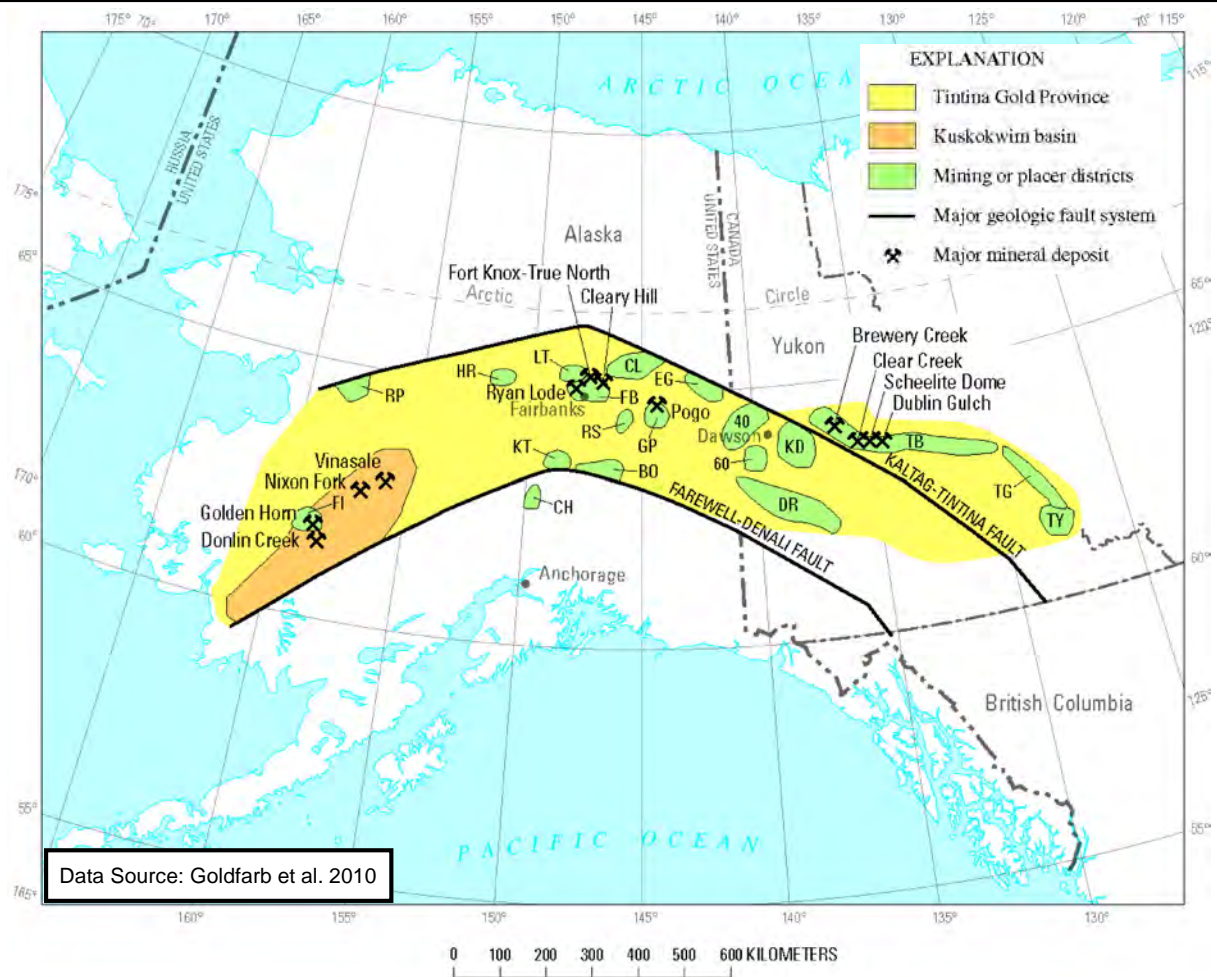
The greater geologic region that includes the EIS Analysis Area lies in the center of the Kuskokwim Mineral Belt at the southwestern end of the larger Tintina Gold province, a broad arc-shaped region of mineral deposits that is bounded on the north and south by major fault systems and extends east into Yukon Territory, Canada (Bundtzen and Miller 1997; Goldfarb et al. 2010) (Figure 3.1-2). The Kuskokwim Mineral Belt hosts numerous placer (unconsolidated) and bedrock precious-metal-bearing deposits. The central portion of the Tintina Gold province hosts the Fort Knox Gold Mine near Fairbanks and the Pogo Gold Mine near Delta Junction. The eastern part hosts the largest gold mine ever constructed in the Yukon, the Brewery Creek Mine (Yukon Energy Mines and Resources 2013), and the Eagle Gold Project, south of Dawson City, which is currently in the development stage of a multi-million-ounce gold resource (Wardrop 2012).

The regional bedrock geology of the area is a complex mixture of sedimentary, igneous, and metamorphic rocks ranging in age from Cenozoic to Proterozoic (Decker et al. 1994; Bundtzen and Miller 1997; Wilson et al. 1998). The bedrock of the region can be grouped into “terranes”, that is, related groups of rocks separated by faults (Plafker and Berg 1994; Silberling et al. 1994; Miller et al. 2008; Goldfarb et al. 2010). In this region these faults are the Denali-Farewell and Iditarod-Nixon Fork faults. These are strike slip faults, and trend northeast through the Kuskokwim Basin and mountains (Plafker et al. 1994; Decker et al. 1994; Miller et al. 2008).

Mine Bedrock Geology

Bedrock geology at the Mine Site consists of sedimentary rocks of the Kuskokwim Group, with younger, late Cretaceous to early Tertiary, intrusions of igneous (solidified from lava or magma) rocks of the Kuskokwim Mountains Group (Decker et al. 1994; Bundtzen and Miller 1997; Szumigala et al. 2000; Miller et al. 2008; Goldfarb et al. 2010). The Kuskokwim Group rocks consist of a deep marine sequence of greenish-gray colored, fine- to coarse-grained, thinly cross-bedded graywacke sandstone, with interbeds of dark gray siltstone and shale that have experienced low grade regional metamorphism and deformation (Cady et al. 1955; Dusel-Bacon et al. 1996; Szumigala et al. 2000).

Bedrock at the Mine Site reflects a complex history of folding, faulting, and intrusion. An east-west trending fold deforms the Kuskokwim Group rocks, with strike-slip fault expressions of the Donlin and Crooked Creek faults trending northeast-southwest at the northwest edge of the Mine Site, and the ACMA fault trending northwest-southeast. Numerous thrust and reverse fault expressions exist throughout the Mine Site, generally trending northwest-southeast (Figure 3.1-3). After folding and faulting, molten igneous rocks intruded along the north-northeast and west-northwest trending structural weaknesses, creating numerous dikes and sills (Figure 3.1-3). This was followed by cross-cutting high-angle faulting along northeast and northwest trends (Figure 3.1-3). Finally extensional fractures cross-cut all previous structures, and are concentrated within the igneous and coarse-grained sedimentary rocks (Goldfarb et al. 2004). It is these structures that are gold bearing.



DONLIN GOLD
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REGIONAL GEOLOGY AND MINE SETTING

The proposed mine targets bedrock associated with the dike and sill complex. The rock consists of plutonic granite porphyry¹ to volcanic dacite/rhyodacite. The rock is categorized as hydrothermal mercury-antimony-gold intrusion (Goldfarb et al. 2004, 2010; Bundtzen and Miller 1997; Gray et al. 1997a; Robert et al. 2007; Szumigala et al. 2000; Flanigan et al. 2000).

The Donlin mineral deposit is characterized as both vein-hosted and disseminated ore that developed within a shallow, low-temperature hydrothermal system. Gold occurs primarily in the igneous rhyodacite rock and minor mafic intrusive rocks, as well as in sulfide and quartz-carbonate-sulfide vein networks in igneous and sedimentary rocks (Robert et al. 2007; Flanigan et al. 2000; Bundtzen and Miller 1997; Goldfarb et al. 2004, 2010). The ore mineralogy is characterized by sulfide assemblages of pyrite, arsenopyrite, and stibnite (Szumigala et al. 2000; SRK Consulting (US), Inc. [SRK] 2006a; AMEC Americas Limited [AMEC] 2009). Pyrite is attributed to the earliest sulfide mineralization phase and arsenopyrite is the dominant gold-bearing mineral (Szumigala et al. 2000). The primary alteration phase is a sericite assemblage found predominantly in the intrusive rocks, and characterized by sericite, illite, and kaolinite. The geochemistry of the ore and its relationship to water quality is presented in Section 3.7, Water Quality.

3.1.2.1.3 SURFICIAL GEOLOGY

Surficial geology includes the unconsolidated materials above the bedrock. These materials may consist of soil (sand, gravel, peat, etc.) or broken rock. These unconsolidated materials originate through the chemical, physical, and biological weathering of the underlying rock. These materials are important to the project since they may be excavated and used for construction. Soil types and taxonomy classifications are presented in Section 3.2, Soils.

Surficial deposits in the mine site area include colluvium² on hill slopes, and coarse- and fine-grained alluvium³ associated with upland valleys and stream courses, such as the Crooked Creek drainage and its tributary streams (Karlstrom et al. 1964). The region has been dominated by the deposition of fluvial⁴ material since the last glacial advances in the Alaska Range (Péwé 1975; Reger et al. 2003a). Small accumulations of loess⁵ have also been mapped in the Kuskokwim River Basin (Péwé 1975).

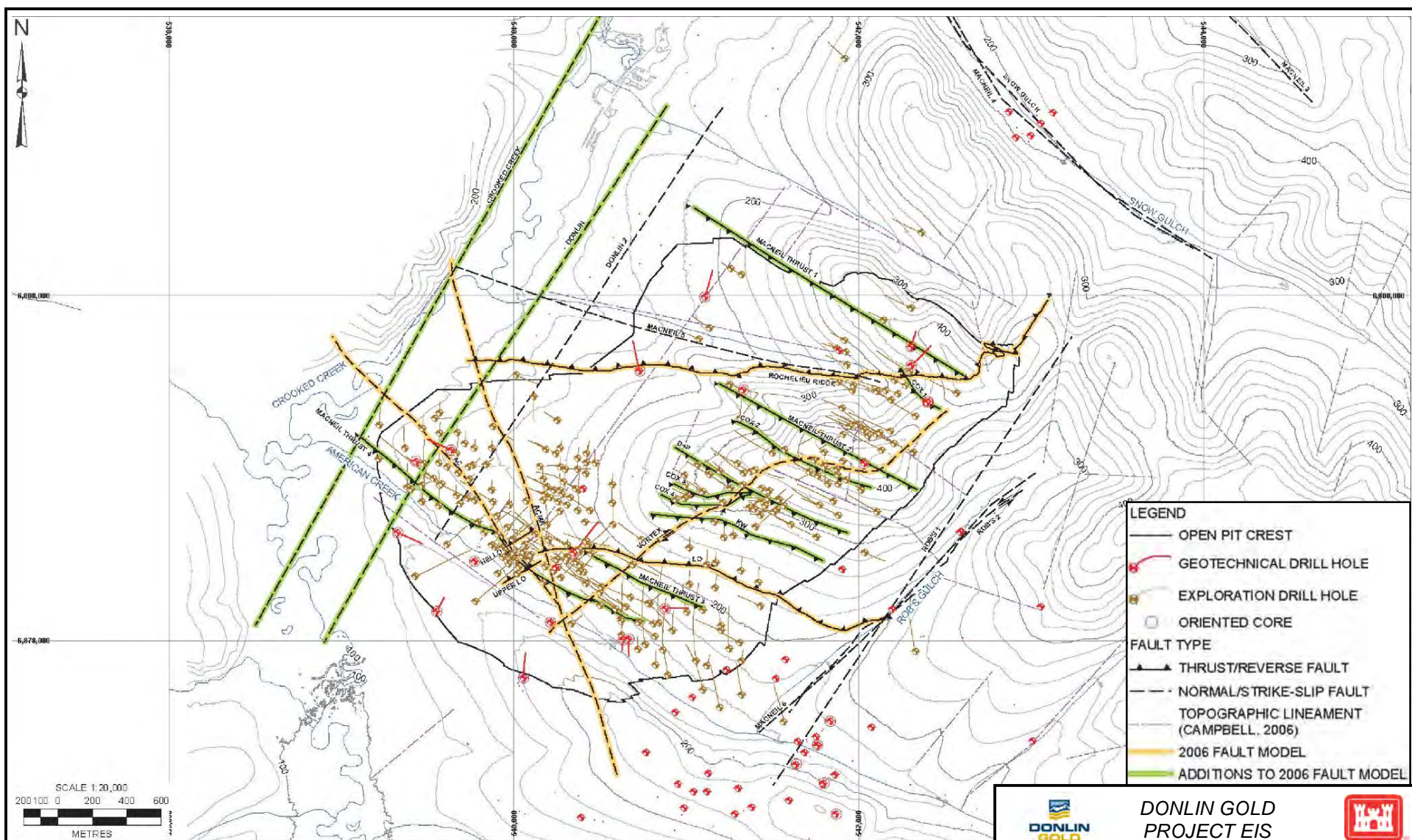
¹ Porphyry is a rock texture describing the presence of large crystals within a groundmass of smaller aphanitic crystals, that is, small-size minerals that cannot be seen with the unaided eye.

² Colluvium is a general term applied to loose material displaced by gravity or freeze-thaw mechanisms (solifluction). Colluvium found at the foot of steep slopes includes talus and cliff debris.

³ Alluvium is detritus material picked up and deposited by flowing water. Alluvium is generally observed in stream beds, floodplains, and lake beds.

⁴ Fluvial refers to rivers and streams and the material produced from their action. Glaciofluvial materials have been deposited by streams flowing from glaciers.

⁵ Loess is fine-grained (silt) material of glacial origin deposited by wind, also referred to as eolian processes.



Data Source: BGC 2017c



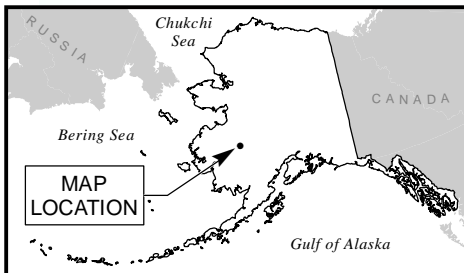
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LOCAL FAULTING IN MINE SITE VICINITY

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FIGURE 3.1-3



Legend

Intrusive Rocks Differentiated by Donlin Gold:

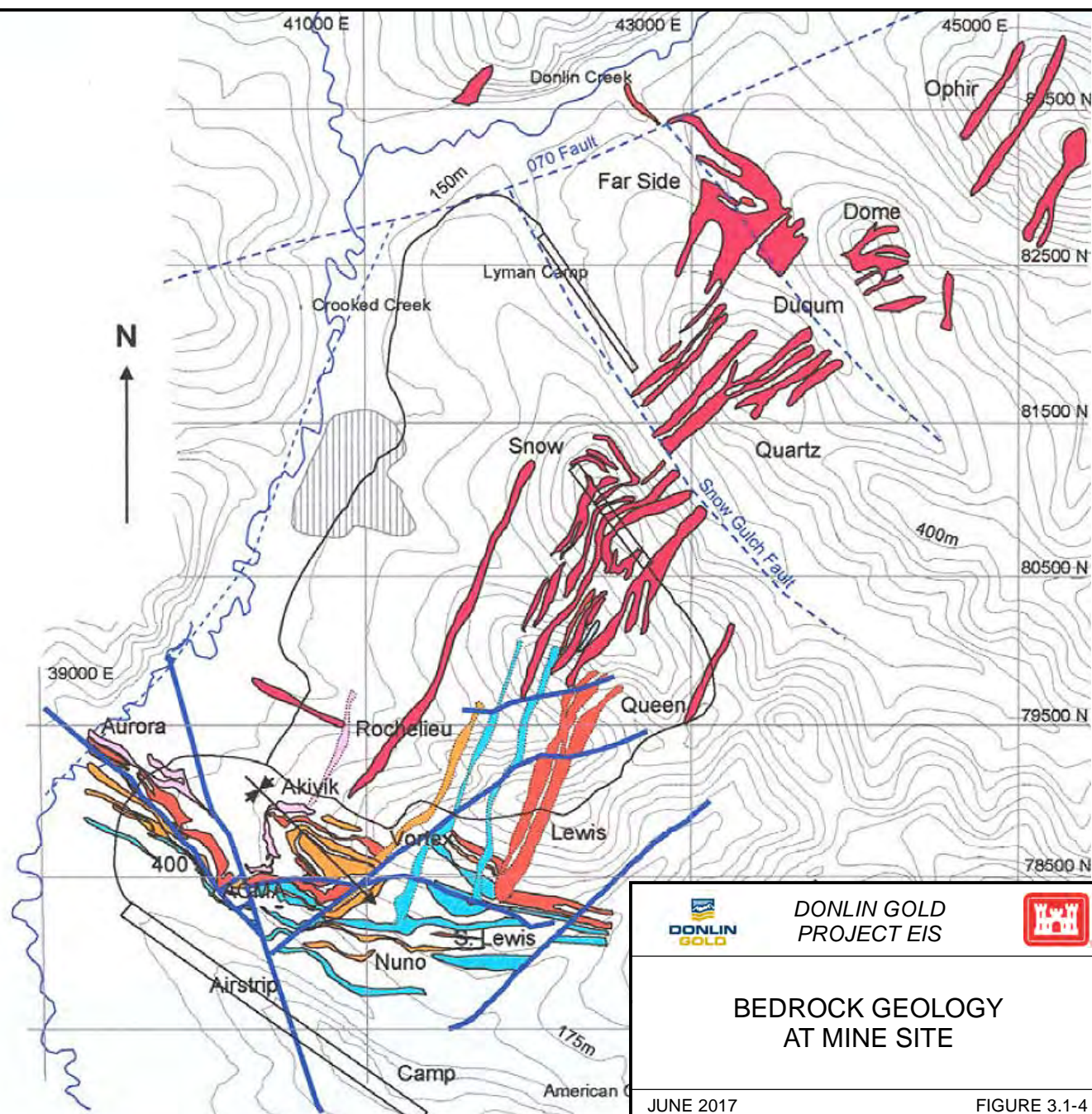
- Aphanite Porphyry (RDA)
- Crowded Porphyry (RDX)
- Lath-Rich Porphyry (RDXL)
- Blue Porphyry (RDXB)
- Undifferentiated Intrusive Rocks
- Kuskokwim Group Sedimentary Rocks
- Faults
- Syncline Showing Axis and Plunge

Ophir Gold Prospect Mine

- Placer Mining Area
- 25m Topo Contour
- Creeks
- Roads
- Airstrips

1000 Meters

Data Sources: Hanson et al. 2009



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BEDROCK GEOLOGY AT MINE SITE

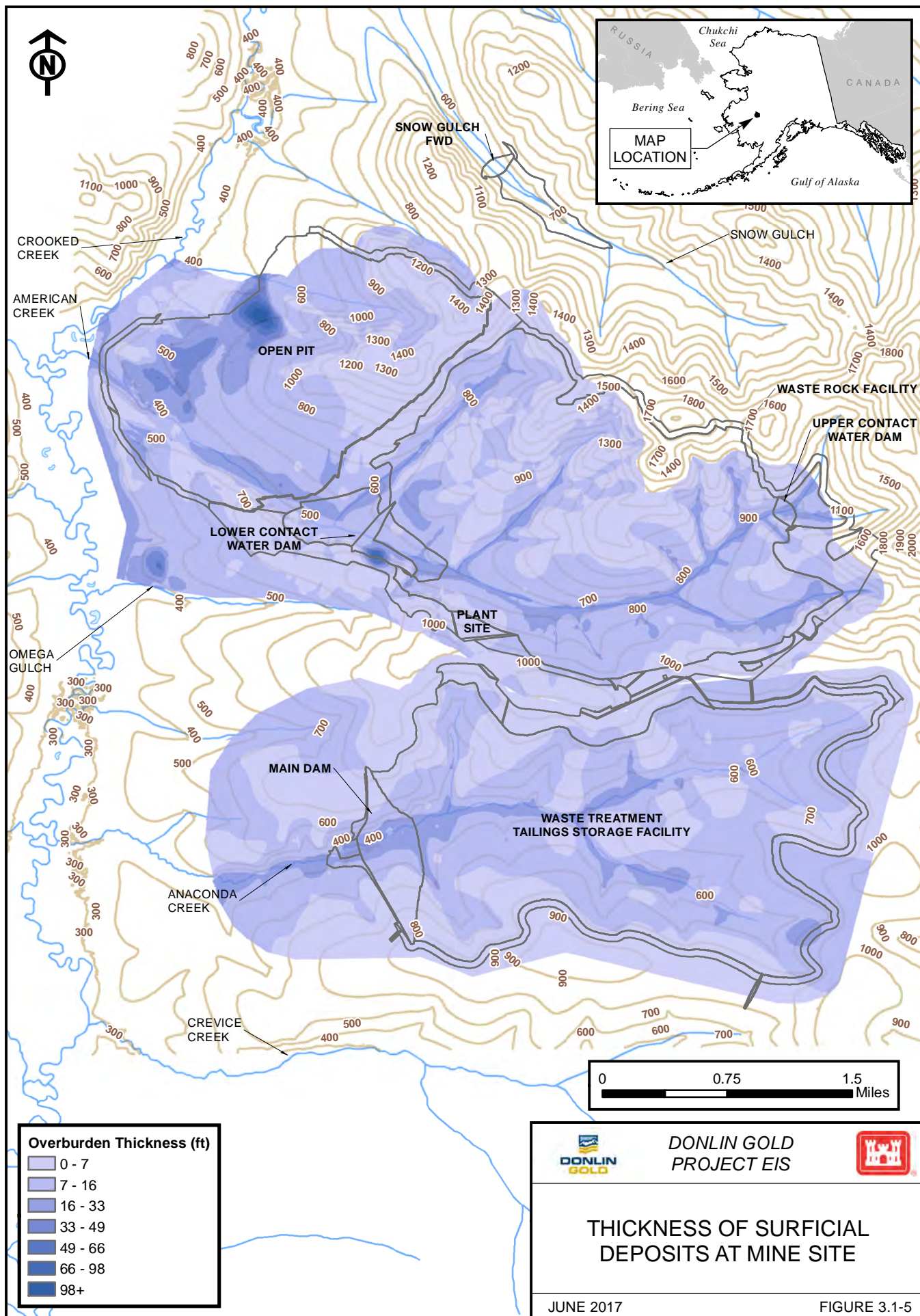
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FIGURE 3.1-4

Geotechnical studies conducted in 2004 through 2011 for the proposed Donlin Gold Project inspected surficial geology baseline conditions in and around the Mine Site. These studies included geophysical surveys, excavation of soil test pits, drilling of exploratory borings, installation of groundwater wells, hydrogeological testing, landslide surface investigations, open pit slope stability analysis, fault studies, permafrost investigations, and geochemical testing for ore processing. The geophysical surveys consisted of shallow surface seismic refraction and downhole shear wave testing. Approximately 4,350 feet of seismic refraction surveying was conducted across nine separate seismic traverses at the mine site facility. The downhole shear wave tests were conducted in three test borings, one at the proposed location of the Upper Contact Water Dam (CWD) and two at the proposed plant site. The purpose of the geophysical surveys was to evaluate the thickness of unconsolidated material above bedrock and to assess the competency (seismic stability) of the bedrock (BGC 2009a). More than 100 test pits were excavated and over 200 exploratory borings were drilled at select locations in the mine site area for analysis of soil and rock physical characteristics. Soil and permafrost are described in Section 3.2, Soils, and other geotechnical conditions in Section 3.3, Geohazards and Seismic Conditions. Groundwater wells were installed in more than 50 of the exploratory borings. Hydrogeological conditions of the Mine Site are presented in Section 3.6, Groundwater Hydrology.

The thickness of surficial deposits identified during the geotechnical studies is shown on Figure 3.1-5. These include colluvium, alluvium, loess, and glaciofluvial deposits as described below (BGC 2005, 2007a, 2009a, 2010, 2011d):

- Colluvium was reported to vary from 0.7 feet thick on ridge tops to up to 20 feet thick in the American Creek drainage, and reaches a maximum thickness of 47.5 feet within the Mine Site in the area south of Lewis Gulch. The colluvium was found to consist of mostly fine-grained material at lower elevations where the thickest portions were measured (BGC 2009a). The colluvium generally includes gray to brown, medium dense, sandy to silty gravel with clay and trace wood fragments; gravel clasts (individual pieces) are blocky, and angular to sub-rounded.
- Alluvium was reported along the length of Crooked Creek in the mine site area and along associated tributary channels. Borehole data indicate thicknesses ranging from 6.5 to 33 feet within the Crooked Creek floodplain. The alluvium ranges from fine sandy silt with trace gravel, to coarse-grained stratified gravels, sands, and silts; which are medium-dense with rounded to subangular gravel clasts.
- Loess was observed throughout the mine site area on ridge tops and stream drainages, as a thin layer ranging from 0.3 to 3.3 feet thick. The loess was found to be light to medium gray-brown, firm, sandy silt with some clay.
- Glaciofluvial deposits, found above the active streambed of Crooked Creek, were recognized as Pleistocene-age terrace gravels. These deposits lie stratigraphically below the loess and colluvium units, and have a measured thickness of up to 49 feet. The terrace gravels include oxidized surfaces, are of dense to very dense consistency, and contain well-graded, gravelly sand with minor silt and clay. Gravel clasts are sub-rounded to rounded and consist of both igneous and sedimentary rock types.



Mine Borrow Sites

Based on the work performed, there would appear to be surficial materials of sufficient quality and quantity to supply the project. The project has identified several locations for “borrow” sites to supply construction materials for the project. Quarried bedrock is blasted, mined, and processed to produce crushed stone, or aggregate, which is used for construction. Large-sized crushed stone, called riprap or armor rock, is typically used for erosion control at stream crossings and along rivers and shorelines. Borrow material gravel is used as sub-base, base, or surfacing on roads or building pad. Bedrock or gravel can be used as aggregate in concrete.

Several borrow material sites have been proposed at the Mine Site: two on ridges northeast of Snow Gulch and in the upper American Creek drainage south of the Upper CWD (Figure 2.3-1); and four along the east side of Crooked Creek, three of which would be co-located with (and predate) overburden stockpiles. The type of material expected at the two ridge sites includes a thin layer of colluvium and loess over weathered and fractured Kuskokwim Group sedimentary rocks. The type of material expected at the lower sites include mostly gravel and sand with some clay associated with alluvial terrace deposits along the ancestral Crooked Creek (Bundtzen 2004).

3.1.2.1.4 PALEONTOLOGICAL RESOURCES

Regional Setting

Cady et al. (1955) used 38 fossil locations to determine the age of the Kuskokwim Group sedimentary rocks as Late Cretaceous. Most fossils in the area consist of marine invertebrate fossils and are more abundant in the younger (upper strata) of the Kuskokwim Group. Fauna include pelecypod and cephalopod mollusks, as well as annelid worms, brachiopods, and barnacles. Fish fossils occur locally, and where present, are abundant. Flora fossils include terrestrial ferns and flowering plants. Most fossil material is fragmental, which suggests transport from place of origin prior to deposition.

Since Cady et al. (1955), Box and Elder (1992) and Elder and Box (1992) identify 15 Inoceramid bivalves of Late Cretaceous age in the Kuskokwim Group. Quaternary vertebrate fossils have also been reported in overlying sediments in the region (Reuther et al. 2014).

Mine Site Paleontology

Fossils potentially present at the Mine Site would likely be contained within Kuskokwim Group sedimentary rocks that have not been altered by hydrothermal processes (i.e., the non-ore-containing bedrock or waste rock); if such unaltered rocks are present at the Mine Site. Non-marine strata within the Kuskokwim Group, while rare, are known to contain fragmental plant fossils, which suggest the potential for dinosaur tracks and skeletal remains based on geologic similarities with other depositional settings of Cretaceous age, such as the Cantwell Formation of Denali National Park and Preserve (Alaska Dispatch News 2014; Fiorillo et al. 2014; Jacobus and Druckenmiller 2013). No obvious macrofossils have been found to date in nearby outcrops. Exposures of non-marine Cretaceous rocks do not occur in the mine site area (Reuther et al. 2014).

Figure 3.1-6 depicts PFYC values for the mine region. Part of the Mine Site is rated PFYC Class 2 (most of the open pit), indicating low fossil potential or the presence of invertebrate fossils from

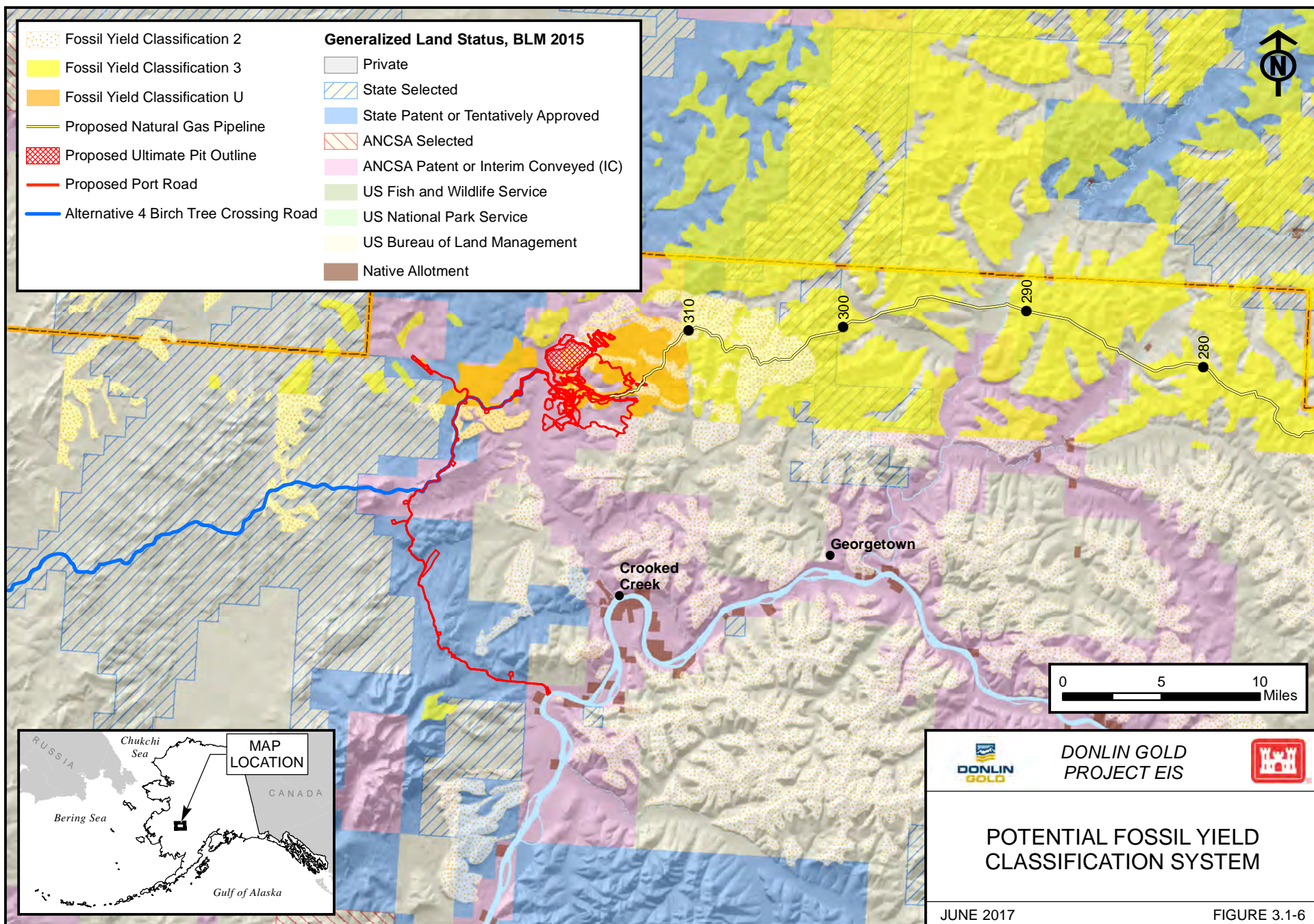
abundant species. In 2010, the BLM regional paleontologist classified the Kuskokwim Group rocks as PFYC 3 (Armstrong 2010), which at the time meant moderate to unknown fossil potential. Under the updated PFYC guidance (BLM 2016) this would place the Kuskokwim Group as a PFYC 3 or U. Lindsey's (1986: 9, 51) statewide paleontological review stated that "no special management" of Kuskokwim Group rocks was necessary due to significant fossil concerns. Preliminary desktop fossil inventories conducted for the project initially classified part of the Mine Site as PFYC U (east and south sides of pit, and areas beneath the WRF and TSF), meaning these rocks have unknown fossil potential and that further reconnaissance and research may be necessary to determine potential impacts, a designation which derives primarily from the possibility of the presence of dinosaur fossils (Druckenmiller et al. 2013). Subsequent field investigations, consisting of aerial and pedestrian survey of the mine site area, found no evidence of vertebrate fossils, and further found that exposures of the Kuskokwim Group are rare in the area (Reuther et al. 2014). Thus these areas of the mine sites are more accurately represented by a PFYC assignment of 3, in that the Kuskokwim Group is known to contain marine invertebrate fossils, and has a moderate potential for significant vertebrate fossils, but these occurrences are widely scattered. The potential to impact a significant fossil locality is low in the PFYC 3 areas underlying the WRF and TSF and east and south sides of pit, but is somewhat higher for common fossils.

Drilling activities at the Mine Site, on the eastern margin of the WRF area, identified the presence of plant fragments, suggesting a non-marine sediment source, and suggesting the potential for land animal fossils (Druckenmiller et al. 2013). Marine invertebrate fossils--gastropods, shell fragments, and fauna of *Inoceramus* species shells--were also observed at a drill site within a 3-foot thick mudstone layer bounded by lime-rich turbiditic sandstone. By the criteria detailed in Section 3.1.1.2, these common invertebrates remains are not considered significant paleontological resources, though the leaf fragments may suggest a non-marine source for sediments and possibility for additional terrestrial fossils.

3.1.2.2 TRANSPORTATION CORRIDOR

3.1.2.2.1 PHYSIOGRAPHY

The majority of the proposed transportation facilities (roadway, river port, and new/upgraded dock facilities) lie within the same physiographic region as the Mine Site, the Kuskokwim Mountains, as well as the adjacent Yukon-Kuskokwim (Y-K) Coastal Lowland sub-province of the larger Bering Shelf province (Figure 3.1-1) (Wahraftig 1965, 1994). The Y-K Coastal Lowlands consist of low-lying plains rising from just above sea level to elevations up to 300 feet. The Kuskokwim River is charged by low-gradient, meandering streams within the Y-K Coastal Lowlands; it discharges southward into Kuskokwim Bay.



The Angyaruaq (Jungjuk) and Birch Tree Crossing (BTC) road alternatives and their respective port sites are located within the Kuskokwim Mountains, which are drained on the north by the Yukon River and to the south by the Kuskokwim River. The BTC Port alternative crosses a portion of the Yukon River drainage where the Iditarod River drains north to the Yukon. Glacial landforms have been recognized in the higher elevations of the Kuskokwim Mountains, such as in the Russian and Horn Mountains along the road alternatives (Meyer 1985; Kline and Bundtzen 1986). The proposed roads would begin at the Mine Site at an elevation of approximately 500 feet and descend to elevations of approximately 200 feet at the proposed Angyaruaq (Jungjuk) Port site and 150 feet at the BTC Port site, located 14 miles downstream from Aniak. The proposed road from the Mine Site follows the same route in both alternatives until the southwest end of Juninggulra Mountain, where the two routes diverge (Figure 2.3-42, Chapter 2, Alternatives). The proposed Angyaruaq (Jungjuk) route heads south from that point, traverses the north flank of the Horn Mountains, then runs east to the mouth of Jungjuk Creek on the Kuskokwim River. The proposed BTC access road heads west from the point of divergence, then southwest towards Molybdenum Mountain and Cobalt Creek, traverses the northwest flank of the Russian Mountains parallel to the Owhat River, then runs west across numerous streams flowing from the uplands of the Portage Mountains north of Aniak.

The riverine transportation route from the Angyaruaq (Jungjuk) and BTC port sites descends to an elevation of approximately three feet at Bethel. Bethel lies in the Yukon-Kuskokwim Coastal Lowlands, approximately 199 river miles downstream from the proposed Angyaruaq (Jungjuk) Port site and approximately 124 river miles downstream from the proposed BTC Port site. The Bethel fuel depot and port (a connected action) would be located in the southwest section of the community, near the existing Bethel Fuel Sales pumphouse and tank farm on the western cut bank of the Kuskokwim River.

Proposed transportation facilities outside the immediate area include additional facilities at Dutch Harbor, approximately 460 miles south-southwest of the mouth of the Kuskokwim River, across Bristol and Kuskokwim bays. The town of Dutch Harbor lies on Amaknak Island adjacent to the larger Unalaska Island, and the body of water referred to as Dutch Harbor lies between the two islands (Figure 2.3-8). In physiographic terms, the Dutch Harbor fuel storage depot is located in the Aleutian Islands sub-province within the larger Alaska-Aleutian province of the Pacific Mountain System physiographic division (Wahrhaftig 1965, 1994). Amaknak and Unalaska islands are bounded to the north by the Bering Sea and to the south by the Pacific Ocean. The Aleutian Islands form an arcuate chain of volcanoes (Aleutian Arc) extending westward from the southern Alaska Range (Aleutian Range) approximately 1,000 miles to its terminus at Attu Island. Volcanoes dominate the topography of the Aleutian Islands, with elevations varying from 2,000 to 9,000 feet (Wahrhaftig 1965).

3.1.2.2.2 BEDROCK GEOLOGY

Upper Kuskokwim Area

Bedrock is exposed along the proposed transportation corridor upriver of Kalskag. The regional bedrock and structural geology of this area is similar to that described for the Mine Site (Section 3.1.2.1.2).

The bedrock geology of the proposed Angyaruaq (Jungjuk) Road and port site is dominated by Late Cretaceous age Kuskokwim Group sedimentary rocks (Cady et al. 1955; Hoare and

Coonrad 1959a; Decker et al. 1994; Wilson et al. 1998). These rocks are intruded by a Late Cretaceous through Tertiary age igneous complex exposed in the Horn Mountains as far north as Juninggulra Mountain. The Horn Mountains igneous complex is an ancient volcanic center, made up of intrusive quartz monzonites, volcanic rhyolites, andesite, and granite porphyry (Hoare and Coonrad 1959a; Wilson et al. 1998).

The proposed BTC Road alternative follows the same path as the Angyaruaq (Jungjuk) route, until the point of divergence at Juninggulra Mountain. From Juninggulra Mountain west to the Iditarod River and in the Cobalt Creek area north of Russian Mountain, BTC route bedrock is dominated by sandstone, shale, and limestone of the Kuskokwim Group (Hoare and Coonrad 1959a; Bundtzen and Laird 1991; DMA 2007a; Reger et al. 2003c). Russian Mountain is recognized as a Late Cretaceous through Tertiary igneous complex similar to the Horn Mountains, but larger in size. The central portion of the proposed BTC Road traverses the north half of this igneous complex, which is dominated by basalt and andesite, with andesite to dacite flows and tuffs, and volcanic agglomerate (Bundtzen and Laird 1991). The north-trending Aniak-Thompson Creek Fault truncates rocks of the Kuskokwim Group and the Russian Mountains igneous complex near the Owhat River crossing (Decker et al. 1994; Wilson et al. 2013). West of the Owhat River, the Portage Mountains consist of Permian and Triassic age deformed volcanic and sedimentary rocks. The volcanic rocks here include flows, lahars (mud-flows), tuff, diabase, and andesitic breccia. The sedimentary rocks include graywacke sandstone, mudstone, calcareous conglomerate, and limestone.

Bedrock is exposed in bluffs and cut-banks along the Kuskokwim River upriver of Kalskag (Cady et al. 1955; Meyer 1985; Miller et al. 2002). River bluff exposures near Aniak exhibit deformation features that provide evidence of the Aniak-Thompson Creek Fault (Decker et al. 1994). There are no bedrock exposures in the Bethel community area (Dorava and Hogan 1995). Exploration test wells have recorded bedrock at depths greater than 500 feet in this area.

Dutch Harbor

The general geologic setting of Dutch Harbor includes Tertiary age sedimentary and volcanoclastic rocks of the Unalaska Formation, intrusive rocks, and Quaternary age volcanic rocks of Makushin volcano (Drewes et al. 1961; Lankford and Hill 1979; Decker et al. 2012a). The bedrock geology of Amaknak Island includes hydrothermally altered andesite and basalt volcanic rocks (Lemke and Vanderpool 1995). The Unalaska Formation is the dominant bedrock on the portion of Unalaska Island adjacent to Dutch Harbor, and consists of volcanic breccias, flows, tuffs, and intermixed sedimentary rocks (Lankford and Hill 1979).

3.1.2.2.3 SURFICIAL GEOLOGY

Kuskokwim River Corridor

Surficial deposits along the Kuskokwim River include coarse- and fine-grained alluvium, colluvium associated with hilly regions in the upper river, glacial moraines and associated drift (till)⁶, fluvial floodplain deposits associated with the Kuskokwim River, and marine coastal deposits mixed with alluvial sediments (Karlstrom et al. 1964). The Kuskokwim River floodplain has been dominated by deposition of fluvial material since the last glacial advances

⁶ Glacial drift or till is non-sorted, non-stratified, thin-layered material deposited by glacial action.

in the Alaska Range (Péwé 1975). Thick deposits of overbank flood, slack water deposits, and fluvial bar accretion deposits result from action associated with the Kuskokwim River in the Aniak area (Dorava 1994). Overbank flood deposits have been observed to be up to 33 feet thick and consist of silt and fine sand. Slack water deposits are found in sloughs and oxbow lakes and contain a higher proportion of organic material. Bar accretion deposits consist of sand and gravel with minor amounts of silt, which occupy the banks and bars of the Kuskokwim River. Marine coastal deposits south of Bethel include delta deposits and older coastal deposits, with a mixture of marine coastal and non-marine alluvium, including glacial drift.

Jungjuk Road and Port

Surficial Geology

Geotechnical studies conducted in 2005 through 2010 for the Donlin Gold Project inspected local baseline conditions in this area. These studies included excavation of 50 soil test pits, 37 exploratory borings, and borrow material site investigations. Fourteen of the borings were completed at the proposed Angyaruaq (Jungjuk) Port site and were advanced to depths ranging from 11.5 to 60 feet (DMA 2007b). Twenty-three boreholes advanced to depths ranging from 6 to 26 feet were completed along the access route from Juninggulra Mountain to the Angyaruaq (Jungjuk) Port site (RECON 2011a).

The stream channels and hill slopes of the proposed Angyaruaq (Jungjuk) Road and Port site are generally underlain by unconsolidated surficial deposits of colluvium and alluvium (Wilson et al. 1998). The floodplain of Crooked Creek west of the Mine Site consists of a mixture of organic material, silt and sand up to three feet thick, overlying alluvial gravel above weathered bedrock. Ridge tops between Crooked Creek and the proposed Angyaruaq (Jungjuk) Port site contain frozen colluvial silt up to six feet thick over weathered broken bedrock. Accumulations of glacial till were also observed mantling bedrock in this area. The drainages of Getmuna and Jungjuk creeks contain alluvium and colluvium consisting of sandy and cobble gravel, silty sand, and silt layers up to 26 feet thick, over broken bedrock and in lower elevations frozen glacial till (RECON 2011a).

The proposed Angyaruaq (Jungjuk) Port site slopes gently to the south. The site is bordered to the southwest by Jungjuk Creek and to the south by the Kuskokwim River. Sixteen test borings advanced in 2005 through 2007 at the site indicate that alluvium is the dominant surficial deposit, consisting of silt and sand overlying gravel cobbles and gravelly sand. Silt and sand layers exhibit soft to medium dense consistency, and range in thickness from 6 to 45 feet (DMA 2007b). The underlying gravel exhibits medium to very dense consistency with thicknesses ranging from 5 to 16 feet.

Borrow Material Sites

Based on the work performed, there would appear to be surficial materials of sufficient quality and quantity to supply the project. Route inspections along the proposed Angyaruaq (Jungjuk) Road were conducted to investigate the consistency and quality of bedrock and surficial deposits for suitability as construction aggregate resources. For planning purposes, the maximum distance between material sites to be used for road fill purposes was 3.1 miles. The proposed volume of aggregate resource to be utilized from each site ranges from 50,000 to 2,500,000 cubic yards. Fourteen sites were investigated by excavating test pits to collect soil and

rock samples for grain size distribution and rock quality analysis. The material sites north of Juninggulra Mountain also involved advancing boreholes by diamond core drilling methods to depths up to 290 feet to ascertain depth of weathering and extent of fracturing in the bedrock. The inspections identified mostly coarse gravel in Getmuna and Jungjuk Creek valleys and varying qualities of igneous and sandstone bedrock along the ridges. The material sites (MS) are designated MS01 through MS10 and MS12 through MS15 from north to south as described below (DMA 2007b; RECON 2011a):

- Sites MS01 and MS08 are located on ridge tops that contain moderately weathered, highly fractured granodiorite with potential utilization areas of approximately 36 and 22 acres, respectively, that will require blasting.
- Sites MS02 through MS04 are located on ridge tops with gentle slopes containing highly weathered and fractured quartz sandstone. Two of the three sites are likely rippable, and one may require blasting below weathered bedrock. These have potential utilization areas of approximately 10 to 22 acres each.
- Site MS10 is located on a level alluvial plain in the Getmuna Flats area between the north and south forks of Getmuna Creek. It contains glaciofluvial outwash gravel alluvium that covers a potential source area of 208 acres. The coarse gravel at this site was found to be good quality aggregate suitable for use in producing concrete.
- Sites MS05 through MS07, and MS09 are located on moderate slopes that contain moderately weathered volcanic rock (rhyolite), with potential utilization areas of approximately three to 24 acres each that will require blasting.
- Site MS11 testing revealed poor quality rock; the site was removed from further consideration.
- Sites MS12 through 14 are located south of Basalt Pass on moderate slopes that contain basalt, with a total potential utilization area of approximately 100 acres that will require blasting. Physical testing indicates the rock from these sites is of high quality for a potential source of aggregate. Site MS13 is located in a section of the access road where a proposed bedrock cut extending approximately 65 feet is planned. The gravel alluvium resource from MS10 is planned for mixing with the basalt from MS12 through MS14 to create suitable aggregate for producing concrete.
- MS15 is located on a sedimentary ridge top. The rock at this location is highly fractured and weathered siltstone and greywacke. Blasting is likely to be required. This material could be used for crushed aggregate.

Birch Tree Crossing Road and Port

Surficial Geology

Surficial deposits in the upland valleys and stream courses along the route of the proposed BTC Road generally include alluvium in the larger drainages and their associated tributary streams, and colluvium on the hill slopes (Karlstrom et al. 1964; Reger et al. 2003c). North of the Russian Mountains, incised channels that cut through the igneous bedrock contain a variety of glacial

till, rock glaciers⁷, colluvium (talus), and alluvium (Bundtzen and Laird 1991). In the southeastern portion of the Portage Mountains the primary surficial deposit is colluvium (Reger et al. 2003c).

Geotechnical studies conducted in 2007 for the Donlin Gold Project inspected local baseline conditions along the proposed BTC Road corridor and port site. These studies included 92 exploratory borings advanced to depths ranging from 3.5 to 59 feet, and 37 material sites investigated for construction aggregate resource. The predominant surficial geologic units encountered along the BTC Road alternative during the geotechnical studies include the following (DMA 2007a; RECON 2007a):

- Colluvium and loess deposits associated with ridges and side slopes generally consist of silt, gravelly silt, and silty gravel overlying weathered bedrock, and range from less than five feet to more than 20 feet thick. Deposits are generally thinner along the ridges and uplands west of Juninggulra Mountain, and thicker in the western part of the route along the lower slopes of the Russian Mountains and in the Portage Mountains.
- Glacial outwash deposits, consisting of sandy and silty gravel and gravelly sand, occur beneath colluvium and loess along the west slope of the Russian Mountains.
- Alluvium ranges from silt and silty gravel in smaller drainages, to thick interbedded deposits of coarser gravel, sand, and silt in larger drainages -- such as Iditarod and Kaina creeks and the Owhat River. Alluvial deposits in Ones Creek near the Kuskokwim River reach more than 59 feet thick.
- Muskeg and bog deposits contain thick organic silt, silt, and peat to over 20 feet deep in some areas.

The BTC Port site slopes gently to the southeast, bordered by hills to the west and by Ones Creek to the east. The closest borehole to this site, located about 0.5 mile to the northeast along the road alignment, encountered a thick sequence of frozen sandy, gravelly silt to depths over 27 feet (DMA 2007a), material likely associated with loess or colluvium from the lower hill slopes and Kuskokwim floodplain alluvium.

Borrow Material Sites

Material sites along the first 11 miles (northeast end) of the proposed BTC route would be the same as those described above for the proposed Angyaruaq (Jungjuk) Road (MS01 through MS06). Thirty-seven additional material sites were investigated for construction aggregate resource along the BTC route from Juninggulra Mountain to the proposed BTC Port site. These are designated MS16 through MS52, numbered from east to west. The proposed volume of aggregate resource to be utilized from each site ranges from 20,000 to 1,500,000 cubic yards, and consists of the following (DMA 2007a; RECON 2007a, d):

- Roughly two-thirds of the 37 sites contain highly fractured and weathered sedimentary rock consisting of graywacke sandstone/siltstone. Ten of these sites covering approximately 339 acres appear rippable, and 14 sites covering 425 acres would require blasting;

⁷ A rock glacier is a mass of broken rock that moves down a sloping valley under its own weight or by the action of frost or interstitial ice.

- Eight quarry sites contain volcanic rock consisting of weathered and fractured rhyolite or basalt. Together these sites total about 294 acres and would require blasting;
- Five gravel borrow sites are located within alluvial floodplains. Four of these are associated with abandoned outwash plains of meandering streams along the north and west slopes of the Russian Mountains, and one is located in the Owhat River floodplain. These borrow sites cover a total of about 164 acres.

Bethel Port

The surficial geology of the Bethel Port site is dominated by alluvial deposits of the Kuskokwim River floodplain and reworked silt in upland deposits (Hoare and Conrad 1959b; Stevens et al. 2003; Wilson et al. 2013). The floodplain alluvium consists of mainly silt, sand, and gravel intermixed with fragments of wood and peat, but may also include beach sand deposits, clay-rich silt from estuarine deposits, and fine-grained wind-blown (eolian) sand. The upland deposits are separated from floodplain deposits by low erosional scarps, and are characterized by a surface consisting of large and small thaw lakes. The upland materials include reworked silt, sandy silt, and bog deposits (Wilson et al. 2013). Any actions that would occur at Dutch Harbor or the Port of Bethel at the Bethel Yard Dock are not part of the proposed action, and are considered connected actions (see Section 1.2.1, Connected Actions, in Chapter 1, Project Introduction and Purpose and Need).

Dutch Harbor

Surficial geologic units at Unalaska and Amaknak Islands consist of alluvium, glacial till, and slope deposits (Karlstrom et al. 1964). The majority of the material is comprised of disintegrated volcanic rock, Pleistocene age glacial deposits, and air-fall tephra deposits from Makushin volcanic field. Surficial deposits on Amaknak Island near the Dutch Harbor airport consist of 2 feet of glacial till made up of gravel cobbles in a silt and clay matrix, overlain by volcanic air-fall ash deposits (Drewes et al. 1961; Lemke and Vanderpool 1995). Beach cliff faces bordering the harbor are dominated by talus cones (Lemke and Vanderpool 1995). Alluvial deposits of coarse sand and gravel occur in active stream channels. Any actions that would occur at Dutch Harbor or the Port of Bethel at the Bethel Yard Dock are not part of the proposed action, and are considered connected actions (see Section 1.2.1, Connected Actions, in Chapter 1, Project Introduction and Purpose and Need).

3.1.2.2.4 PALEONTOLOGICAL RESOURCES

There are several documented fossil locations along the Kuskokwim River between the communities of Aniak and Sleetmute (Cady et al. 1955; Elder and Box 1992; Elder and Miller 1991; Reuther et al. 2014). Plant macrofossils have been found in the Cretaceous age sandstones and siltstones of the Kuskokwim Group in the region. The non-marine strata within the Kuskokwim Group are known to contain plant fossils, which are associated with the potential for dinosaur tracks and skeletal remains from similar geologic units. No significant vertebrate macrofossils have been found to date in outcrops within or near the project area; however, exposures of non-marine Cretaceous rocks are limited in the area (Reuther et al. 2014). The occurrence of Late Cretaceous age marine bivalves has been documented several miles upstream of the proposed Angyaruaq (Jungjuk) Port site and in the vicinity of Napaimute (Druckenmiller et al. 2013; Jacobus and Druckenmiller 2013). As discussed in Section 3.1.2.4

Kuskokwim Group rocks in the area are assigned as PFYC 3, moderate potential for significant fossils. The potential for the project to be sited on or impact a significant fossil locality is low, but is somewhat higher for common fossils.

The BTC Road corridor also crosses sedimentary rocks of the Kuskokwim Group, although outcrops are sparse in the western part of the route and associated fossil assemblages have not been identified (Bundtzen and Laird 1991). The BTC Port site lies partially on metasedimentary rocks of the Gemuk Group that are highly metamorphosed. While these rocks are correlated with fossiliferous limestone further west in the Portage Mountains, no fossils have been noted in Gemuk Group rocks in the vicinity of the BTC Port site (Bundtzen and Laird 1991; Hoare and Coonrad 1959a). Lindsey (1986) reports that “fossils from the Gemuk Group in this area are not abundant or diverse.” Thus, the Gemuk Group here is assigned as PFYC class 2, low potential for significant fossils. Localities containing important resources may exist, but would be rare and would not influence the classification. Assessment or mitigation is usually unnecessary except in rare or isolated circumstances. The probability for impacting vertebrate fossils or scientifically significant invertebrate or plant fossils is low.

Pleistocene vertebrate fossils (mammoth, bison), that are considered “significant” to paleontological research in accordance with BLM classification terminology (see Section 3.1.2.4), have been found in river bluffs about eight miles downstream of the Angyaruaq (Jungjuk) Port site. Similar stratigraphy exists along river bluffs further downstream near Napaimute, suggesting the potential for Pleistocene fossils in this area as well. Younger deposits in the vicinity of Jungjuk have low potential for paleontological remains (Reuther et al. 2014).

Vertebrate and invertebrate fossils have been documented in a sandstone, conglomerate, and turbidite member of the predominately volcanic Unalaska Formation southeast of Dutch Harbor. Fossils documented in these rocks, referred to as the Dutch Harbor Member of the Unalaska Formation, include early Miocene bivalves (*Chalmys* and *Pododesmus*) and bones and teeth of a marine mammal resembling a sea cow. The stratigraphic trend of the Dutch Harbor Member suggests that rocks underlying the port areas of Dutch Harbor are composed primarily of the non-fossiliferous upper volcanic sequence of the Unalaska Formation (Lankford and Hill 1979).

3.1.2.3 PIPELINE

3.1.2.3.1 PHYSIOGRAPHY

Alternative 2 – Donlin Gold’s Proposed Action

The proposed pipeline physical footprint includes the 316-mile-long ROW, terminal facilities, access roads, camps, storage yards, airstrips, and more than 60 borrow material sites. The proposed pipeline route crosses five physiographic sub-provinces: the Cook Inlet-Susitna Lowlands, the southern and west-central Alaska Range, the Tanana-Kuskokwim Lowlands, the Nushagak-Big River Hills, and the Kuskokwim Mountains (Figure 3.1-1) (Wahrhaftig 1965, 1994).

The proposed route begins along the western shore of Cook Inlet within the flat, glaciated Cook Inlet-Susitna Lowlands. The lowlands are bordered to the northwest by the foothills of the

Alaska Range. From Beluga the route extends along the east flank of Little Mount Susitna, then continues westward paralleling the Skwentna River.

Continuing northwest along the Skwentna and Happy River valleys, the proposed pipeline route enters the rugged, northwest-trending glaciated mountains of the Alaska Range with elevations ranging from 7,000 to 12,000 feet. Alternative 2-North Option would shift the proposed route from the south to the north side of Happy River as it passes through Happy River Valley between MP 84.8 and MP 112. An unnamed pass at the highest point along the proposed route lies at an elevation of about 3,900 feet between Threemile and So Long creeks. The climb up to the pass from Threemile Creek Valley gains over 1,300 feet elevation in a distance of approximately three miles, and the descent on the north side of the pass is equally steep. The proposed pipeline corridor exits the Alaska Range along the Jones River Valley into the Tanana-Kuskokwim Lowlands, crossing the South Fork of the Kuskokwim River near Farewell.

The proposed route heads southwest across the rounded mountain tops of the Nushagak-Big River Hills province, with elevations ranging from 1,500 to 2,500 feet, until reaching the Kuskokwim River. At the Kuskokwim River crossing (Mile Post [MP] 238), the route continues westerly and enters the Kuskokwim Mountains sub-province. The west end of the proposed pipeline corridor traverses Anaconda Peak at an elevation of approximately 2,200 feet and ends at the Mine Site at an elevation of approximately 500 feet.

Alternative 3B – Reduced Diesel Barging: Diesel Pipeline

Under Alternative 3B and Alternative 3B Options, an 18-inch diameter diesel pipeline would be constructed from Cook Inlet to the Mine Site to reduce required diesel barging on the Kuskokwim River. The diesel pipeline would be buried and located in the same corridor proposed for the Natural Gas Pipeline under Alternative 2 (Figure 2.3-14 in Chapter 2, Alternatives).with a connecting segment either to Tyonek or Port MacKenzie, depending on the option selected. Under Alternative 3B and Alternative 3B Collocated Natural Gas and Diesel Pipeline Option, an additional 19-mile segment between Tyonek and the start of the proposed corridor for the natural gas line would be constructed, for a total of 334 miles (Michael Baker Jr. 2013a). This additional segment would cross the Beluga River using horizontal directional drilling (HDD). Under the Alternative 3B Port MacKenzie Option, an approximately 48-mile pipeline would connect Port MacKenzie with approximately MP 28 of the Alternative 2 Natural Gas Pipeline corridor, with a total length of approximately 354 miles.

The affected environment for most of the Alternative 3B route would be the same as what is described under Alternative 2. The additional pipeline segments under Alternative 3B and Alternative 3B options are physiographically in the Cook Inlet-Susitna Lowlands (Figure 3.1-1). The lowlands are flat and formerly glaciated. The lowlands are bordered to the northwest by the foothills of the Alaska Range, and the west and south by Cook Inlet.

Alternative 6A – Modified Natural Gas Pipeline Alignment: Dalzell Gorge Route

The Dalzell Gorge route diverges from the Alternate 2 alignment at approximately MP 106.5 in the 2-mile wide Happy River drainage for roughly 5 miles before turning northwest at Pass Creek in the upper reaches of Ptarmigan Valley. The general physiography at the mouth of Pass Creek consists of a narrow drainage valley with an elevation of approximately 2,700 feet bordered by rugged, steep mountainous terrain. The route climbs the Pass Creek drainage up to

its headwaters at Rainy Pass Lake and the west side of Rainy Pass. From the mouth of Pass Creek, the route gains approximately 460 feet of elevation reaching Rainy Pass at an elevation of 3,160 feet. The route then descends the east side of Rainy Pass parallel to the Pass Fork of Dalzell Creek as the route enters the two-mile long Dalzell Gorge. Dalzell Gorge is characterized by steep, rugged terrain following the V-shaped Dalzell Creek drainage as it descends in elevation until emptying into the Tatina River drainage at an elevation of approximately 1,500 feet. The route crosses the Tatina River and then the South Fork of the Kuskokwim River near Rohn, then parallels the west bank of the South Fork Kuskokwim River as it heads toward the south side of Egypt Mountain and High Lakes at an elevation of approximately 1,700 feet before rejoining the Alternative 2 route at approximately MP 152.7.

3.1.2.3.2 BEDROCK GEOLOGY

Regional Setting

The regional geology of the western portion of the proposed pipeline corridor is similar to the geology of southwest Alaska as described for the mine site area (Section 3.1.2.1.2), with primary bedrock consisting of the deep marine sequence of the Cretaceous age Kuskokwim Group (Wilson et al. 1998). The rocks of the Alaska Range are separated into sequences which include, from west to east, parts of the Farewell terrane known as Dillinger and Nixon Fork sub-terrane, and the Kahiltna assemblage (Decker et al. 1994; Bradley et al. 2003; Nokleberg et al. 1994; Wilson et al. 1998, 2013). The Upper Cook Inlet region consists of Mesozoic and Cenozoic age sedimentary, volcanic, and plutonic rocks. The plutonic rocks are associated with the Late Cretaceous and Tertiary age Alaska–Aleutian Range batholith, and the sedimentary and volcanic rocks are associated with the Early Jurassic age Talkeetna island arc (Wilson et al. 2012; Haeussler and Saltus 2011). These rocks are intruded and overlain by Cenozoic volcanic rocks of the modern Aleutian magmatic arc (Wilson et al. 2012; Herriott et al. 2011). The west side of Cook Inlet is dominated by several active volcanoes, including Mount Spurr and Redoubt Volcano, located near the proposed pipeline corridor (Keith 1995; Schaefer 2012; AVO 2013).

There are two primary regional-scale structural features along the proposed pipeline corridor (Figure 2.3-33 in Chapter 2, Alternatives). The Denali-Farewell Fault system is the dominant morphological feature expressed along the northern flank of the Alaska Range. The southwest extent of the Castle Mountain-Lake Clark Fault system, and a sub-parallel splay off of that system called the Bruin Bay Fault, lie near the eastern end of the proposed pipeline route (Wilson et al. 2012; Haeussler and Saltus 2011; Koehler and Reger 2009, 2011). Seismic and other geologic hazards related to these faults are presented in Section 3.3, Geohazards and Seismic Conditions.

Local Bedrock Geology

Alternative 2 – Donlin Gold’s Proposed Action

Sedimentary rocks of the Beluga Formation and plutonic rocks of Little Mount Susitna are exposed near the east end of the proposed pipeline route. The Miocene age Beluga Formation is exposed in the Chuitna River drainage near Tyonek and consists of non-marine sandstone, siltstone, carbonaceous shale, and coal. Beluga Formation rocks encountered in wells in the Tyonek to Beluga area at depths of 4,000 feet define the top of one of the primary gas-producing zones of the Cook Inlet Basin petroleum province (ADNR 2009b). Shallow bedrock was

encountered on Little Mount Susitna in two geotechnical boreholes at depths of 3 to 12 feet (CH2MHill 2011b). Little Mount Susitna consists of Paleocene age granodiorite, tonalite, and monzonite dikes (Wilson et al. 1998, 2012).

Bedrock in the upper Skwentna River Valley consists of Cretaceous age sedimentary rocks of the Kahiltna sequence, Paleocene age granitic rocks, and Cretaceous to Paleocene age volcanic rocks (Wilson et al. 2012). The route is underlain by Kahiltna sequence rocks along Happy River, and Cambrian to Devonian age shallow marine carbonate rocks of the Dillinger sequence in the Tatina River drainage (Bundtzen et al. 1997). From the Jones River region southwest, bedrock consists of predominantly Dillinger sequence rocks until the Big River crossing, where Nixon Fork, Kuskokwim Group, and Kahiltna sequence rocks are exposed nearby (Bundtzen et al. 1997; Wilson et al. 1998). From Big River to the George River crossing, the proposed pipeline corridor crosses rocks of the Kuskokwim Group until reaching the end of the proposed pipeline at the Mine Site (Wilson et al. 1998).

Alternative 3B – Reduced Diesel Barging: Diesel Pipeline

Under Alternative 3B and Alternative 3B Options, the Diesel Pipeline segments between Tyonek and the start of the Natural Gas Pipeline corridor, and between Port MacKenzie and MP 28 of the Natural Gas Pipeline corridor are similar to what is described under Alternative 2 for the east end of the pipeline route. These optional segments are underlain by the Beluga Formation of non-marine sandstone, siltstone, carbonaceous shale, and coal. Shallow bedrock was encountered on Little Mount Susitna in two geotechnical boreholes at depths of 3 to 12 feet (CH2MHill 2011b). Little Mount Susitna consists of Paleocene age granodiorite, tonalite, and monzonite dikes (Wilson et al. 1998, 2012).

Alternative 6A – Modified Natural Gas Pipeline Alignment: Dalzell Gorge Route

The general bedrock geology along the Alaska Range section of Alternate 6A consists predominantly of marine sedimentary rocks of the Upper Jurassic to Cretaceous age Kahiltna sequence (Wilson et al. 1998, 2012). The Kahiltna sequence is made up of thin beds of black shale and dark gray sandstone with minor amounts of conglomerate, black chert, and limestone. The sedimentary rocks are moderately deformed and locally exhibit strong metamorphic textures. In this region of the Alaska Range, the Kahiltna sequence is very similar to the Kuskokwim Group to the west where the Mine Site is located (Flanigan 2011). Both rock sequences are recognized to have similar lithology and character, and some studies suggest they should be identified as the same rock unit (Wilson et al. 2012; Flanigan 2011; CH2MHill 2011b).

Isolated plutons of Paleocene to Late Cretaceous age intrusive rocks occur in the eastern portion of the Dalzell Gorge route and intrude the sedimentary Kahiltna sequence rocks. The Late Cretaceous age intrusive rocks include fine- to coarse-grained granite, granodiorite, and quartz monzonite. Smaller isolated stocks of Paleocene age intrusive rocks intrude through the Kahiltna sequence and consist of medium-grained granite, syenite, tonalite, quartz monzonite, quartz diorite, granodiorite, and minor diorite (Wilson et al. 2012).

3.1.2.3.3 SURFICIAL GEOLOGY

Regional Setting

Surficial units in the Cook Inlet coastal lowlands consist of Quaternary age deposits that record the advance and retreat of glaciers in the Cook Inlet Basin. The upper northwest shorelands of Cook Inlet contain glacial till deposits of gravel, sand, silt, and clay (ADNR 2009a; Karlstrom et al. 1964). From Tyonek to Little Mount Susitna, the area is dominated by Upper Pleistocene age glacioestuarine deposits and Holocene and Upper Pleistocene age alluvial fan deposits that transition into colluvium and talus beyond Little Mount Susitna (Reger et al. 2003b; Wilson et al. 2012). From Little Mount Susitna to the drainages of the Skwentna and Happy rivers, the predominant unconsolidated material includes Upper Pleistocene age glacial moraine and kame deposits, Holocene age floodplain alluvium and terraces, and Upper Pleistocene age glacial outwash plains and fans (Wilson et al. 2012).

The central Alaska Range is dominated by: glaciofluvial, colluvial, and alluvial deposits in steep mountainous terrain; glacial moraines and associated drift (till) in higher elevations; and fluvial, alluvial and colluvial deposits in the hilly regions of drainages on the north side of the Alaska Range (Wilson et al. 1998). On the North flank of the Alaska Range, from the South Fork Kuskokwim River to the Tatlawiksuk River, the proposed pipeline corridor crosses predominantly alluvial fan and floodplain material that has been deposited in the Kuskokwim River Basin since the last glacial advances of the Alaska Range (Pévé 1975). From there to the Mine Site, the upland valleys and stream courses of the Kuskokwim Mountains contain alluvium in the larger drainages and tributary streams, and colluvium on hill slopes (Karlstrom et al. 1964).

Local Surficial Geology

Alternative 2 – Donlin Gold's Proposed Action

In 2010 and 2013, geotechnical studies were conducted along the corridor to investigate local baseline conditions, collect and analyze soil samples for physical characteristics, and support development of terrain maps. These investigations included: the advancement of 530 exploratory boreholes, using direct push technology, to depths up to 27 feet; 50 test pits excavated to depths up to eight feet along the western segment of the route; and geophysical surveys and 15 air-rotary boreholes to depths up to 135 feet at six major river crossings to estimate the depth of bedrock and evaluate suitability of HDD methodology for pipeline installation (BGC 2013a, 2013c; CH2MHill 2011b).

Terrain mapping conducted by CH2MHill (2011b) identified five classifications of surficial deposits in GIS along the proposed pipeline route based on geologic origin and process:

- Alluvial and fluvial deposits consisting of sand and gravel, fine to coarse gravels, and sands with some silt;
- Colluvial deposits consisting of unsorted material with a wide range of particle sizes, including talus and landslide debris;
- Lacustrine and bog units consisting of peat and organic silt and clay deposited in lakes and ponds;

- Glacial deposits consisting of (1) outwash fans, terraces, and broad plains near ancestral glacial margins, consisting of stratified drift of gravel with sand and silt lenses, and glaciofluvial gravel, sand, and silt; and (2) till consisting of unsorted mixtures of mostly silt with gravel, sand, and clay deposited by glacial ice; and
- Residual deposits consisting of in-place weathered bedrock.

Additional terrain mapping completed by BGC (2013a) between about MP 75 and MP 150 classified surficial deposits based primarily on slope stability process: debris flow, slow mass movement (creep), rockfall, rock or debris avalanches, or river erosion (see Section 3.3).

The following paragraphs summarize the types of surficial deposits present along the proposed pipeline route from east to west (BGC 2013a, 2013c; CH2MHill 2011b):

- From MP 0 to MP 75, surficial units consist of glacial ground moraine and outwash deposits near the shore of Cook Inlet; sloping alluvial plain material on the lower slopes of Little Mount Susitna, which consist of reworked glacial till incised by active mass wasting and storm event slope erosion; and in the Skwentna River valley, glacial outwash, alluvial creek channel fill, hummocky ground moraines with isolated outwash terraces, and low elongate glacial drumlin-type hills surrounded with swamp bogs and small thaw lakes.
- From MP 75 to MP 150, surficial deposits consist of glacial outwash and fluvial sand and gravels of the Skwentna and Happy river valleys, debris flow material and bank slope colluvium through the unnamed pass and down to the South Fork of the Kuskokwim River, into broad glaciofluvial plain leading to the north edge of the Alaska Range (Figure 3.3-4, Section 3.3, Geohazards and Seismic Conditions). The majority of the valley bottoms consist of glacial till poorly graded silty gravels, then sandy gravel alluvium in the main river bed and stream floodplains. Lower valley slopes consist of colluvium talus and alluvium of silt and sand and glacial till ground moraine.
- Near MP 150 south of Farewell, lies a surficial mineral deposit consisting of yellowish brown, hydrothermally altered glacial drift with distinct silcrete (silica) or ferricrete (iron) alteration rinds. These deposits, known as the Farewell Mineral Licks, and frequented by buffalo and moose, consist of three circular exposures, up to 120 feet in diameter, that occur over a 0.5 mile distance along the trace of the Denali-Farewell Fault (Bundtzen et al. 1997; Owl Ridge 2013a).
- From MP 150 to MP 225, the proposed pipeline corridor traverses the Kuskokwim Lowlands consisting of sand and gravel alluvial fans and glacial outwash; several large braided streams that flow northward draining the Alaska Range; and terrain of past glaciations characterized by coarse- to fine-grained moraine and till deposits, hummocky silt dominated kames, large broad river drainages, and sporadic boulders. Terminal moraines⁸ at MP 185 and MP 195 form prominent morphological features in this area. The area west of Big River contains remnants of a stagnated large valley glacier including glacial till kames and kettle lakes, hummocky hills, and braided floodplain channels. The moraine at MP 195 marks an abrupt change to reworked ground moraine and recent outwash channel deposits related to the Big River glacier and older glacial

⁸ Terminal moraines identify the furthest advance of a glacier.

deposits. The rounded hilltops west of Tatlawiksuk River at MP 217 contain colluvium consisting of silt, sand, and gravel.

From MP 225 to MP 316, surficial deposits consist of mostly colluvium from mass wasting and bedrock weathering on ridges and hilltops of the Kuskokwim Mountains. The colluvium consists of silt, sand, angular gravel, and degraded bedrock. The lower hill slopes have thicker accumulations of these materials. The majority of the alluvial deposits in this area are composed of thick accumulations of glaciofluvial material.

Alternative 3B – Reduced Diesel Barging: Diesel Pipeline

Under Alternative 3B and Alternative 3B Options, the Diesel Pipeline segments between Tyonek and the start of the Natural Gas Pipeline corridor, and between Port MacKenzie and MP 28 of the Natural Gas Pipeline corridor are similar to what is described under Alternative 2 for the east end of the Alternative 2 pipeline route. These segments are underlain by glacial ground moraine and outwash deposits.

Alternative 6A – Modified Natural Gas Pipeline Alignment: Dalzell Gorge Route

Surficial deposits along the Dalzell Gorge segment of Alternative 6A are found within the flat-lying drainage basins and the slopes bordering stream channels. In the low-lying areas, surficial deposits include Holocene age alluvium along the major stream courses, consisting of sand and gravel from actively reworked deposits in bars and low terraces; outwash from present day glaciers; and small alluvial fans (Wilson et al.2012). The stream alluvial deposits are intertwined with Late Pleistocene age outwash from glacial moraines, consisting of well-bedded and sorted gravel and sand, and major glacial moraine and kame deposits of poorly bedded and sorted gravel and sand.

Holocene and Late Pleistocene age landslide and colluvial deposits, derived from downslope movement, occupy slopes bordering narrow stream channels. The landslide and colluvial deposits consist of mixed fragments of various sizes of bedrock, unconsolidated sand and gravel, and minor amounts of clay and organic materials (Wilson et al.2012). A 1.8-mile segment of the Dalzell Gorge route would be installed using HDD methodology to avoid these deposits and steep terrain (CH2MHill 2011b).

Material Sites

Alternative 2 – Donlin Gold's Proposed Action

Proposed pipeline construction estimates indicate that roughly 2,875,000 cubic yards of bedrock aggregate would be needed for pads, camps, airstrips, access roads, and trench backfill in ice-rich soils (SRK 2013b). Seventy potential material sites (gravel and bedrock) were identified for construction aggregate resources along the pipeline corridor from Beluga to the Mine Site. Of the identified material sites, 21 are on federal (BLM)-managed land and the remainder on state or other lands (Table 2.3-27, Chapter 2, Alternatives). Material sites on BLM-managed lands lie between MP 174 and MP 299 on the north flank of the Alaska Range and in the Kuskokwim Hills regions. There is the same overall number of material sites for the North Option.

The locations of borrow sites along the pipeline route are presented in Appendix D. These are designated MS00 through MS63 from east to west (with some site numbers used multiple times

followed by letter designations), and contain the following materials (CH2MHill 2011b; SRK 2013b):

- Twenty-seven material sites contain bedrock (26 sites contain sedimentary rock, and one site near Little Mount Susitna contains granitic rock). Two of the sedimentary rock sites contain a combination of bedrock and gravel. The bedrock quarry sites have a total potential affected area of approximately 500 acres. The largest of these are located in the Kuskokwim Hills. It is unknown how many of these sites would require blasting. Two of three material sites located in similar Kuskokwim Group sedimentary rocks along the mine access road were found to be highly weathered, fractured, and rippable, suggesting that many of the pipeline material sites could be rippable. The granitic rock material site is likely to require blasting.
- Forty-three material sites contain gravel, and have a total potential affected area of approximately 580 acres. Two bedrock sites also contain usable gravel resources. The largest of the gravel material sites, each with potential usage greater than 150,000 cubic yards, are located in the Cook Inlet Lowlands, Skwentna River Valley, near the South Fork Kuskokwim crossing, on the lower slopes of Beluga Mountain, in alluvial fan material near Farewell, and in glacial deposits near Big River.
- The North Option would utilize the same number of material sites; however, the anticipated area of effect would be reduced by approximately 30 acres, and the volume of gravel required would be reduced by approximately 200,000 cy. The North Option would not affect the use of bedrock aggregate resources.

Alternative 3B – Reduced Diesel Barging: Diesel Pipeline

Under Alternative 3B and Alternative 3B Options, the Diesel Pipeline segments between Tyonek and the start of the Natural Gas Pipeline corridor, and between Port MacKenzie and MP 28 of the Natural Gas Pipeline corridor are similar to what is described under Alternative 2 for gravel material sites. Under Alternative 3B and Alternative 3B Collocated Natural Gas and Diesel Pipeline Option, there would be up to five additional material sites containing glacial gravel deposits between the eastern end of the Natural Gas Pipeline corridor and Tyonek. Under the Alternative 3B Port MacKenzie Option, there would be up to 13 additional material sites.

Alternative 6A – Modified Natural Gas Pipeline: Dalzell Gorge Route

A total of 11 material sites were identified along the Dalzell Gorge section of Alternate 6A, all but one of which contain alluvial gravel (SRK 2013b). The Airfield Quarry at MP 108.5 would utilize sedimentary bedrock exposed along a ridge and has a potential utilization area of approximately 22 acres. The 10 alluvial gravel sites are located predominantly in stream channels and have a total potential utilization area of approximately 107 acres. The largest utilization would be from Dalzell Creek at MP 123.6 that has a potential utilization area of approximately 29 acres and would be used for constructing a camp, laydown yard, and airstrip (SRK 2013b).

3.1.2.3.4 PALEONTOLOGICAL RESOURCES

No known paleontological sites are reported from the proposed pipeline corridor footprint. Fifteen known paleontological sites are reported from within one mile of the proposed pipeline ROW (Table 3.1-1). All of these consist of marine invertebrate and leaf fossils, none of which would be considered “significant” by the criteria detailed in Section 3.1.1.2. The nearest known fossil site (see Table 3.1-1) is within 68 feet of the proposed pipeline ROW. Thirteen of the fossil sites are on non-federal lands; two are on BLM lands (Table 3.1-1).

Alternative 2 – Donlin Gold’s Proposed Action

Upper Skwentna River Area: No known fossil sites occur on, or within one mile, of the proposed pipeline ROW in the Upper Skwentna area. Regional fossil localities far from the pipeline ROW known from other areas in the Tyonek and Talkeetna quadrangles are associated with Tertiary age Kenai Group coal occurrences and Cretaceous age marine sedimentary rock. Based on comparison to the geologically similar fossil-bearing Chickaloon Formation, the Kenai Group might have the potential to contain fossils of plant impressions, petrified wood, amber; and trace fossils of invertebrates and vertebrates. Fossils in the deformed and locally metamorphosed Cretaceous rock include bivalves, and possibly other marine invertebrates. Given the scarcity of known fossils in the Kenai Group from the area, absence of significant vertebrate fossils, and widespread Quaternary surficial deposits, this area should be assigned PFYC class 2 in that these units are not likely to contain vertebrate fossils or scientifically significant non-vertebrate fossils. Management concern for paleontological resources in Class 2 units is generally low. Localities containing important resources may exist, but would be rare and would not influence the classification. The probability for impacting vertebrate fossils or scientifically significant invertebrate or plant fossils is low. Outcrops of these rocks are generally absent along the proposed pipeline corridor due to the prevalence of Quaternary surface deposits; however, the possibility does remain to encounter fossil-bearing substrates below the Quaternary deposits, or fossils amongst the Quaternary glacial outwash and till materials.

Alaska Range: The McGrath quadrangles (1:63,360) represent the northern portion of the Alaska Range crossed by the proposed pipeline footprint. Most fossil bearing strata in the region occurs on State lands consisting primarily of marine sediment. Within the general region, floral and faunal remains of late Cretaceous and Tertiary age have been documented along ridgelines in McGrath A-6 and A-6 quadrangles, in addition to well preserved Tertiary age plant fossils in the McGrath B-2 and B-3 quadrangles. The Dillinger Terrane consisting of deep water marine rock contains numerous graptolite-bearing fossil locales of Cambrian-Ordovician to Late Silurian age along the northern portion of the Alaska Range. Most of the known fossil localities in the southeast corner of the McGrath quadrangle (1:250,000) in the Alaska Range are associated with Cretaceous age Kahiltna Flysch sequence rocks. This sequence consists of locally metamorphosed and intensely deformed marine sediments bearing marine invertebrates which include bivalves.

Twelve fossil sites are reported from within 1 mile of the proposed pipeline in the Alaska Range region (Table 3.1-1). The nearest is within 380 feet of the pipeline. All of these consist of marine invertebrate and leaf fossils, none of which would be considered “significant” by the criteria detailed in Section 3.1.1.2. One of these sites lies on BLM lands; the remainder are on non-federal lands. The fossils are generally associated with the St. John’s Fm, Mystic Terrane, the

Windy-Fork Tonzona Group, or the Yukon-Tanana Terrane (Druckenmiller et al. 2013). The BLM regional paleontologist has preliminarily assigned a PFYC Class 3 to the Tonzona Group. Given the lack of known significant vertebrate fossils from these units, the classification for the Tonzona Group, and other geologic units crossed by the pipeline in the Alaska Range, should remain PFYC Class 3, moderate potential. Geologic units in the Alaska Range crossed by the proposed pipeline are known to contain non-vertebrate fossils, but these occurrences are widely scattered. The potential for a project to be sited on or impact a significant fossil locality is low, but is somewhat higher for common fossils.

Table 3.1-1. Fossil Sites Along Pipeline (within one mile)

Site ID	Distance to Pipeline ROW (ft)	Nearest MP	Landowner	Fossils	Age Estimate	Geologic Unit
ID002	996	307	BLM	Marine invertebrates (<i>Ostrea sp.</i> , <i>Incoceramus sp.</i>)	Late Cretaceous	Kuskokwim Group
ID003	68	304	State Selected	Leaf fragments (dicotlydon)	Late Cretaceous	Kuskokwim Group
ID004	5,097	302.5	State Selected	Marine Invertebrates (<i>Ostrea sp.</i> , <i>Inoceramus reach ensis</i>)	Late Cretaceous	Kuskokwim Group
MG065	4,473	173.25	BLM	Leaf and wood fragments (<i>Alnus evidens</i> ; <i>Alnus n. sp.</i> ; <i>Glyptostrobus sp.</i> ; <i>Metasequoia cf. M. glyptostroboides</i>)	Oligocene	Windy Fork-Tonzona Group
MG067	1,670	168.75	State Patent or Tentatively Approved (TA)	Leaf fragments (genus/species not identified/listed)	Middle Tertiary	Windy Fork-Tonzona Group
MG072	2,233	161.25	State Patent or Tentatively Approved (TA)	Marine invertebrates (Phaceloid corals; conodont data but species not listed)	Frasnian (early to late Devonian)	St. John's Hill Formation, Mystic Terrane
MG073	1,939	161	State Patent or Tentatively Approved (TA)	Marine invertebrates (corals, bryozoans, and brachiopods)	Frasnian (early to late Devonian)	St. John's Hill Formation, Mystic Terrane

Table 3.1-1. Fossil Sites Along Pipeline (within one mile)

Site ID	Distance to Pipeline ROW (ft)	Nearest MP	Landowner	Fossils	Age Estimate	Geologic Unit
MG167	380	158.25	State Patent or Tentatively Approved (TA)	Marine invertebrates (<i>Syringopora cf. S. rockfordensis</i> , <i>Smithiphyllum sp.</i>)	Frasnian (early to late Devonian)	St. John's Hill Formation, Mystic Terrane
MG168/ MG169	3,967	158.25	State Patent or Tentatively Approved (TA)	Marine invertebrates and foraminifera microfossils (<i>Tikhiella sp.</i> , <i>Paratikhiella sp.</i> , <i>Nanicella sp.</i> , <i>Multiseptida sp.</i> , <i>Kamaena sp.</i> , <i>Issinella sp.</i> , <i>Girvanella sp.</i> , <i>Evlania sp.</i> , <i>Eonodosaria sp.</i> , <i>Earlandia sp.</i> , <i>Cyrtospirifer sp.</i> , echinoderm debris, <i>indet.</i> , <i>Gravia levinsoni</i> , <i>Kloedenellid</i> , <i>Knoxites sp.</i> , <i>Gravia levinsoni</i> , <i>Cyrtospirifer sp.</i> , ostracodes, echinoderm debris)	Frasnian (early to late Devonian)	St. John's Hill Formation, Mystic Terrane
MG088	2,838	156.75	State Patent or Tentatively Approved (TA)	Marine invertebrates (<i>Atrypa sp.</i> brachiopods)	Middle to Late Devonian	St. John's Hill Formation, Mystic Terrane
MG096	2,260	155.75	ANCSA Patent or Interim Conveyed (IC)	Marine invertebrates (<i>Favosites</i> , <i>Alveolites</i> , and <i>Syringopora sp.</i> corals)	Middle Devonian	St. John's Hill Formation, Mystic Terrane
MG115	1,615	152.25	ANCSA Patent	Marine	Frasnian to Early	St. John's

Table 3.1-1. Fossil Sites Along Pipeline (within one mile)

Site ID	Distance to Pipeline ROW (ft)	Nearest MP	Landowner	Fossils	Age Estimate	Geologic Unit
			or Interim Conveyed (IC)	invertebrates (<i>Cyrtospirifer</i> sp. brachiopod and a pteroid clam)	Mississippian	Hill Formation, Mystic Terrane
MG148	1,857	131.75	State Patent or Tentatively Approved (TA)	Marine invertebrates (Pelecypods: <i>Entolium</i> sp., <i>Eopecten</i> sp.)	Jurassic	Tatina River Volcanics, Mystic Terrane
MG159	3,486	123	State Patent or Tentatively Approved (TA)	Microscopic marine invertebrates and foraminifera (Radiolarians, <i>Cibdelosphaera</i> fragment, sponge spicules) spicules	Devonian or Triassic	Yukon-Tanana Terrane

Source: Druckenmiller et al. 2013; Jacobus and Druckenmiller 2013; Lindsey 1986; Zhang and Blodgett 2017

Western Kuskokwim Hills: Known fossil localities in the Iditarod quadrangles are associated with Cretaceous age sedimentary sandstones and siltstones of the Kuskokwim Group, and include marine invertebrate, plant fossils, coal, and black organic residue. Though none have been documented, skeletal and trace (footprints) dinosaur fossils might be present in Kuskokwim Group units based on geologic similarities with other Cretaceous age depositional settings from other regions in Alaska. There are, however, few exposures of the Kuskokwim Group in this area and no such fossils have been found.

Three fossil sites are reported from within one mile of the proposed pipeline ROW in the Western Kuskokwim Hills (Table 3.1-1). The nearest is within 68 feet of the pipeline. All of these consist of marine invertebrate and leaf fossils, none of which would be considered “significant” by the criteria detailed in Section 3.1.1.2. All of the fossil sites here are associated with the Kuskokwim Group (Druckenmiller et al. 2013). As discussed in Section 3.1.2.1.4 the Kuskokwim Group should be classified as PFYC Class 3, moderate potential. Geologic units in the Kuskokwim Hills crossed by the proposed pipeline are known to contain non-vertebrate fossils, but these occurrences are widely scattered. The potential for a project to be sited on or impact a significant fossil locality is low, but is somewhat higher for common fossils.

Alternative 3B – Reduced Diesel Barging: Diesel Pipeline

Under Alternative 3B and Alternative 3B Options, the Diesel Pipeline segments between Tyonek and the start of the Natural Gas Pipeline corridor, and between Port MacKenzie and MP 28 of the Natural Gas Pipeline corridor are similar to what is described under Alternative 2 with regard to fossil potential in Quaternary surficial deposits, consisting of glacial ground moraine and outwash.

Alternative 6A – Modified Natural Gas Pipeline: Dalzell Gorge Route

As presented above under Alternate 2, numerous paleontological occurrences are recognized in the McGrath and Tyonek quadrangles that include the Alternate 6A route (Table 3.1-1). Thus, the paleontological occurrences for the Dalzell Gorge section of Alternate 6A are the generally same as those found in Alternate 2.

3.1.2.4 CLIMATE CHANGE

Climate change is affecting resources in the EIS Analysis Area and trends associated with climate change are projected to continue into the future. Section 3.26.3, Climate Change, discusses climate change trends and impacts to key resources in the physical environment including atmosphere, water resources, and permafrost. Effects from climate change to physiography, bedrock, surficial geology, and paleontological resources are limited to date, and future effects are generally associated with changes in permafrost and increased risk of erosion (discussed in Sections 3.26.3.3 and 3.26.3.2, Climate Change).

3.1.3 ENVIRONMENTAL CONSEQUENCES

This section describes potential impacts to geological resources as a result of the project. Table 3.1-2 provides the impact methodology framework applied to assessing direct or indirect impacts to geological resources based on four factors of intensity or magnitude, duration, extent or scope, and context (40 CFR 1508.27, described in Section 3.0, Approach and Methodology).

Table 3.1-2: Impact Methodology for Geological Resources

Type of Effect	Impact Factor	Assessment Criteria		
Changes to Physical Resource Character (General Physical Resources)	Magnitude or Intensity	Changes in resource character may not be measurable or noticeable.	Noticeable changes in resource character.	Acute or obvious changes in resource character.
	Duration	Resource would be reduced infrequently, but not longer than the life of the project construction, and would be expected to return to pre-activity levels at the completion of the construction activity.	Resource would be reduced through the life of the project and would return to pre-activity levels long-term (from the end of construction through the life of the mine, and up to 100 years).	Chronic effects; resource would not be anticipated to return to previous levels even if actions that caused the impacts were to cease.
	Extent or Scope	Impacts limited geographically; discrete portions of the EIS Analysis Area affected.	Affects resources beyond a local area, potentially throughout the EIS Analysis Area.	Affects resources beyond the region or EIS Analysis Area.
	Context	Affects usual or ordinary resources; not depleted or protected by legislation.	Affects depleted resources within the locality or region or resources protected by legislation, or resource hazards governed by regulation.	Affects rare resources or resources protected by legislation.

In evaluating impacts to geological resources, relevant factors for this project include:

- The area of the impacts. Larger project footprints change and modify the landforms over a bigger area. Areas covered with tailings piles or waste rock may no longer be accessible for other uses.
- Permanent decrease in the volume of resources remaining. For example, excavation and processing of the ore and aggregate removes these resources from the Project Area.
- Disruption/changes to landforms. This predominately consists of slope and elevation changes. This can also impact geotechnical stability.
- Modifications or reduction in unique resources. This could include a negative impact of the loss of high value fossils, or a beneficial impact of mining ore, which supports the project's purpose and need.

3.1.3.1 ALTERNATIVE 1 – NO ACTION

There would be no construction and operations of facilities, and no extraction or reduction of existing mineral resources or aggregate. Ongoing geological exploration would cease. Thus, there would be no direct or indirect effects on bedrock geology, mineral resources, surficial geology, aggregate resources, or paleontological resources from this alternative.

Not developing the mineral resources would contradict the objective of Calista in selecting these lands for their mineral development potential pursuant to ANCSA.

3.1.3.2 ALTERNATIVE 2 – DONLIN GOLD'S PROPOSED ACTION

Based on comments on the Draft EIS from agencies and the public, one route option has been included in Alternative 2 to address concerns due to pipeline crossings of the Iditarod National Historic Trail (INHT):

- North Option: The MP 84.8 to 112 North Option would realign this segment of the natural gas pipeline crossing to the north of the INHT before the Happy River crossing and remain on the north side of the Happy River Valley before rejoining the alignment near MP-112 where it enters the Three Mile Valley. The North Option alignment would be 26.5 miles in length, compared to the 27.2 mile length of the mainline Alternative 2 alignment it would replace, with one crossing of the INHT and only 0.1 mile that would be physically located in the INHT right-of-way (ROW). The average separation distance from the INHT would be 1 mile.

3.1.3.2.1 BEDROCK GEOLOGY AND RELATED RESOURCES

Mine Site

The Donlin Gold Project involves the construction, operations, reclamation, and closure of an open pit, hard-rock gold mine that would produce approximately 30 million ounces of gold over an estimated operational mine life of 28 years. Construction of the Donlin Gold Project would take approximately four years. The proposed mine would be a conventional truck-shovel open pit operation. Predominantly sulfide ore would be processed to produce an average of over 1 million ounces of gold annually. The ultimate pit would target the Lewis and ACMA

deposits and extend to a depth of approximately 1,850 feet from the highest point of the pit wall to final pit bottom. The mine would operate year-round and process an average of approximately 59,000 tons of ore per day.

Construction

As a result of Alternative 2, disturbance of bedrock would occur during site preparation, pre-stripping, haul road construction, aggregate production, and ramp-up to operations (pre-production across several areas within the overall mine site footprint. Construction of the TSF would potentially require excavation of weathered bedrock across approximately 130 acres underlying the dam. The initial ACMA pit area that would be excavated during the construction phase covers approximately 200 acres (Figure 3.5-19) (SRK 2017b). The process facilities, power plant, and fuel storage areas, which encompass approximately 480 acres, may require grading of a bedrock ridge. Two bedrock material sites located on the ridges above the mine encompass a total of approximately 240 acres.

During pre-production, approximately 10 million short tons (Mt) of ore would be blasted, excavated, and stockpiled for processing (SRK 2016d). Approximately 33 Mt of waste rock would be generated from blasting and excavating the ore during pre-production and placed in the Waste Rock Facility (WRF). Minor blasting of the bedrock material sites may also occur during construction. Approximately 5 Mt of waste rock from material sites would be utilized to construct foundation pads, rock drains, and roads. At the end of construction, roughly 17 Mt of waste rock would be utilized for construction of the TSF dam (SRK 2016d).

Potential direct impacts from construction activities and surface disturbances would expose bedrock at the Mine Site to erosion from potential channelization of runoff. The effects of erosion and mass wasting, as well as planned mitigation to address these issues, are covered in Sections 3.2, Soils, and 3.3, Geohazards and Seismic Conditions, respectively.

Direct impacts to bedrock during construction of Alternative 2 would involve acute or obvious changes in resource character due to ground disturbances and reshaping of landforms by blasting, excavation, and direct removal of weathered bedrock, waste rock, and ore. These changes would be such that localized bedrock resources would not be anticipated to return to previous levels. Landforms that would be affected include hills and ridges (Section 3.1.2.1.1, Physiography). The extent or scope of effects would be limited to discrete portions of the mine footprint. While the context of most geologic resources impacted by the project are usual or ordinary resources that are not depleted, the ore excavated during construction is a rare economic resource driving the purpose and need of the project.

Operations

Potential direct impacts from Alternative 2 during operations would involve processing of 546 Mt of ore that would be blasted, excavated, and stockpiled for processing (SRK 2016d). Approximately 3,000 Mt of waste rock would be blasted and excavated from the pit during operations. A small amount of this waste rock would be used for construction (about 100 Mt), or to backfill the pit in late operations (467 Mt), but most would be placed in the WRF (2,460 Mt), which would reach an ultimate elevation of about 1,700 feet at the end of operations, a difference in elevation up to about 600 feet higher than original topography (SRK 2016d). The shape of the WRF has been designed to conform to the surrounding natural landforms to the extent possible, and would not rise above surrounding topography. Minor blasting and

excavation of bedrock at material sites may occur during operations. Approximately 10 Mt of waste rock from these sites would be used to construct rock drains. The ultimate pit size at the end of operations would extend across about 1,460 acres. Bedrock beneath the WRF and TSF that would be covered during operations and inaccessible for future uses (such as mineral or aggregate extraction) encompasses about 4,610 acres.

The potential direct impacts on bedrock during Operations would be similar to Construction Phase impacts, and would include acute or obvious changes in resource character due to blasting, excavation, and removal/alteration of bedrock. These changes would be such that the localized resource would not return to previous levels. The extent or scope of effects would be limited to discrete portions of the mine footprint. The context would range from usual or ordinary to rare, depending on grade of the mineral resource.

Closure

The Donlin Gold Project would utilize a “design for closure” concept for reclamation and closure planning at the Mine Site. Design for closure incorporates methods for safe and efficient closure of the mine as an integral part of the mine design and operations. Implementing design for closure can have the effect of minimizing disturbance and the re-handling of materials. For example, some reclamation activities would be conducted concurrently with the operations phase of the project wherever possible in areas no longer required for active mining (SRK 2016a). Inactive or dormant areas of the WRF would be graded and contoured to aid in development of the vegetative cover and minimize impacts on other resources (e.g., water quality, soil erosion).

During closure and reclamation activities, about 2.5 Mt of potentially acid-generating (PAG) waste rock temporarily stored in the low-grade stockpile at the toe of the WRF would be moved to backfill portions of the pit (SRK 2016d), resulting in final elevation differences between the surrounding ground surface and the bottom of the backfilled pit of up to 600 feet. Potential direct impacts on bedrock from closure and reclamation activities would involve grading and contouring of the WRF, TSF, freshwater ponds, contact water ponds, road cuts and fills, power plant, ore processing facilities, safety berms around the pit rim, and areas of the pit designed to allow human access. Bedrock slopes and benches within the interior of the pit would not be graded. Haul roads in and around the pit would be smoothed of berms, except those necessary for erosion control and safety (SRK 2015g). Other road cut and fill areas would be contoured to match surrounding landforms as much as feasible.

The WRF cover would be designed to minimize infiltration through potentially acid generating (PAG) materials (discussed in Section 3.7, Water Quality). The cover itself would consist of non-PAG materials. At the completion of contouring, a layer of unconsolidated material from the North and South Overburden Stockpiles would be spread over the surface and overlain with an additional layer of growth media (topsoil and overburden). Closure of the TSF would include the reuse of non-PAG waste rock for cover material, overlain by overburden and growth media, and contoured to promote runoff and minimize infiltration. The use of growth media in reclamation throughout the Mine Site is expected to encourage revegetation, which is important to long term slope stability and erosion control.

Potential direct impacts on bedrock during Closure would range from immeasurable or unnoticeable physical changes in the pit where bedrock slopes/benches would remain as is, to noticeable changes in the resource character for the rest of the Mine Site, where shaping and

covering of waste rock and exposed bedrock would occur. These effects would be such that the localized resource would not return to previous levels. The extent or scope of impacts would be limited to mine site footprint. The context would mostly affect usual or ordinary resources that are not depleted.

Summary of Mine Site Impacts – Bedrock Geology and Related Resources

Potential direct impacts to bedrock at the Mine Site during Construction, Operations, and Closure of Alternative 2 would range from immeasurable or unnoticeable changes (e.g., areas of minor grading during closure) to acute or obvious changes in resource character (ground disturbances and reshaping of landforms by blasting, excavation, and fill). These activities would result in the alteration of about 556 Mt of ore and 3,100 Mt of waste rock from the 1,464 acre pit, and final elevation changes up to about 600 feet, which would not be anticipated to return to previous levels. All effects on bedrock would be local as they would be limited to areas within the mine footprint. While the context of most bedrock impacted by the project is usual or ordinary and not depleted, the ore is a rare economic resource driving the purpose and need of the project.

Transportation Corridor

Construction

Disturbance of bedrock resources from construction activities along the Transportation Corridor could occur along the proposed mine access road route, at the new airstrip and permanent camp, and the Dutch Harbor fuel storage facility. No bedrock exposures occur in the community of Bethel or along the Kuskokwim River downstream of Kalskag, or at the Angyaruaq (Jungjuk) Port.

Impacts to bedrock from cut and fill activities could occur along ridge and side-slope segments of the proposed 30-mile long mine access road and three-mile long airstrip spur road where shallow bedrock (bedrock less than six feet below the surface) is present. This occurs along roughly half of these road lengths, or a total of about 16 miles. The airstrip itself and permanent camp are also located on a ridge with potential shallow bedrock; these facilities would encompass approximately 23 and 10 acres, respectively. Indirect effects on bedrock from expansion of the Dutch Harbor fuel storage facility could encompass approximately five acres. Potential direct impacts to bedrock would occur at 12 out of 13 designated material sites along the mine access road where bedrock is present; these encompass a total of approximately 240 acres. Nine of the 12 sites would require blasting. Rock aggregate is a resource often found in the region. The total volume of bedrock aggregate that would be removed and used in transportation facilities construction under Alternative 2 is about 2.8 million cubic yards (cy) (Recon 2011a).

Potential direct impacts on bedrock along transportation infrastructure would range from immeasurable or unnoticeable where only minor excavating or reshaping of the landscaping occurs, to acute or obvious changes in resource character where blasting, reduction in material resources, or landform scars occur such as at borrow pits. Landforms that would be affected include primarily hills and ridges along the mine access road. The duration of effects would be such that these localized resources would not return to previous conditions. The extent or scope

of impacts would be limited to discrete portions of the Mine Site. In context, these changes affect usual or ordinary resources that are not considered depleted.

Operations

Potential direct impacts on bedrock during operations could occur from utilization of bedrock aggregate to rehabilitate/refurbish road base and stream crossing passages along the mine access road, and stabilize foundation pads and the airstrip. During operations, three of the 13 material sites along the road would remain open for this purpose (SRK 2015g). Potential direct impacts to bedrock would likely occur across a small portion of the remaining material sites, and may require some additional blasting. Blasting and excavation effects would vary in intensity and range from immeasurable to noticeable changes in resource character. Bedrock would not be anticipated to return to previous levels even if actions that caused the impacts were to cease. The extent or scope of impacts would be limited geographically to discrete portions of the Mine Site. The context would affect usual or ordinary resources that are not depleted and changes to landform character for the incremental amounts of aggregate used during operations may or may not be noticeable.

Closure

During Closure and post-Closure, the main access road from the Angyaruaq (Jungjuk) Port to the Mine Site, airstrip, and permanent camp would remain to provide access for required long-term monitoring and water treatment at the Project Area (SRK 2015g). As such, three of the 13 material sites would remain open to provide aggregate for long-term road and airstrip maintenance. Potential direct impacts to bedrock from these activities would be the same as those described above for Operations.

Ten of the 13 material sites would be reclaimed immediately after construction is completed (SRK 2015g) and the areas contoured to match existing landform to the extent practicable. The closure of the sites would reduce potential access to these common resources by other future users. Reclamation activities at bedrock material sites, which would be located on ridge tops and upper slopes, would involve minor grading, contouring, growth media placement, and revegetation; however, some bedrock may remain exposed in benched slopes in accordance with ADEC's Best Management Practices for Gravel/Rock Aggregate Extraction Projects (Shannon & Wilson 2012). Where graded and revegetated, the material sites are expected to remain stable and not result in adverse effects on other resources. Erosion control and inspection of material site reclamation are discussed in Section 3.2, Soils.

Potential direct impacts to bedrock material sites in closure from minor grading, contouring, and possible continued exposure to erosion (if slopes remain as is) would such that bedrock would locally not be anticipated to return to previous levels, even if actions that caused the impacts were to cease. The intensity of impacts would cause noticeable changes in resource character in discrete portions of the Mine Site. The context of impacts would affect usual or ordinary geologic resources that are not considered depleted.

Summary of Transportation Corridor Impacts – Bedrock Geology and Related Resources

Potential direct impacts to bedrock along Transportation Corridor facilities during Construction, Operations, and Closure of Alternative 2 would range in intensity from changes

in resource character that may not be measurable or noticeable (minor excavating or reshaping of the landforms) to acute or obvious changes (blasting, indefinite reduction of material resources, landform scars). Impacts would primarily affect areas along the mine access road with shallow bedrock, (less than 2 meters below the surface) which applies to about 16 miles of road; an additional 400 acres at other facilities (airstrip, camp, material sites); and reduction of about 2.8 million cy of bedrock aggregate resources. The extent or scope of these effects would not extend outside the facility footprints. The context of impacts would affect usual or ordinary resources that are not considered depleted.

Pipeline

Construction

Disturbance of bedrock resources from construction activities along the 316-mile long pipeline would mostly occur in the western portion of the route in the Kuskokwim Hills where shallow bedrock is present. Twenty-seven of the 70 material sites along the pipeline contain bedrock, all but four of which are located in the western third of the pipeline route. The bedrock material sites cover a total of about 500 acres. Some of these may require blasting, the need for which would be determined in final design (SRK 2013b); however, rock similar to that expected in the Kuskokwim Hills was evaluated in the northern part of the mine access road and found to be rippable. The total volume of bedrock aggregate planned for use in pipeline and related infrastructure construction is roughly 2.9 million cy. The North Option would not affect the use of bedrock aggregate resources.

Intermittent shallow bedrock is expected within trenching depth west of the Kuskokwim River crossing from about MP 246 to the Mine Site (SRK 2013b). Sporadic shallow bedrock is also expected along a short (one-mile long) segment of the pipeline on the southeast side of Little Mount Susitna. Most of the bedrock encountered in boreholes in these areas is weathered and unlikely to require blasting during trenching. Bedrock beneath the ROW in these areas would be subject to cut and fill construction in areas of steep cross-slopes. Shallow bedrock may also be impacted at other infrastructure sites in these areas, such as shoofly roads, camps, storage yards, and the Kuskokwim River airstrips. Bedrock impacts during HDD are described in Section 3.3, Geohazards and Seismic Conditions.

Potential direct impacts on bedrock along the pipeline would range in intensity depending on the type of activity conducted. Where only minor excavating or reshaping of the landforms occurs, the changes in resource character may not be measurable or noticeable. Blasting activities, indefinite reduction in material resources, or landform scars occur such as at borrow pits, acute or obvious changes in resource character would occur. Landforms that would be affected along the pipeline route are described in Sections 3.1.2.3.1 and 3.1.2.3.3. Potential direct impacts from ground disturbance at material sites could include loss of slope stability and accelerated erosion (discussed in Section 3.2, Soils). The extent or scope of these effects would not extend outside the facility footprints. The context of impacts would affect usual or ordinary resources that are not considered depleted.

Operations

Potential direct impacts from Alternative 2 on pipeline entities during operations would likely involve little to no disturbance of bedrock at pipeline infrastructure sites such as access roads,

airstrips, and material sites, as these are all planned to be reclaimed as soon as practicable following construction. Donlin Gold does not anticipate retention of material sites beyond the construction period. However, it is possible that selected sites may be reopened or retained for maintenance purposes. In this event, potential direct impacts would occur from bedrock aggregate utilization to rehabilitate/stabilize the ROW, stream crossings, and airstrips as needed. Potential direct impacts to bedrock in this case would occur across a small portion of any retained material sites and may require minor additional blasting. The intensity of these impacts would vary from measurable to noticeable changes in the bedrock character. The bedrock would not be anticipated to return to previous levels even if actions that caused the impacts were to cease. The extent or scope of impacts would be limited geographically to discrete portions of the Mine Site. Impacts would affect usual or ordinary bedrock resources that are not depleted. Changes to landform character for the incremental amounts of material used during maintenance may or may not be noticeable.

Closure

Potential direct impacts that could affect bedrock resources during closure would involve decommissioning of temporary infrastructure facilities that are located in shallow bedrock areas, such as access roads, airstrips, camps, material sites, storage yards, and ROW cuts in the Kuskokwim Hills portion of the pipeline route. During closure and reclamation, these facilities would be contoured to blend with original topography (SRK 2013b). Potential direct impacts to bedrock would be reduced by minor grading, contouring, topsoil replacement, and natural revegetation; however, some bedrock may remain exposed in benched slopes. Where graded and revegetated, the material sites are expected to remain stable and not result in adverse effects on other resources. Potential direct impacts on bedrock material sites and reclamation of pipeline infrastructure facilities in areas of shallow bedrock would cause noticeable changes in bedrock character. These changes would be such that bedrock resources locally would not be anticipated to return to previous levels, even if actions that caused the impacts were to cease. The extent or scope of impacts would be limited geographically to discrete portions of the Mine Site. Impacts would affect usual or ordinary bedrock resources that are not depleted.

Summary of Pipeline Impacts – Bedrock Geology and Related Resources

Potential direct impacts on bedrock along the pipeline during Construction, Operations, and Closure of Alternative 2 would range in intensity from changes in bedrock character that may not be measurable or noticeable (minor excavating or reshaping of the landforms) to acute or obvious changes (blasting, permanent reduction of material resources, landform scars). Impacts would primarily occur in the western portion of the route where most shallow bedrock exists, and potentially affect about 70 miles of ROW and associated infrastructure (camps, storage yards, airstrip); bedrock material sites covering a total of 500 acres; and a total reduction of about 2.9 million cy of bedrock aggregate resources. These impacts would be limited to discrete portions of the EIS Analysis Area and affect usual or ordinary resources that are not depleted.

3.1.3.2.2 SURFICIAL GEOLOGY AND GRAVEL RESOURCES

Mine Site

Construction

As a result of Alternative 2, disturbance of surficial geology would occur across most areas of the mine site footprint. During pre-production at the pit and initial construction of the mine facilities, overburden would be excavated from about 80 acres of the pit, from the first and third lifts of the WRF, and about 2,400 acres of the TSF; the material would be placed in the North and South Overburden Stockpiles which would receive approximately 1.3 and 4.7 Mt across approximately 320 and 160 acres, respectively. Four gravel material sites would be utilized for construction purposes, encompassing an area of approximately 360 acres. These are planned along the east side of Crooked Creek, three of which would be co-located with (and predate) the placement of overburden and growth media stockpiles. Approximately 6 Mt of overburden from the material sites would be utilized to construct foundation pads, rock drains, and roads (SRK 2016d).

Potential direct impacts from construction activities and ground disturbance would alter topography, and potentially expose unconsolidated materials to erosion. These potential impacts would be reduced by utilizing best management practices (BMPs) as described in Section 3.2.3.2.3 (Soils, Erosion, Mine Site) and Chapter 5 (Impact Avoidance, Minimization, and Mitigation). These impacts would cause acute or obvious changes in the character of surficial geology and gravel resources due to excavation, large scale redistribution of deposits, and reshaping of geomorphic landforms (hills and ridges). Resources would not be anticipated to return to previous levels even if actions that caused the impacts were to cease. The extent or scope of impacts would be limited to discrete portions of the Mine Site. Gravel resources are not often found in this area; however, demand for these resources is currently very low, and is likely to stay very low for the foreseeable future.

Operations

Potential direct impacts from Alternative 2 during operations would involve removal of overburden material across approximately 7,500 acres. Approximately 27 Mt of overburden would be generated from excavating the open pit and placed in the WRF. Roughly 860,000 tons of overburden would be utilized for TSF dam construction during operations (SRK 2016a, 2016d), and the North and South Overburden Stockpiles would receive an additional 5.5 and 6.7 Mt of overburden, respectively. Minor amounts of additional aggregate may be utilized during operations from the terrace gravel borrow pits. These ground disturbance activities could potentially expose unconsolidated material to erosion, unless mitigated by utilizing BMPs under a Multi-Sector General Permit (MSGP) for storm water discharges (discussed in Section 3.2, Soils).

The intensity, duration, extent, and context of impacts during Operations would be the same as described above for the Construction Phase.

Closure

The Donlin Gold Project would utilize a “design for closure” concept at the Mine Site. The arrangement of major facilities such as the ultimate pit walls, WRF, mill, and TSF have been

designed to limit overall ground disturbance beneath and between facilities, while allowing for the efficient extraction and processing of ore. Limited reclamation activities would be conducted during active operations, such as concurrent grading and contouring of inactive areas of the WRF, to minimize the volume of overburden stockpiles needing to be managed for erosion effects, minimize erosion and mass wasting effects at the WRF (Sections 3.2, Soils and 3.3, Geohazards and Seismic Conditions), and aid in early development of a vegetative cover.

Potential direct impacts on surficial deposits during closure and reclamation activities would involve backfill of approximately 14,000 tons of overburden in the pit (SRK 2016d), and minor grading and contouring of the mine facilities and areas of the pit that allow human access. Haul roads around the pit would be smoothed of berms except those necessary for erosion control and safety (SRK 2015g).

Growth media used in site reclamation would include reuse of stockpiled surficial deposits. The total area of reclamation at the Mine Site involving reuse of surficial deposits is roughly 9,000 acres. At the completion of contouring of successive tiers in the WRF, a layer of unconsolidated material from the North and South Overburden Stockpiles would be spread over the surface and overlain with a layer of growth media (SRK 2015g). TSF closure would also include a cover of waste rock overlain by overburden material and growth media. The finished surface would be contoured to promote controlled runoff and reduce the potential for infiltration through the cap. While the physical and chemical characteristics of the existing surficial deposits could impede potential vegetative growth and/or be susceptible to erosion, these effects would be minimized through reclamation practices such as tilling prior to media placement, surface roughening, and soil amendments (SRK 2015g).

Potential direct impacts on surficial geology and gravel resources during closure would involve noticeable changes in the character of the resource from grading and contouring. The duration, extent or scope, and context of impacts would be the same as described above for the Construction and Operations phases.

Summary of Mine Site Impacts

Potential direct impacts to surficial deposits and gravel resources at the Mine Site from Construction, Operations, and Closure of Alternative 2 would range in intensity from noticeable changes (grading and contouring during Closure) to acute or obvious changes in resource character (large scale redistribution of deposits, reshaping of geomorphic landforms). These activities would result in the changes to roughly 50 Mt of overburden covering about 9,000 acres and resources would not be expected to return to previous levels even if actions that caused the impacts were to cease. Covering surficial deposits with growth media would result in mitigating impacts to soil and vegetation. All effects on surficial deposits and gravel resources would be limited to areas within the mine footprint. Gravel resources in this area are not prevalent, but potential demand from other possible users is very low.

Transportation Corridor

Construction

Disturbance of surficial geology from construction activities along the transportation corridor would occur along the proposed mine access road route, at the new airstrip, the Angyaruaq (Jungjuk), port site, the Bethel Port site (a connected action), and the Dutch Harbor fuel storage

facility. Construction of the Bethel and Angyaruaq (Jungjuk) Ports would impact surficial deposits across approximately 16 and 21 acres, respectively. Surficial deposits excavated for construction of the Angyaruaq (Jungjuk) barge berth would be placed in a stockpile at the north side of the port facility. Impacts to unconsolidated material during construction would occur during cut and fill and grading activities along the proposed 30-mile long, two lane, mine access road and three-mile long spur road off of the mine access road to the new airstrip would impact roughly 300 acres. Surface disturbances at the airstrip would encompass approximately 100 acres. Indirect effects on surficial deposits from the expansion of the Dutch Harbor fuel storage facility could encompass approximately five acres.

Potential direct impacts to gravel resources would also occur at one of the 13 material sites along the mine access road. Material Site MS10 located on an alluvial plain in the Getmuna Flats area encompasses an area of approximately 200 acres. Gravel resources are somewhat limited in this region of Alaska; however current demand is also low. The volume of material that would be removed from this site and used in transportation infrastructure construction under Alternative 2 is roughly 1.5 million cubic yards (cy) (Recon 2011a).

Impacts on surficial geology and gravel resources as a result of Alternative 2 would range in intensity from immeasurable or unnoticeable where minor excavating or grading to noticeable changes in resource character where road cuts and fills are noticeable, and higher intensity impacts at the MS10 borrow site where large scale resource reduction would occur. These effects would extend through the life of the project and resources may not be anticipated to return to previous levels even if actions that caused the impacts were to cease. The extent or scope of impacts would be limited geographically to discrete portions of the EIS Analysis Area. Impacts would vary in context and may affect usual or ordinary resources that are not depleted or depleted resources within a region.

Operations

Potential direct impacts during operations would likely involve minimal disturbance to surficial geology and gravel aggregate along the transportation corridor. Impacts could occur from the use of gravel aggregate to rehabilitate/refurbish road base and stream crossings along the mine access road, and to potentially stabilize foundation pads, ports, and the airstrip, if MS10 remains open for this purpose during the operations period. In this event, impacts would likely occur across a small portion of this borrow site and the infrastructure requiring maintenance, and would include minor excavation, fill, and grading. The intensity, duration, extent, and context of impacts during Operations would be the same as described above for the Construction Phase.

Closure

During Closure and post-Closure, the mine access road, airstrip, and permanent camp would remain to provide access for required long-term monitoring of the project site. It is possible that the Getmuna Creek material site (MS10) would remain open to provide gravel aggregate for long-term road maintenance. Direct effects from these activities would be the same as described above for operations. Detailed plans for closure of MS10 have not yet been specified, but would likely include minor grading and contouring and/or possible creation of fish and wildlife habitat using ponds or stream connections in accordance with ADEC and ADF&G guidance (Chapter 5, Impact Avoidance, Minimization, and Mitigation). Closure may also preclude access

to these potentially important aggregate resources by other future users, although the current potential for other uses is low.

The Angyaruaq (Jungjuk) Port would be decommissioned and reclaimed during closure. Potential direct impacts to surficial deposits would involve minor grading and contouring to blend with original topography (SRK 2015g). Potential indirect effects from exposed surficial deposits causing erosion or impeding vegetative growth would be minimized through growth media placement, tilling and soil amendments.

The intensity, duration, extent, and context of impacts during Closure would be the same as described above for the Construction and Operations Phases.

Summary of Transportation Corridor Impacts

Potential direct impacts on surficial geology and gravel resources along the transportation corridor during the Construction, Operations, and Closure Phases of Alternative 2 would range considerably in intensity. Minor excavating or grading would cause changes in resources that may not be measurable or noticeable. However, activities at the MS10 borrow site would involve acute or obvious changes in resource character due to large scale resource reductions. Impacts would involve ground disturbance and landform alterations across a total of about 700 acres and reduction of about 1.5 million cy of gravel resources. Changes to surficial geology and gravel resources would extend through the life of the project and resources may not be anticipated to return to previous levels even if actions that caused the impacts were to cease. The extent or scope of impacts would be limited geographically to discrete portions of the EIS Analysis Area. Affected resources are mostly usual or ordinary and not considered depleted in context. However, the availability of gravel aggregate is somewhat depleted in this region of Alaska, although the current potential for other uses of the resource is limited.

Pipeline

Construction

Disturbance of surficial geology and gravel resources from excavation and grading activities during construction would occur at a number of facilities and locations along the pipeline. Except at fault crossings and stream crossings, construction of the pipeline would require excavation of surficial deposits in the 1.5- to 2.5-foot wide trench zone throughout the length of the pipeline (about 50 to 90 acres). The total ROW acreage that would be cleared for construction is roughly 4,150 acres (150 feet wide), with up to an additional 4,150 acres available (up to 300 feet wide) for additional temporary space that may be needed in areas of challenging ground conditions (SRK 2013b). There would be little to no impact on surficial deposits within the ROW in areas of wetland construction using mats or winter construction in flat terrain. Much of the ROW and access roads, however, are located in areas with cross-slopes that would require cut and fill construction. These conditions occur throughout most of the Alaska Range and Kuskokwim Hills portions of the route, are common in Cook Inlet Basin and upper Skwentna Valley, and occur intermittently along the north front of the Alaska Range. The total length of ROW requiring cut and fill construction and increased grading due to cross-slopes (generally greater than 6 percent) would be about 262 miles under Alternative 2. The length of cut and fill construction along the North Option would be roughly the same as the main route under Alternative 2. Conservatively assuming the maximum ROW width is needed for all of

these segments, the total area of impacts to surficial deposits would be roughly 8,300 acres. The total length of shoofly roads potentially requiring cut and fill construction is about 80 miles and would cover approximately 225 acres.

Six of the nine new airstrips (about 330 acres) under Alternative 2, and an additional new airstrip proposed along the North Option (about 15 acres), would also require some cut and fill construction. Specific siting was conducted to reduce the amount required for runway construction (SRK 2013b). Impacts to surficial geology during construction of the remaining airstrips and at storage yards, camps, stream crossings, and the compressor station would be mostly limited to minor disturbances during grading, leveling, and drilling activities across a total of roughly 500 acres.

Impacts to gravel resources would occur at 43 material sites encompassing roughly 580 acres. Direct effects on surficial deposits at material sites include exposure to erosion (Section 3.2, Soils); and excavation, removal, and redistribution of material. The total estimated volume of aggregate usage from gravel material sites under Alternative 2 is roughly 3.4 million cy (SRK 2013b, Donlin Gold 2017k). The North Option would utilize the same number of gravel material sites; however, the anticipated area of effect would be reduced by approximately 30 acres, and the volume of gravel required would be reduced by approximately 200,000 cy. The North Option would not affect the use of bedrock aggregate resources.

Potential direct impacts on surficial geology as a result of Alternative 2 would range considerably in intensity. Changes in resource character may not be measurable or noticeable where only minor grading occurs (e.g., at camps and storage yards). Changes would be noticeable where ROW, road, and airstrip cuts and fills are present. Acute changes would occur at gravel pits where landform scars are obvious and large scale resource reduction occurs. The duration of impacts would also vary considerably and may extend through the Construction Phase only, to chronic effects for some landform alterations. The extent or scope of effects would be limited within the Project Area. The context of impacts would affect usual or ordinary resources that are not depleted. Gravel resources are widely available in the glaciated deposits of Cook Inlet basin, Skwentna Valley, and braided rivers draining the Alaska Range, and less so in the Kuskokwim Hills. However, there is little demand for gravel resources outside of Cook Inlet basin.

Operations

Potential direct impacts during pipeline operations and maintenance would likely involve minimal disturbance to surficial geology and gravel aggregate at pipeline infrastructure sites such as access roads, airstrips, and material sites, as these are all planned to be reclaimed as soon as practicable following construction. Donlin Gold does not anticipate retention of material sites beyond the construction period. However, it is possible that selected sites may be reopened or retained for maintenance purposes. In this event, potential direct impacts could occur from the use of aggregate to rehabilitate/refurbish the ROW and stream crossings along the pipeline as needed. Potential direct impacts in this case would likely occur across a small portion of any such material sites. These impacts would range in intensity from immeasurable to noticeable changes in the resource character. Surficial geology and gravel resources would not be anticipated to return to previous levels even if actions that caused the impacts were to cease. The extent or scope of impacts would be limited geographically to discrete portions of the pipeline area. The additional extraction volumes of this potentially depleted resource would be

small, and changes to landform character for the incremental amounts of material used for maintenance may or may not be noticeable.

Closure

Immediately following pipeline installation, ROW cuts in surficial deposits would be graded to match original contours; workpad fills would remain in place (SRK 2013b). At the end of the construction period, temporary infrastructure such as access roads, airstrips, camps, material sites, and storage yards would be decommissioned as soon as practicable. During closure and reclamation activities, these areas would undergo minor grading and contouring to blend with original topography, provide for adequate drainage, and prevent erosion (Section 3.2, Soils), resulting in mitigating impacts to soils and vegetation. Impacts at gravel material sites would involve more extensive grading and contouring. Closure actions at material sites may preclude access to these aggregate resources by future users.

The pipeline, compressor station, and any maintenance sites that may have been used during operations, would be closed at the end of the project. There would be no disturbance of the ROW during closure activities, as the pipeline would remain buried. Minor excavation and grading would occur at fault crossings, maintenance sites, and compressor station site following infrastructure removal.

Potential direct impacts on surficial geology and aggregate resources would cause noticeable changes in the character of the resource. The duration, extent or scope, and context of impacts would be the same as described above for the Construction and Operations phases.

Potential direct impacts on surficial geology and aggregate resources would be permanent, of medium intensity (in that grading and contouring effects would be noticeable), cover local extents, and affect a common to important geologic resource.

Summary of Pipeline Impacts

Potential direct impacts on surficial geology and gravel resources along the pipeline during Construction, Operations, and Closure phases of Alternative 2 and the North Option would range considerably in intensity. Minor grading at camps would cause immeasurable or unnoticeable changes in the resource character. However, landform scars and resource reduction at gravel pits would result in acute or obvious changes. Reclamation activities would result in mitigating impacts to soils and vegetation. Impacts would occur across the majority of the route, potentially affecting about 262 miles of the total 316 mile Pipeline ROW, and 80 miles of shoofly roads where cross-slopes may require cut and fill construction; and would result in a total reduction of about 3.4 million cy of gravel resources. The duration of these effects would extend through the Construction Phase, but resources would not be anticipated to return to previous levels even if actions that caused the impacts were to cease for resource use and landform alterations. The extent or scope of impacts would not extend outside the Project Area. The context of impacts would affect resources that may be depleted within the locality, as gravel material is widely available in the eastern and central parts of the route, and less so in the Kuskokwim Hills.

3.1.3.2.3 PALEONTOLOGICAL RESOURCES

Mine Site

Construction

Disturbance of paleontological resources could occur across the same areas described above for bedrock effects at the Mine Site (Section 3.1.3.2.1), as paleontological resources are associated with bedrock units (formations, members, beds) that contain them. Impacts to paleontological resources could occur through the destruction of fossil-bearing bedrock (by blasting, excavation, and grading) that reduces the availability of fossils potentially valuable for research and exposes them to erosion (Section 3.2, Soils). Mine blasting and excavation could also have the beneficial effect of exposing new bedrock surfaces and increase the availability of fossils. However, new outcrops may be difficult to access, and the context and age of loose samples may be lost owing to mixing of different stratigraphic horizons. Unauthorized collecting would be limited at this controlled access site.

Donlin Gold has conducted studies (Druckenmiller et al. 2013; Jacobus and Druckenmiller 2013; Reuther et al. 2014) to assess the fossil potential of the mine region using a PFYC system developed by the U.S. Bureau of Land Management (BLM) (Figure 3.1-6), which provides guidance for predicting, assessing, and mitigating paleontological resources, and is useful in understanding the importance of these resources in context. The PFYC system serves as a process for determining whether vertebrate fossils, or noteworthy occurrences of other fossils, are known or likely to occur in an area (BLM 1998).

Figure 3.1-6 depicts PFYC values for the mine site region. Part of the Mine Site is rated PFYC Class 2 (most of the open pit), indicating low fossil potential or invertebrate fossils present from abundant species; and part of the Mine Site is rated Class 3b (east and south sides of pit, and areas beneath the WRF and TSF), meaning these rocks have unknown fossil potential and that further reconnaissance and research may be necessary to determine potential impacts.

If fossils are present at the Mine Site, they are only likely to be present in Kuskokwim Group sedimentary rocks that have not been altered by hydrothermal processes (i.e., they are very unlikely to be present in ore). Non-marine strata within the Kuskokwim Group are known to contain abundant plant fossils, which are associated with the potential for dinosaur tracks and skeletal remains based on similarities to other areas of Alaska (see Section 3.1.2.1.4). Paleontological surveys of the mine site region identified no obvious macrofossils in nearby outcrops, and found that exposures of non-marine Cretaceous rocks are limited in the area (Reuther et al. 2014). Quaternary vertebrate fossils have also been reported in overlying sediments in the region (Reuther et al. 2014).

Thus, paleontological resources at the Mine Site are considered to range from usual or ordinary in context to resources that are depleted within the locality, depending on whether dinosaur fossils are present. Potential direct impacts on these resources as a result of blasting and grading under Alternative 2 would involve chronic effects and resources would not be anticipated to return to previous levels even if actions that caused the impacts were to cease. The intensity of impacts would vary from immeasurable to noticeable changes in the character of paleontological resources. Roughly 55 Mt of waste rock, covering 80 acres in the pit area and about 500 acres in the process facility area and material sites, which may require grading of

bedrock ridges, would be disturbed (Section 3.1.3.2.1). The effect of this activity could negatively impact paleontological resources, if fossils are present.

Operations

During operations, approximately 3,000 Mt of potential paleontological resource-containing bedrock covering about 1,450 acres would be blasted and excavated from the pit and material sites (SRK 2016d). Most of this rock would be permanently buried in the WRF (Section 3.1.3.2.1). As with the construction period, these activities could destroy or cover potentially important paleontological resources, particularly in the east and south sides of the pit, expose them to erosion, and reduce the availability of fossils for research. Bedrock beneath the WRF and TSF that would be covered during operations and inaccessible for future research encompasses about 5,400 acres.

The intensity of impacts to paleontological resources during the Operations Phase may potentially involve acute or obvious changes in the resource character. The extent or scope would be limited to discrete portions of the mine site area. Impacts are considered to range from usual or ordinary in context to resources that are depleted within the locality, depending on whether dinosaur fossils are present.

Closure

During late Operations and Closure, roughly 470 Mt of potential fossil-containing waste rock would be used to backfill portions of the pit (SRK 2016d), which would eventually become permanently covered by water. Grading and contouring of mine facilities during Closure would permanently cover some paleontological resources. Minor sloughing and raveling of the pit walls is expected to occur during post-Closure, conditions which would not be maintained or repaired, and would cover potential fossil-bearing outcrops. Formation of a pit lake would make future access for research unsafe. Thus, there would likely be no beneficial effects to potential fossil-bearing rock exposures during this phase of the project. The intensity, duration, extent, and context of impacts during Closure would be the same as described above for the Construction and Operations phases.

Summary of Mine Site Impacts

Potential direct impacts to paleontological resources at the Mine Site during all phases of Alternative 2 would range in intensity from noticeable grading and sloughing of rock exposures to acute or obvious changes in resource character from blasting and resource removal. These activities would result in the alteration of a total of about 3,100 Mt of potentially fossil-bearing rock (waste rock) covering about 1,450 acres in the pit area, and permanent burial of potential fossil-bearing rock in other areas of the site covering about 6,000 acres. This alteration would not be anticipated to return to previous levels even if actions that caused the impacts were to cease. Potential beneficial effects from exposure of new fossils in pit wall outcrops would be dependent on adoption of additional mitigation measures (described in Chapter 5, Impact Avoidance, Minimization, and Mitigation). All effects would be limited to areas within the mine footprint. While most rock impacted by the proposed mine is expected to be either non-fossiliferous or rated PFYC Class 2 and would therefore be considered usual or ordinary in context, non-marine strata in the east and south sides of the pit (rated Class 3b) have unknown fossil potential and further evaluation of pit walls would be necessary to determine their

importance. A Cultural Resources Management Plan (CRMP) is being developed as part of the project that will include mitigation for potential paleontological resources as well as cultural resources. The CRMP will identify measures that would help to minimize effects on potential fossils encountered.

Transportation Corridor

Construction

Disturbance of paleontological resources from construction of the various transportation facilities could occur along the proposed mine access road route, at the new airstrip and permanent camp, along the Kuskokwim River corridor, and at the Dutch Harbor fuel storage facility. Impacts to these resources would occur through destruction of bedrock by excavation and blasting at material sites, road cuts, and infrastructure facilities; and erosion of cut slopes and river bluffs. Surface disturbances may also have the beneficial effect of exposing additional outcrops for study or public education.

Fossils potentially present along the mine access road would likely be contained in sedimentary Kuskokwim Group rocks. The PFYC values and high potential for dinosaur fossils in these rocks are considered the same as those described above for the Mine Site. Kuskokwim Group rocks rated Class 2 and 3 have been mapped along a total of about seven miles of the northern portion of the mine and airport access roads, at three materials sites in this area covering about 33 acres, and at the airstrip itself which extends across 23 acres (Jacobus and Druckenmiller 2013). The central and southern portions of the mine access road are mostly underlain by intrusive and volcanic igneous rocks with no fossil potential. Young (Holocene age) surficial deposits at the Angyaruaq (Jungjuk) Port are considered to have low potential for paleontological resources (Reuther et al. 2014). No bedrock or Pleistocene exposures are found in the community of Bethel.

The potential for significant Pleistocene vertebrate fossils (e.g., mammoth, bison) is considered high along the Kuskokwim River from about eight miles downstream of Jungjuk to the Napaimute vicinity (Reuther et al. 2014), a total of about 25 miles. Potential increased effects from barge-induced erosion in exposing these fossils in river bluffs relative to existing natural processes are expected to be relatively minor (BGC 2007a), particularly when compared to natural erosion by river flooding and ice during breakup (Section 3.5, Surface Water Hydrology). Two critical sections of the river where barge tows may need to relay during low water conditions (Holokuk and Oskawalik North) are located in this area. Intermittent increased shoreline activities at these locations could contribute to localized bank/bluff erosion and increased access for unauthorized fossil collection. Depending on the presence or absence of rare vertebrate fossils at these specific locations, effects would vary considerably in intensity. However, the use of BMPs to prevent soil erosion (Section 3.2, Soils) is expected to minimize new exposures of fossils at these locations.

The Dutch Harbor fuel storage facility would likely be located in an area underlain by volcanic rock with little to no fossil potential. While vertebrate and invertebrate fossils (marine mammals, bivalves) have been documented in sedimentary sections of the Unalaska Formation, the stratigraphic trend of these rocks suggest that units underlying the port areas of Dutch Harbor are composed primarily of the non-fossiliferous upper volcanic sequence of this formation (Lankford and Hill 1979).

The intensity of direct impacts on paleontological resources during construction of the various transportation infrastructure sites would vary based on the type of activity conducted. Minor grading and erosion would cause changes in resource character that may not be measurable or noticeable. However, blasting and potential unauthorized collection would cause acute or obvious changes in the character of resources. The extent or scope of impacts would be limited to discrete portions of the transportation corridor. The context of paleontological resources in these areas range from usual or ordinary resources to those considered depleted within the locality.

Operations

Potential direct impacts from Alternative 2 during operations would likely involve minimal additional disturbance to paleontological resources at the three material sites that remain open for maintenance purposes along the proposed mine access road route (Section 3.1.3.2.2). While the three sites have not been selected yet, it is likely that one of the three could be located in Kuskokwim Group rocks in the northern portion of the road. Potential direct impacts to Pleistocene vertebrate fossils at relay points along the Kuskokwim River corridor upstream of Napaimute would be the same as described above for construction. The overall intensity, duration, extent, and context of impacts during Operations would be the same as described above for the Construction Phase.

Closure

Potential direct impacts to paleontological resources along the mine access road and remaining material sites during Closure and post-Closure would be the same as those described above for Operations and Construction, as these facilities would remain open to support long-term monitoring and water treatment. The likelihood of incremental effects on Pleistocene fossils at relay points along the Kuskokwim River corridor is low during Closure, as the barging required to support Closure and post-Closure activities would likely be timed to avoid low water periods and the need for relays at critical sections.

Summary of Transportation Corridor Impacts

Potential direct impacts on paleontological resources along the Transportation Corridor during all Phases of Alternative 2 would range considerably in intensity. Grading at airstrips and erosion at relay points would cause changes in the resource character that may not be measurable or noticeable. Blasting at material sites and unauthorized collection at relay points would cause acute or obvious changes in the resource character. Potential beneficial effects from exposure of new fossils in material site outcrops would be dependent on adoption of additional mitigation measures (described in Chapter 5, Impact Avoidance, Minimization, and Mitigation). The duration of these effects may extend through the life of the project, and may even include chronic effects to resources such that those resources locally would not be anticipated to return to previous levels even if actions that caused the impacts were to cease. The extent or scope of impacts would be within the following specific locations having fossil potential: road cuts along 7 miles of the northern part of the mine/airstrip access roads, at the airstrip and three material sites (about 60 acres total), and at two low-water relay points upstream of Napaimute. Paleontological resources at these locations range in context from formations with little fossil potential to areas where the potential is elevated for dinosaur fossils in Kuskokwim Group

rocks or vertebrate fossils in Pleistocene deposits. A CRMP is being developed as part of the project would minimize effects on potential fossils encountered.

Pipeline

Construction

Disturbance of pre-Quaternary paleontological resources from construction activities along the pipeline could occur primarily at material sites, ROW cross-slope cuts, and shoofly road cuts in the western portion of the pipeline corridor. The fossil potential of the sedimentary Kuskokwim Group rocks in this area is described above under Mine Site and shown on Figure 3.1-6. PFYC values of 2 and 3 for these rocks suggest they range from common to important in context, depending on the potential presence of dinosaur fossils. Shallow Kuskokwim Group bedrock underlies about 70 miles of pipeline ROW, 40 miles of associated shoofly roads, and about 460 acres of material sites. Bedrock material sites near the southeastern end of the pipeline corridor (Little Mount Susitna area) target igneous rocks with no fossil potential. One bedrock material site in the Alaska Range near MP 130, covering about 27 acres, would be located in the southeast McGrath Quadrangle where fossil localities have been assigned PFYC values of 2 and 3, indicating low to moderate yield potential or the presence of abundant invertebrate specimens.

No fossils have been recorded in the widely distributed Quaternary deposits in the Alaska Range foothills and Cook Inlet areas of the pipeline route, partly because they are poorly documented, but it is possible these deposits contain Pleistocene vertebrate remains of scientific interest (Druckenmiller et al. 2013). No PFYC values have been assigned to the Quaternary deposits. The extent of Quaternary deposits that could be disturbed during pipeline construction is similar to estimates provided in Section 3.1.3.2.2 for surficial deposits: for example, cross-slope cuts could occur along roughly 262 miles of the pipeline ROW and 80 miles of shoofly roads, and gravel material sites would cover about 550 acres. Based on fossil occurrences in other areas of Alaska (BLM 2002a; Porter 1988; Reuther et al. 2014), Pleistocene vertebrate fossils are more likely to be preserved in loess, glaciofluvial, and fluvial deposits (such as the alluvial terrace deposits targeted by some of the gravel material sites on the north front of the Alaska Range), and less likely to be found in coarse glacial deposits such as the morainal deposits of upper Skwentna Valley.

Potential direct impacts to these resources during construction activities could occur through excavation of ROW and road cuts; possible blasting at material sites; trench excavation; grading at infrastructure sites; and exposure of fossil-bearing formations to erosion. These impacts would vary considerably in intensity and range from changes that may not be measurable or noticeable to acute or obvious changes in the resource character. Resources would not be anticipated to return to previous levels even if actions that caused the impacts were to cease. The extent or scope of impacts would be limited to discrete portions of the pipeline area. The context of paleontological resources in these areas range from usual or ordinary resources to those considered depleted within the locality. Beneficial effects could also result from exposing new fossil-bearing outcrops for study.

As part of the project, Donlin Gold has developed a Paleontological Resources Protection Plan, contained in the Cultural Resources Management Plan that includes measures for protection of unanticipated discoveries of paleontological resources and sites, such as notification of

significant discoveries to State Pipeline Coordinator's Section (SPCS) or other appropriate authorities (SRK 2013b). Additional plan details have not been specified to date.

Operations

Direct impacts during Operations would likely involve minimal disturbance to paleontological resources, as all pipeline infrastructure is planned to be reclaimed as soon as practicable following construction. In the event that selected material sites are reopened or retained for maintenance purposes, direct impacts from additional ground disturbance would be the same as described above for Construction, but on a much smaller, more confined scale.

Closure

Direct impacts to paleontological resources during closure and reclamation activities would involve grading and contouring of potential fossil-bearing exposures at material sites, and ROW and road cuts. These activities would protect paleontological resources from further ground disturbances, but also preclude access for further study. These effects would vary in intensity and may cause noticeable changes in the resource character. The duration, extent or scope, and extent of impacts would be the same as described above for the Construction and Operations phases.

Summary of Pipeline Impacts

Direct impacts on paleontological resources along the pipeline during all phases of Alternative 2 could range considerably in intensity. Grading at infrastructure sites would cause changes in the resource character that may not be measurable or noticeable. ROW and road cut excavations, and blasting at material sites would cause acute or obvious changes in the resource character, depending on the actual presence of fossils. Beneficial effects could also result from exposing new fossil-bearing outcrops for study. These effects would range from exposures open during the Construction Phase only to resources removed from material sites that would not be anticipated to return to previous levels even if actions that caused the impacts were to cease. The extent or scope of impacts would be limited to the EIS Analysis Area, and at locations having fossil potential: pre-Quaternary and Quaternary deposits along roughly 262 miles of the pipeline ROW, 80 miles of shoofly roads, and material sites covering about 1,000 acres. Paleontological resources along the pipeline range from ordinary formations with no or low fossil potential areas where the potential is elevated for dinosaur fossils in Kuskokwim Group rocks. A CRMP is being developed as part of the project which would minimize effects on potential fossils encountered.

3.1.3.2.4 CLIMATE CHANGE

Predicted overall increases in temperatures and precipitation and changes in the patterns of their distribution have the potential to influence the projected effects of the Donlin Gold Project on surficial geology, aggregate resources, and paleontological resources. These effects are generally associated with changes in permafrost and increased risk of erosion as discussed in Sections 3.26.4.2.3 and 3.26.4.2.2.

3.1.3.2.5 SUMMARY OF IMPACTS FOR ALTERNATIVE 2

The intensity of direct impacts to bedrock, mineral/rock aggregate resources, surficial deposits, gravel resources, and paleontological resources at the Mine Site would range considerably in intensity. Areas of slight grading of bedrock during Closure would cause changes in the resource character that may not be measurable or noticeable. Blasting and resource removal, major landform changes, and widespread aggregate resource utilization would cause acute or obvious changes in the resource character. These activities would result in the alteration of resources that would not be anticipated to return to previous levels even if actions that caused the impacts were to cease. All effects on geologic resources would be limited to areas within the mine site footprint. While most bedrock impacted by the project is considered usual or ordinary in context, the ore is a rare economic resource that is driving the purpose and need of the project. The context of gravel resources in the area of the mine site may be depleted within the locality, but potential demand from other users is very low. There is also Cretaceous non-marine strata located in the east and south sides of the pit that have unknown fossil potential, but could be elevated in context if dinosaur fossils are present. Reshaping and covering surficial deposits with growth media would result in mitigating related impacts to soil and vegetation. Potential beneficial effects from exposure of new fossils in pit wall outcrops would be dependent on adoption of additional mitigation measures as well.

At the Transportation Corridor, direct impacts to bedrock, mineral/rock aggregate resources, surficial deposits, gravel resources, and paleontological resources would also range considerably in intensity. Minor excavating and grading at airstrips would cause changes in the resource character that may not be measurable or noticeable. However, activities such as blasting would cause an acute or obvious reduction of material resources. Acute or obvious changes would also be experienced specifically at the MS10 borrow site, where large-scale gravel resource reduction would occur. These effects would persist through the life of the project and may not be anticipated to return to previous levels even if actions that caused the impacts were to cease. Most impacts would primarily affect areas within the transportation facilities footprints. These geologic resources are considered usual or ordinary, but may be depleted within the locality or region. The availability of gravel aggregate is somewhat limited in this region of Alaska, and the transportation facilities intersect with areas with elevated potential for dinosaur or vertebrate fossils.

The intensity of impacts to bedrock, mineral/rock aggregate resources, surficial deposits, gravel resources, and paleontological resources would also range considerably. Minor excavating would result in changes in the resource character that may not be measurable or noticeable. However, blasting, permanent reduction of materials, and landform scars would result in acute or obvious changes in the resource character. Beneficial effects could also result from exposing new fossil-bearing outcrops for study. The duration of impacts would range from paleontological resource exposure during the Construction Phase only to resource use and landform alterations that would not be anticipated to return to previous levels even if actions that caused the impacts were to cease. The extent or scope of all impacts would not extend beyond the EIS Analysis Area. The context of impacts would vary as well, from usual or ordinary resources to areas with elevated potential or dinosaur or vertebrate fossils. Gravel material is widely available in the eastern and central parts of the pipeline route, but less so in the Kuskokwim Hills.

Applying the methodology defined in Table 3.1-2 to the information and data presented in this section, Alternative 2 has potential direct and indirect impacts on geological resources. Table 3.1-3 provides a summary of impacts by the four assessment factors.

3.1.3.2.6 MITIGATION AND MONITORING FOR ALTERNATIVE 2

Effects determinations take into account impact reducing design features (Table 5.2-1 in Chapter 5, Impact Avoidance, Minimization, and Mitigation) proposed by Donlin Gold and also the Standard Permit Conditions and BMPs (Section 5.3) that would be implemented.

Design features important for reducing impacts to geology and paleontology include:

- Areas of disturbed bedrock and surficial deposits along the ROW, roads, and material sites would be contoured to match existing landforms as feasible, ripped to mitigate compaction effects, covered with growth media as needed and revegetated, and would support the overall drainage of the site, the long-term geotechnical stability, and post-mining land use;
- The shape of the WRF has been designed to conform to the landscape to the extent practicable to reduce visual impact;
- During the Operations Phase, concurrent reclamation activities (e.g., certain tiers and areas within the WRF) would be conducted immediately after construction and stabilization and whenever practicable in disturbed areas no longer required for active mining;
- The mine plan incorporates the concept of design for closure. This incorporates methods for safe and efficient closure of the mine as an integral part of the planned mine design and operations. Implementing design for closure can have the effect of minimizing disturbance and the re-handling of materials;
- At the completion of contouring of the WRF and TSF, a layer of unconsolidated material from the North and South overburden stockpiles would be spread over the surface and overlain with an additional layer of growth media (topsoil and overburden). This material will be tested to ensure it is non-PAG. The WRF would be designed to maximize concurrent reclamation, minimize the effects of PAG materials, minimize infiltration and erosion, and promote controlled surface runoff and revegetation; and
- The pipeline ROW would be reclaimed progressively throughout construction to minimize erosion effects on exposed bedrock and surficial deposit cuts.

Table 3.1-3: Summary Impacts¹ of Alternative 2 on Geological Resources by Project Component

Impacts	Assessment Criteria			
	Magnitude or Intensity	Duration	Extent or Scope	Context
Mine Site				
Bedrock Geology and Related Resources	Varies depending on the type of project activity. Areas of minor grading during Closure would cause changes in the character of resources that may not be measurable or noticeable. Ground disturbances and reshaping of landforms by blasting, excavation, and fill would result in acute or obvious changes to the character of resources.	Chronic effects; resource would not be anticipated to return to previous levels even if actions that caused the impacts were to cease.	Impacts limited geographically; discrete portions of the EIS Analysis Area affected.	Affects usual or ordinary bedrock in most cases. However, ore is a rare resource that may be depleted within the locality.
Surficial Geology and Gravel Resources	Varies depending on the type of project activity. Grading and contouring during Closure would result in noticeable changes in the character of resources. Large scale redistribution of deposits and reshaping of geomorphic landforms would result in acute or obvious changes to the character of resources.	Same as Bedrock Geology listed above.	Same as Bedrock Geology listed above.	Affects usual or ordinary resources; not depleted or protected by legislation.
Paleontological Resources	Varies depending on the type of project activity. Grading and sloughing of rock exposures would result in noticeable changes in the character of resources. Blasting and resource removal would result in acute or obvious changes in the character of resources.	Same as Bedrock Geology listed above.	Same as Bedrock Geology listed above.	Mostly affects usual or ordinary resources that are not depleted (e.g., non-fossiliferous or PFYC Class 2). Possibly affects depleted resources (e.g., non-marine strata or Class 3b) within the locality or region.
Transportation Corridor				

Table 3.1-3: Summary Impacts¹ of Alternative 2 on Geological Resources by Project Component

Impacts	Assessment Criteria			
	Magnitude or Intensity	Duration	Extent or Scope	Context
Bedrock Geology and Related Resources	Varies depending on the type of project activity. Excavating or reshaping of the landforms would cause changes in the character of resources that may not be measurable or noticeable. Blasting, reduction of material resources, and landform scars would result in acute or obvious changes in the character of resources.	Same as Bedrock Geology listed under Mine Site above.	Same as Bedrock Geology listed under Mine Site above.	Affects usual or ordinary resources that are not depleted.
Surficial Geology and Gravel Resources	Same as Transportation Corridor – Bedrock Geology listed above.	Changes to resources would extend through the life of the project and resources may not be anticipated to return to previous levels even if actions that caused the impacts were to cease.	Same as Bedrock Geology listed under Mine Site above.	Mostly affects usual or ordinary resources that are not depleted. However, the availability of gravel aggregate is somewhat depleted in this region of Alaska, although the current potential for other uses of the resource is limited.
Paleontological Resources	Same as Transportation Corridor – Bedrock Geology listed above.	Same as Transportation Corridor– Surficial Geology listed above.	Same as Bedrock Geology listed under Mine Site above.	Mostly affects usual or ordinary resources (formations with little fossil potential) that are not depleted. May affect depleted resources where the potential is elevated for dinosaur fossils in Kuskokwim Group rocks or vertebrate fossils in Pleistocene deposits.

Table 3.1-3: Summary Impacts¹ of Alternative 2 on Geological Resources by Project Component

Impacts	Assessment Criteria			
	Magnitude or Intensity	Duration	Extent or Scope	Context
Pipeline				
Bedrock Geology and Related Resources	Same as Transportation Corridor – Bedrock Geology listed above.	Chronic effects; resource would not be anticipated to return to previous levels even if actions that caused the impacts were to cease.	Same as Bedrock Geology listed under Mine Site above.	Affects usual or ordinary resources that are not depleted.
Surficial Geology and Gravel Resources	Same as Transportation Corridor – Bedrock Geology listed above. North Option would require slightly more gravel resources than Alternative 2 main route.	Most resources would be reduced infrequently, but no longer than the duration of the Construction Phase. However, landform alterations from project activities would result in chronic effects where resources would not be anticipated to return to previous levels even if actions that caused the impacts were to cease.	Same as Bedrock Geology listed under Mine Site above.	Mostly affect usual or ordinary resources, as gravel material is widely available in the eastern and central parts of the route. However, impacts would affect depleted resources in the Kuskokwim Hills area.
Paleontological Resources	Same as Transportation Corridor – Bedrock Geology listed above.	Same as Pipeline – Bedrock Geology listed above.	Same as Bedrock Geology listed under Mine Site above.	Paleontological resources along the pipeline range from ordinary formations with no or low fossil potential areas where the potential is elevated for dinosaur fossils in Kuskokwim Group rocks.

Notes:

- 1 The expected impacts account for impact reducing design features proposed by Donlin Gold and Standard Permit Conditions and BMPs that would be required. It does not account for additional mitigation measures being considered.

Standard Permit Conditions and BMPs important for reducing impacts to geology and paleontology include:

- Implementation of Stormwater Pollution Prevention Plans (SWPPPs) and/or Erosion and Sediment Control Plans (ESCPs) and use of industry standard BMPs for sediment and erosion control; and
- Preparation and implementation of a Stabilization, Rehabilitation, and Reclamation Plan.

Additional measures are being considered by the Corps and Cooperating agencies and are further assessed in Chapter 5, Impact Avoidance, Minimization, and Mitigation (Section 5.5 and Section 5.7). Examples of additional measures being considered that are applicable to this resource include:

- Develop Plans and Procedures for notification, documentation, sampling, and curation in the event that scientifically important paleontological resources (e.g., dinosaur fossils) are found during ground disturbing activities; and
- Specific plans for borrow site reclamation would be completed in a later phase of the project. In addition to standard BMPs for contouring, drainage, and erosion controls (Section 3.2, Soils), reclamation should create ponds and/or stream connections for fish and wildlife habitat at borrow sites in low lying areas (e.g., at Getmuna Creek) in accordance with ADEC and ADF&G guidance (McClellan 1993; Shannon & Wilson 2012; Owl Ridge 2017c).

3.1.3.3 ALTERNATIVE 3A – REDUCED DIESEL BARGING: LNG-POWERED HAUL TRUCKS

3.1.3.3.1 BEDROCK GEOLOGY AND RELATED RESOURCES

Effects on bedrock and related resources under Alternative 3A would be the same as those described for Alternative 2 for the Mine Site and natural gas pipeline project components. While there would be slightly less effects on shallow bedrock at transportation facilities due to the elimination of Dutch Harbor fuel storage expansion under this alternative, the reduction would be small (about 5 acres) compared to overall bedrock impacts for transportation facilities (about 400 acres and 16 miles of road).

3.1.3.3.2 SURFICIAL GEOLOGY AND GRAVEL RESOURCES

Mine Site

Effects on surficial geology and gravel resources under Alternative 3A would be the same as those described for Alternative 2 for the Mine Site. Some diesel fuel storage facility space would be decreased, and space for the LNG production and storage facilities would be required, thus likely resulting in a neutral impact to surficial geology. There would be no difference in the amount of ground disturbance affecting surficial deposits, or the amount of gravel aggregate use between the two alternatives.

Transportation Corridor

Effects on surficial geology under Alternative 3A would be the same as Alternative 2, except for a reduction in utilization of surficial deposits at the Dutch Harbor and Bethel ports. Because these ports would not require as much expansion (if any) under Alternative 3A, total disturbances of surficial deposits would be reduced by about 10 to 20 acres, as would the need for gravel aggregate fill for these facilities. However, because this is a small area compared to the total area of impacts for the Transportation Corridor (about 700 acres), the range of effects would be the same as Alternative 2 (Section 3.1.3.2.2). Any actions that would occur at Dutch Harbor or the Port of Bethel at the Bethel Yard Dock are not part of the proposed action, and are considered connected actions (see Section 1.2.1, Connected Actions, in Chapter 1, Project Introduction and Purpose and Need).

Pipeline

Impacts to surficial geology and gravel resources associated with the Construction, Operations, and Closure of the natural gas pipeline would be the same as discussed under Alternative 2.

3.1.3.3.3 PALEONTOLOGICAL RESOURCES

Mine Site

Effects on paleontological resources under Alternative 3A would be the same as those described for Alternative 2 for the Mine Site. There would be no difference in the types of impacts and amount of ground disturbance for this component.

Transportation Corridor

The reduction in barging associated with Alternative 3A would reduce potential impacts on Quaternary fossils along the Kuskokwim River bank. Activities at relay points along the river would be rare under this alternative, as reduction of barge traffic by about one-third would nearly eliminate the need for barge travel during low water conditions. Thus, there would be a low likelihood of shoreline access to potential fossils at relay points, and the potential for impacts (if any) would occur very infrequently. However, the reduction of impacts along the river would not change the range of effects on paleontological resources for other transportation facilities.

Pipeline

Effects to paleontological resources under Alternative 3A would be the same as discussed under Alternative 2.

3.1.3.3.4 SUMMARY OF IMPACTS FOR ALTERNATIVE 3A

Effects on bedrock, mineral/rock aggregate resources, surficial deposits, gravel resources, and paleontological resources under Alternative 3A at the Mine Site and the natural gas pipeline would be the same as those described for Alternative 2. Impacts associated with climate change would also be the same as those discussed for Alternative 2. Some diesel fuel storage facility space would be decreased, and space for the LNG production and storage facilities would be required, thus likely resulting in a neutral impact to surficial deposits. There would be no

difference in the amount of ground disturbance affecting surficial deposits, paleontological resources, or the amount of gravel aggregate use between the two alternatives at the Mine Site.

Effects associated with the Transportation Corridor under Alternative 3A would be similar to those described for Alternative 2. Even though there would be a reduction in effects to shallow bedrock and the utilization of surficial deposits because the Dutch Harbor and Bethel ports would not require as much expansion under Alternative 3A, the reduction would be small compared to other impacts to the Transportation Corridor discussed under Alternative 2. Any actions that would occur at Dutch Harbor or the Port of Bethel at the Bethel Yard Dock are not part of the proposed action, and are considered connected actions (see Section 1.2.1, Connected Actions, in Chapter 1, Project Introduction and Purpose and Need).

Design features, Standard Permit Conditions and BMPs most important for reducing impacts to geology would be similar to those described for Alternative 2.

3.1.3.4 ALTERNATIVE 3B – REDUCED DIESEL BARGING: DIESEL PIPELINE

Two options to Alternative 3B have been added based on Draft EIS comments from agencies and the public:

- **Port MacKenzie Option:** The Port MacKenzie Option would utilize the existing Port MacKenzie facility to receive and unload diesel tankers instead of the Tyonek facility considered under Alternative 3B. A pumping station and tank farm of similar size to the Tyonek conceptual design would be provided at Port MacKenzie. A pipeline would extend northwest from Port MacKenzie, route around the Susitna Flats State Game Refuge, cross the Little Susitna and Susitna rivers, and connect with the Alternative 3B alignment at approximately MP 28. In this option, there would be no improvements to the existing Tyonek dock; a pumping station and tank farm would not be constructed near Tyonek; and the pipeline from the Tyonek tank farm considered under Alternative 3B to MP 28 would not be constructed.
- **Collocated Natural Gas and Diesel Pipeline Option:** The Collocated Natural Gas and Diesel Pipeline Option (Collocated Pipeline Option) would add the 14-inch-diameter natural gas pipeline proposed under Alternative 2 to Alternative 3B. Under this option, the power plant would operate primarily on natural gas instead of diesel as proposed under Alternative 3B. The diesel pipeline would deliver the diesel that would be supplied using river barges under Alternative 2 and because it would not be supplying the power plant, could be reduced to an 8-inch-diameter pipeline. The two pipelines would be constructed in a single trench that would be slightly wider than proposed under either Alternative 2 or Alternative 3B and the work space would be five feet wider. The permanent pipeline ROW would be approximately two feet wider. This option could be configured with either the Tyonek or Port MacKenzie dock options.

3.1.3.4.1 BEDROCK GEOLOGY AND RELATED RESOURCES

Mine Site

Effects on bedrock and related resources at the Mine Site under Alternative 3B would be the same as those described for Alternative 2. There would be no difference in the amount of

ground disturbance affecting bedrock, or the amount of mineral resource reduction or rock aggregate use.

Transportation Corridor

Effects on bedrock and related resources for Transportation Corridor facilities under Alternative 3B would be the same as those described for Alternative 2, except that there would be no indirect effects on bedrock from expansion of the Dutch Harbor fuel storage facility. There would be no difference in direct effects on bedrock along the mine access road, material sites, or airstrip.

Pipeline

Effects on bedrock and related resources under Alternative 3B would be the same as Alternative 2, except for some off-ROW facilities located in shallow bedrock areas. These include new airstrips required to support potential oil spill recovery (OSR) activities, airstrips that remain open during the operations phase, and required helipads at valve locations. There is no shallow bedrock along the pipeline ROW between Beluga and Tyonek (Alternative 3B and Alternative 3B Collocated Natural Gas and Diesel Pipeline Option) or between Port MacKenzie and MP 28 (Alternative 3B Port MacKenzie Option) that would be affected by the added pipeline segments in these areas. Of three additional new airstrips required under this alternative, one (George River) would require some cut and fill construction and is located in an area of shallow bedrock. This airstrip would potentially affect an additional 60 acres of bedrock. Other new airstrips and helipads would either require grading only or are not located in shallow bedrock areas.

The types of construction activities and intensity of impacts at the additional ROW and off-ROW locations under this alternative would be the same as Alternative 2, and the geographic extent of effects would be unchanged (within the footprints of various facilities). The additional area of shallow bedrock potentially affected under Alternative 3B is small compared to the total estimated under Alternative 2 for the pipeline (e.g., about 500 acres off-ROW, and about 70 miles or up to 2,600 acres of ROW).

3.1.3.4.2 SURFICIAL GEOLOGY

Mine Site

With the exception of reduced fuel storage capacity at the Mine Site, effects on surficial deposits and gravel resources under Alternative 3B are generally the same as those described for Alternative 2. The decreased fuel storage capacity required at the mine under this alternative would reduce the required fuel storage footprint by roughly 75 percent in comparison to Alternative 2 (from 15 tanks down to 4), resulting in roughly 10 acres less fuel storage under Alternative 3B at the Mine Site, although the same area may be disturbed for other purposes (e.g., laydown). The reduction in fuel storage footprint under this alternative is small compared to overall areas of effects on surficial deposits for the Mine Site as a whole (roughly 9,000 acres).

Transportation Corridor

The area of effects on surficial deposits at the Angyaruaq (Jungjuk) Port would likely be similar under this alternative to that of Alternative 2, as fuel storage capacity would be needed at this site for the construction period. Thus, the site footprint would be similar to that of Alternative 2.

There would be less indirect effect on surficial deposits at the Bethel and Dutch Harbor ports due to less amount of fuel storage required. The reduction in effects would be the same as described under Alternative 3A (Section 3.1.3.3.2). Any actions that would occur at Dutch Harbor or the Port of Bethel at the Bethel Yard Dock are not part of the proposed action, and are considered connected actions (see Section 1.2.1, Connected Actions, in Chapter 1, Project Introduction and Purpose and Need).

Pipeline

Effects on surficial deposits and aggregate resources would increase as a result of Alternative 3B or Alternative 3B Options due to additional trenching and material sites (up to five under Alternative 3B or Alternative 3B Collocated Natural Gas and Diesel Pipeline Option, and up to 13 under Alternative 3B Port MacKenzie Option), and additional cut and fill construction and/or grading for new airstrips and helipads. Cut-and-fill construction along either the Tyonek to Beluga segment or the Port MacKenzie to MP 28 segment of the ROW would be minimal due to low relief topography in these areas. The areas of potential cut and fill under this alternative include those described for Alternative 2, plus roughly an additional 5 acres for trenching, 60 to 150 acres for additional material sites, depending on option, and 200 acres for new airstrips.

The types of construction activities and intensity of impacts at the additional ROW and off-ROW locations under this alternative would be the same as Alternative 2, and the geographic extent of effects would still be within the footprints of various facilities. Since the additional areas of surficial deposits potentially affected under Alternative 3B or options are small compared to the total estimated under Alternative 2 for the pipeline.

3.1.3.4.3 PALEONTOLOGICAL RESOURCES

Mine Site

Effects on paleontological resources at the Mine Site under Alternative 3B would be the same as those described for Alternative 2. There would be no difference in the types of impacts and amount of ground disturbance for this project component.

Transportation Corridor

Effects on paleontological resources resulting from the construction, operations, and closure of transportation facilities under Alternative 3B would be similar to Alternative 2. The reduced levels of barge traffic and low water travel on the Kuskokwim River corridor would cause less potential effects on Quaternary fossils in riverbank deposits near relay points. Effects under this alternative would be the same as described under Alternative 3A (Section 3.1.3.3.3).

Pipeline

Effects on paleontological resources under Alternative 3B would be similar to Alternative 2, except that the increase in shallow bedrock cuts at one new airstrip, and increase in cuts in surficial deposits at five pipeline material sites, could potentially cause a slight increase in the probability of encountering either dinosaur track fossils in Kuskokwim Group rocks or Pleistocene vertebrates in surficial deposits. As described above under Bedrock and Surficial

Geology, the additional areas of bedrock and surficial deposits potentially affected by the pipeline under Alternative 3B are small compared to the totals estimated under Alternative 2.

3.1.3.4.4 SUMMARY OF IMPACTS FOR ALTERNATIVE 3B

Direct effects on bedrock, mineral/rock aggregate resources, surficial deposits, and paleontological resources at the Mine Site under Alternative 3B would be the same as those described for Alternative 2. Impacts associated with climate change under Alternative 3B, with the exception of Alternative 3B Collocated Natural Gas and Diesel Pipeline Option, would be greater than those discussed for Alternative 2 during operations due to the increase in GHG emissions from diesel-fired equipment compared to natural gas fired equipment. Under the Alternative 3B Collocated Natural Gas and Diesel Pipeline Option, an increase in GHG emissions during the construction phase over those projected under Alternative 2 would result in a temporarily greater impact on climate change, but during the operations phase, impacts on climate change would be expected to be generally the same as under Alternative 2. There would be no substantial difference in the amount of ground disturbance affecting bedrock or paleontological resources, or the amount of mineral resource reduction or aggregate use. There would be decreased fuel storage capacity at the Mine Site under this alternative, which reduces the fuel storage footprint. However, the reduction is small when compared to the overall areas of effects on surficial deposits for the Mine Site as a whole, and does not change the overall Intensity, duration, extent, or context of impacts.

For the Transportation Corridor, effects on bedrock and related resources under Alternative 3B would be similar to those described for Alternative 2. There would be no difference in direct effects on bedrock along the mine access road, material sites, or airstrip. The small reductions in impacts from Alternative 2 associated with Alternative 3B transportation facilities would be the same as described under Alternative 3A.

While some increased impacts to geologic resources would occur under Alternative 3B at off-ROW diesel pipeline facilities, the increase would be relatively small compared to the rest of the pipeline component for resources that are considered mostly common in context. The types of construction activities and intensity of impacts at the additional ROW and off-ROW locations under this alternative would be the same as Alternative 2, and the geographic extent of effects would still be considered local (within the footprints of various facilities). The additional areas of bedrock and surficial deposits potentially affected under either option of Alternative 3B are small compared to the total estimated under Alternative 2 for the natural gas pipeline. Therefore, the overall level of effects associated with the diesel pipeline under Alternative 3B would be considered the same as Alternative 2.

Design features, Standard Permit Conditions and BMPs most important for reducing impacts to geology would be similar to those described for Alternative 2.

3.1.3.5 ALTERNATIVE 4 – BIRCH TREE CROSSING (BTC) PORT

3.1.3.5.1 BEDROCK GEOLOGY AND RELATED RESOURCES

Mine Site

Effects on bedrock and related resources at the Mine Site under Alternative 4 would be the same as those described for Alternative 2. There would be no difference in the amount of ground disturbance affecting bedrock, or the amount of mineral resource reduction or rock aggregate use for the Mine Site.

Transportation Corridor

Effects on bedrock and rock aggregate resources would increase under Alternative 4 due to additional bedrock material sites required for construction, and the fact that BTC Road would traverse about 10 more miles of shallow bedrock than the mine access road in Alternative 2. The BTC Road would utilize sedimentary and volcanic rock aggregate sourced from 37 material sites (Section 3.1.2.2.3 – Affected Environment), which is more than three times the number under Alternative 2 (there are 12 bedrock material sites along the mine access road in Alternative 2). Bedrock material sites under Alternative 4 would cover about 1,160 acres, or about 5 times more area than that under Alternative 2 (240 acres). Likewise, the total volume of rock aggregate that would potentially be utilized from bedrock material sites under Alternative 4 is roughly 13.8 million cy, or about five times that of the Alternative 2 mine access road (2.8 million cy). The large increase in rock aggregate for the BTC Road is partly due to the increased road length (43 miles longer than Alternative 2) and partly due to more gravel aggregate availability under Alternative 2 (discussed below under Section 3.1.3.5.2, Surficial Geology). As the types of construction activities would be the same under Alternative 4 as for Alternative 2, the range of intensity of effects on bedrock resources would be essentially the same, although more blasting would be required under Alternative 4.

Pipeline

Effects on bedrock and related resources associated with the natural gas pipeline under Alternative 4 would be the same as those described for Alternative 2. There would be no difference in the amount of ground disturbance affecting bedrock, or the amount of mineral resource reduction or rock aggregate use for the pipeline and associated facilities.

3.1.3.5.2 SURFICIAL GEOLOGY

Mine Site

Effects on surficial geology and gravel resources at the Mine Site under Alternative 4 would be the same as those described for Alternative 2. There would be no difference in the amount of ground disturbance affecting surficial deposits, or the amount of gravel aggregate use for this project component.

Transportation Corridor

Effects on surficial deposits under Alternative 4 would be similar to Alternative 2, except that the additional 43 miles of the BTC Road would require roughly 35 percent more cut and fill

along slide slopes with cuts into overburden. While the BTC Road would utilize gravel aggregate sourced from five material sites compared to only one for the mine access road under Alternative 2 (Section 3.1.3.2.2), the 5 BTC material sites combined would yield slightly less extraction volume and cover less acreage than the one under Alternative 2. The total volume and area of gravel material sites under Alternative 4 would be about 0.9 million cy and cover 170 acres, compared to 1.1 million cy covering 240 acres for Alternative 2. Because the types of construction activities would be the same under Alternative 4 as for Alternative 2, the range of intensity of effects on surficial geologic resources would be essentially the same as Alternative 2.

Pipeline

Impacts to surficial geology and gravel resources associated with the construction, operations, and closure of the natural gas pipeline under Alternative 4 would be the same as discussed under Alternative 2.

3.1.3.5.3 PALEONTOLOGICAL RESOURCES

Mine Site

Effects on paleontological resources at the Mine Site under Alternative 4 would be the same as those described for Alternative 2. There would be no difference in the types of impacts and amount of ground disturbance for this project component.

Transportation Corridor

Potential effects on pre-Quaternary paleontological resources would be higher under Alternative 4 than Alternative 2. As described above under Section 3.1.3.5.1, Alternative 4 – Bedrock, approximately five times as much bedrock would be utilized for rock aggregate for the BTC Road than for the mine access road. Of the total number of bedrock material sites along the BTC Road, 25 contain Kuskokwim Group sedimentary rock with the potential for dinosaur fossils (as compared to three sedimentary rock material sites along the mine access road). Although known fossil assemblages and outcrops are sparse in the western portion of the route, the potential for encountering dinosaur fossils in these rocks is considered similar to that of the mine and northern part of the mine access road corridor under Alternative 2 (Section 3.1.3.2.3 – Paleontological Resources). The remaining bedrock material sites and the BTC Port are located in areas of non-fossiliferous igneous, volcanic, and metamorphic rocks.

Potential effects on Quaternary vertebrate fossils along the Kuskokwim River corridor would be reduced under Alternative 4. The reduction on upper river barge travel under this alternative would eliminate travel through several critical sections upstream of the BTC Port (e.g., Aniak, Holokuk, Upper Oskawalik), where barges would need to be relayed during low water periods under Alternative 2. Thus, the Pleistocene vertebrate fossils identified in this area under Alternative 2 would be avoided.

Pipeline

Impacts to paleontological resources associated with the natural gas pipeline under Alternative 4 would be the same as discussed under Alternative 2.

3.1.3.5.4 SUMMARY OF IMPACTS FOR ALTERNATIVE 4

For the Mine Site and the natural gas pipeline components, direct effects on bedrock, mineral/rock aggregate resources and paleontological resources under Alternative 4 would be the same as those described for Alternative 2. Impacts associated with climate change would also be the same as those discussed for Alternative 2. There would be no difference in the amount of ground disturbance affecting bedrock or surficial deposits, or the amount of mineral resource reduction or gravel aggregate use for the Mine Site under this alternative.

The geographic extent and volume of bedrock usage for the transportation facilities would be larger under Alternative 4 than under Alternative 2. The large increase in rock aggregate for the BTC Road is partly due to the increased road length (43 miles longer than Alternative 2) and partly due to less gravel aggregate availability under Alternative 4. The total volume and area of gravel material sites under Alternative 4 would be about 0.9 million cy and cover 170 acres, compared to 1.1 million cy covering 240 acres for Alternative 2. The increased number of bedrock material sites along the BTC Road would increase the probability of potential effects on bedrock paleontological resources under Alternative 4, but effects on Quaternary vertebrate fossils in surficial deposits along the Kuskokwim River would be less under Alternative 4. Because the types of construction activities would be the same under Alternative 4 as for Alternative 2, the intensity of effects on bedrock and rock aggregate resources, and surficial geologic resources would be the same as Alternative 2. As with Alternative 2, potential beneficial effects from exposure of new fossils in material site outcrops would be dependent on adoption of additional mitigation measures (see Chapter 5, Impact Avoidance, Minimization, and Mitigation). The extent and context of impacts would be the same as Alternative 2.

Design features, Standard Permit Conditions and BMPs most important for reducing impacts to geology would be similar to those described for Alternative 2.

3.1.3.6 ALTERNATIVE 5A – DRY STACK TAILINGS

This alternative includes two options:

- **Unlined Option:** The tailings storage facility (TSF) would not be lined with a linear low-density polyethylene (LLDPE) liner. The area would be cleared and grubbed and an underdrain system placed in the major tributaries under the TSF and operating pond to intercept groundwater base flows and infiltration through the dry stack tailings (DST) and convey it to a Seepage Recovery System (SRS). Water collecting in the SRS pond would be pumped to the operating pond, lower contact water dam (CWD), or directly to the processing plant for use in process.
- **Lined Option:** The DST would be underlain by a pumped overdrain layer throughout the footprint, with an impermeable LLDPE liner below. The rock underdrain and foundation preparation would be completed in the same manner as the Unlined Option.

3.1.3.6.1 BEDROCK GEOLOGY AND RELATED RESOURCES

Mine Site

Effects on bedrock and aggregate resources at the Mine Site under Alternative 5A would be similar to those described for Alternative 2. There would be minor differences in the amount of

bedrock and rock aggregate resources disturbed and distributed during Alternative 5A. Waste rock that would be used for capping of the TSF under Alternative 2 would be used to cap the upstream dry stack tailings instead, as the main dam and impoundment under Alternative 5A would be removed at closure. Waste rock that would be used for the reclaim causeway at the TSF under Alternative 2 would be placed in the WRF under Alternative 5A. An increased amount of rock fill sourced mostly from the open pit would be used to construct both the main dam and dry stack tailings dam under Alternative 5A. There would be an increased amount of shallow bedrock excavated at the TSF under this alternative for foundation preparation for both dams. Filling of the Upper Anaconda Creek Valley with the dry stack tailings would result in similar landform and topographic changes as Alternative 2, in that the final dry stack tailings elevation would be roughly 400 feet higher than the original valley bottom, although the final elevation of the dry stack would be 150 feet higher than the top of the TSF under Alternative 2. The top of the dry stack would rise 50 to 150 feet above the ridge on its south side, whereas the TSF under Alternative 2 would not rise above the surrounding landscape.

While there would be minor differences in the amount of bedrock excavated and rock fill used between Alternatives 2 and 5A, the types of construction effects, mineral and aggregate resource reductions, and range of the intensity of effects would be the same as Alternative 2. Like Alternative 2, impacts to bedrock under Alternative 5A would be within the footprint of the mine facilities.

Transportation Corridor

Effects on bedrock and related resources along the transportation corridor under Alternative 5A would be the same as those described for Alternative 2. There would be no difference in the amount of ground disturbance affecting bedrock, or the amount of mineral resource reduction or rock aggregate use for transportation facilities.

Pipeline

The effects to bedrock from natural gas pipeline construction, operations, and closure under Alternative 5A would be the same as Alternative 2. There would be no difference in the amount of ground disturbance affecting bedrock, or the amount of mineral resource reduction or rock aggregate use for this project component.

3.1.3.6.2 SURFICIAL GEOLOGY AND GRAVEL RESOURCES

Mine Site

Effects on surficial deposits and gravel resources at the Mine Site under Alternative 5A would be similar to those described for Alternative 2. There would be minor differences in the area and volume of surficial deposits disturbed and distributed under Alternative 5A. There would be about a 12 percent increase in the amount of excavation and storage required for construction of both the main dam and upper dry stack tailings dam (BGC 2014a), as well as an increase in the amount of gravel resources required for use as filter material in the two dams.

While there would be a minor increase in the amount of surficial deposits disturbed and gravel resources needed under Alternative 5A as compared to Alternative 2, the types of construction effects, overall magnitude of resource reductions, and range of the intensity of effects would be

the same as Alternative 2. Like Alternative 2, impacts under Alternative 5A would be within the footprint of the mine facilities.

Transportation Corridor

Effects on surficial geology and gravel resources along the Transportation Corridor and associated facilities under Alternative 5A would be the same as those described for Alternative 2. There would be no difference in the amount of ground disturbance affecting surficial deposits, or the amount of gravel aggregate use for this project component.

Pipeline

Surficial geology and gravel aggregate impacts experienced as a result of Alternative 5A would be the same as discussed under Alternative 2. There would be no difference in the amount of ground disturbance affecting surficial deposits, or the amount of gravel aggregate use for this project component.

3.1.3.6.3 PALEONTOLOGICAL RESOURCES

Mine Site

Effects on paleontological resources under Alternative 5A would be similar to Alternative 2, except for an additional area of potentially fossil-bearing bedrock beneath the dry stack tailings and holding pond that would be covered during Operations and inaccessible for future research, and additional volumes of shallow weathered bedrock excavated for dam foundations. The areas of bedrock coverage during the closure period would be roughly the same between Alternatives 2 and 5A.

Transportation Corridor

Effects on paleontological resources along the Transportation Corridor and at associated facilities under Alternative 5A would be the same as those described for Alternative 2. There would be no difference in the types of impacts and amount of ground disturbance for these project components.

Pipeline

Paleontological resource impacts associated with the natural gas pipeline under Alternative 5A would be the same as discussed under Alternative 2.

3.1.3.6.4 SUMMARY OF IMPACTS FOR ALTERNATIVE 5A

While there would be small differences in the amount of bedrock excavated and rock fill used between Alternatives 2 and 5A at the Mine Site, the types of construction effects, mineral and aggregate resource reductions, and range of the magnitude of effects would be the same as Alternative 2. Impacts associated with climate change would also be the same as those discussed for Alternative 2. There would also be minor differences in the area and volume of surficial deposits disturbed and distributed under Alternative 5A, but these differences would not change the criteria ratings from Alternative 2 associated with the Mine Site. Effects on paleontological resources at the Mine Site under Alternative 5A would be similar to Alternative

2, except for an additional area of potentially fossil-bearing bedrock beneath the dry stack tailings and holding pond that would be covered during operations and inaccessible for future research, and additional volumes of shallow weathered bedrock excavated for dam foundations.

Effects on bedrock, mineral/rock aggregate resources, surficial deposits, gravel resources, and paleontological resources under along the transportation corridor and the natural gas pipeline under Alternative 5A would be the same as those described for Alternative 2. There would be no difference in the types of impacts and amount of ground disturbance associated with these facilities.

Design features, Standard Permit Conditions and BMPs most important for reducing impacts to geology would be similar to those described for Alternative 2.

3.1.3.7 ALTERNATIVE 6A – MODIFIED NATURAL GAS PIPELINE ALIGNMENT: DALZELL GORGE ROUTE

3.1.3.7.1 BEDROCK GEOLOGY AND RELATED RESOURCES

Mine Site

Effects on bedrock and related resources at the Mine Site under Alternative 6A would be the same as those described for Alternative 2. There would be no difference in the amount of ground disturbance affecting bedrock, or the amount of mineral resource reduction or rock aggregate use between the two alternatives.

Transportation Corridor

Effects to bedrock and related resources from transportation facilities Construction, Operations, and Closure would be the same as discussed under Alternative 2.

Pipeline

Effects on bedrock and aggregate resources along the pipeline under Alternative 6A would be similar as those described for Alternative 2, with minor differences. Alternative 6A traverses steeper terrain requiring additional cut and fill, which could potentially expose more bedrock and require additional aggregate resources. There is almost no shallow bedrock within trenching depth along either of the Alaska Range segments of these alternatives. The number of bedrock material sites in the Alaska Range sections of Alternatives 6A and 2 are roughly the same. Under Alternative 6A, one material site (Airfield Quarry) located near MP 108.5 would utilize sedimentary bedrock and impact an area approximately 22 acres in size. Similarly, there is only one bedrock material site along the Alaska Range section of Alternative 2, which encompasses about 29 acres together with co-located gravel resources.

3.1.3.7.2 SURFICIAL GEOLOGY

Mine Site

Effects on surficial geology and gravel resources at the Mine Site under Alternative 6A would be the same as those described for Alternative 2. There would be no difference in the amount of ground disturbance affecting surficial deposits, or the amount of gravel aggregate use.

Transportation Corridor

Surficial geology and gravel resources impacts associated with the transportation facilities under Alternative 4 would be the same as described under Alternative 2.

Pipeline

The types of effects on surficial deposits and gravel resources along the pipeline corridor under Alternative 6A would be similar to Alternative 2 with minor differences. Ten material sites that would utilize stream channel alluvial gravel deposits have been identified for the Alternate 6A route within the Alaska Range from roughly MP 114.5 to MP 150.5, as compared to 13 gravel material sites for the Alaska Range portion of Alternative 2. Collectively, the 10 material sites under Alternative 6A cover a smaller area than those of Alternative 2, with a total potential utilization area of approximately 110 acres (compared to 230 acres for the Alternative 2 sites). The largest utilization of alluvial gravel under Alternative 6A would occur from Dalzell Creek at MP 123.6 that would impact approximately 29 acres.

The total lengths of ROW that would impact surficial deposits under Alternatives 2 and 6A are comparable, as there is only about a one to two mile difference in length for the two routes. While the Dalzell Gorge route would traverse a greater length of steep unstable slopes along the ROW (see Section 3.3, Geohazards and Seismic Conditions), the total length of gentler cross-slopes (with greater than six percent grade) that would require cut and fill construction and a wider construction ROW is less under Alternative 6A than Alternative 2. The Alaska Range segment of Alternative 2 would require roughly 98 percent (or 46 miles) of cut and fill construction, whereas the Dalzell Gorge segment of Alternative 6A would require about 85 percent (or 38 miles) of cut and fill construction.

3.1.3.7.3 PALEONTOLOGICAL RESOURCES

Mine Site and Transportation Corridor

Effects on paleontological resources at the Mine Site and Transportation Corridor under Alternative 6A would be the same as those described for Alternative 2. There would be no difference in the types of impacts and amount of ground disturbance for these project components.

Pipeline

As presented in Section 3.1.2.3.4 and shown on Figure 3.1-, the Alaska Range segments of the pipeline routes under Alternatives 2 and 6A pass through the McGrath and Tyonek quadrangles with similar paleontological occurrences along both routes. Thus, impacts to

paleontological resources under Alternative 6A would be expected to be generally similar to Alternative 2.

3.1.3.7.4 SUMMARY OF IMPACTS FOR ALTERNATIVE 6A

Effects on bedrock, mineral/rock aggregate resources, surficial deposits, gravel resources, and paleontological resources at the Mine Site and Transportation Corridor under Alternative 6A would be the same as those described for Alternative 2. Impacts associated with climate change would also be the same as those discussed for Alternative 2. There would be no difference in the types of impacts and amount of ground disturbance for these project components.

Under Alternative 6A, effects on geologic resources along the pipeline would be similar as those described for Alternative 2, with minor differences. There would be a small variation in the amounts of bedrock and rock aggregate utilized along the pipeline as compared to Alternative 2. The number of bedrock material sites in the Alaska Range sections of Alternatives 6A and 2 are roughly the same. The total lengths of ROW that would impact surficial deposits under Alternatives 2 and 6A are also comparable, as there is only about a one to two mile difference in length for the two routes. Collectively, the 10 material sites under Alternative 6A cover a smaller area than those of Alternative 2, with a total potential utilization area of approximately 110 acres (compared to 230 acres for the Alternative 2 sites). The Alaska Range segments of the pipeline routes under Alternatives 2 and 6A pass through the McGrath and Tyonek quadrangles with similar paleontological occurrences along both routes. Thus, impacts to paleontological resources under Alternative 6A are expected to be generally similar to Alternative 2. These minor differences between alternatives would not change the range of impacts with respect to intensity, duration, extent, and context.

Design features, Standard Permit Conditions and BMPs most important for reducing impacts to geology would be similar to those described for Alternative 2.

3.1.3.8 ALTERNATIVES IMPACT COMPARISON

Although there are differences among alternatives in the project components that would affect geology, they are relatively small. This is because all alternatives involve excavation and removal of large amounts of surface and bedrock materials, with such removals being necessary for Construction and Operations of the Mine Site, Transportation Corridor, Pipeline, and supporting facilities. The scope and scale of the project are such that minor changes to routing and alignments result in little change to overall impacts. Most of the alternatives being considered have relatively little impacts on Project Area or construction needs. A summary for the impacts from the alternatives is presented in Table 3.1- below.

Table 3.1-4: Comparison of Impacts by Alternative* for Geology and Paleontology

Impact-causing Project Component	Alternative 2 – Proposed Action	Alternative 3A – LNG-Powered Haul Trucks	Alternative 3B – Diesel Pipeline	Alternative 4 – BTC Port	Alternative 5A – Dry Stack Tailings	Alternative 6A – Dalzell Gorge Route
Mine Site						
Bedrock Geology	Alteration of about 556 Mt of ore and 3,100 Mt of waste rock from the 1,462 acre pit, and final elevation changes up to about 600 feet. Resources would not be anticipated to return to previous.	Same as Alternative 2.	Same as Alternative 2.	Same as Alternative 2.	Final elevation of dry stack 50-150 feet higher than south ridge.	Same as Alternative 2.
Surface Geology	Change to roughly 50 Mt of overburden covering about 9,000 acres. Resources would not be anticipated to return to previous.	Same as Alternative 2.	10 acres < Alternative 2.	Same as Alternative 2.	Aggregate needed for dams about 12 % > Alternative 2	Same as Alternative 2.
Paleontology	Alteration of potential fossil-bearing rock over 1,492-acre pit. Resources would not be anticipated to return to previous.	Same as Alternative 2.	Same as Alternative 2.	Same as Alternative 2.	Little additional impact.	Same as Alternative 2.
Transportation Corridor						
Bedrock Geology	16 miles of road; an additional 400 acres at other facilities (airstrip, camp, material sites); and reduction of about 2.8 Mcy of bedrock aggregate resources.	5 acres < Alternative 2.	5 acres < Alternative 2.	960 acres 11.2 Mcy > Alternative 2.	Same as Alternative 2.	Same as Alternative 2.
Surface Geology	Ground disturbance and landform alterations across a total of about 700 acres and reduction of about 1.5 Mcy of gravel resources.	10 to 20 acres < Alternative 2.	5 acres < Alternative 2.	70 acres, 0.2 Mcy < Alternative 2.	Same as Alternative 2.	Same as Alternative 2.
Paleontology	Potential localized impacts in areas having fossil potential:	Reduced impacts along Kuskokwim.	Same as Alternative	Greater impact to bedrock fossils	Same as Alternative 2.	Same as Alternative 2.

Table 3.1-4: Comparison of Impacts by Alternative* for Geology and Paleontology

Impact-causing Project Component	Alternative 2 – Proposed Action	Alternative 3A – LNG-Powered Haul Trucks	Alternative 3B – Diesel Pipeline	Alternative 4 – BTC Port	Alternative 5A – Dry Stack Tailings	Alternative 6A – Dalzell Gorge Route
	road cuts along 7 miles of northern part of mine/airstrip access roads, airstrip, 3 material sites, and 2 low-water relay points.		3A.	along the BTC Road, and less impact to vertebrate fossils along the Kuskokwim River.		
Pipeline						
Bedrock Geology	70 miles of ROW and associated infrastructure bedrock material sites covering a total of about 500 acres; and a total reduction of about 2.9 Mcy of bedrock aggregate resources.	Same as Alternative 2.	60 acres > Alternative 2.	Same as Alternative 2.	Same as Alternative 2.	7 acres less.
Surface Geology	262 miles of ROW (out of 316 mile total ROW) and about 80 miles of shoofly roads where cross-slopes may require cut and fill construction; roughly 580 acres affected by gravel material sites; and a total reduction of about 3.4 Mcy of gravel resources. North Option – Total length of pipeline and shoofly roads is roughly the same as the baseline Alternative 2 route; same overall number of gravel material sites, but about 30 acres less affected area; and a reduction of gravel volume by about 200,000 cy	Same as Alternative 2.	1,365 acres and 5-13 material sites > Alternative 2.	Same as Alternative 2.	Same as Alternative 2.	3 less material sites and 120 acres less than Alternative 2.

Table 3.1-4: Comparison of Impacts by Alternative* for Geology and Paleontology

Impact-causing Project Component	Alternative 2 – Proposed Action	Alternative 3A – LNG-Powered Haul Trucks	Alternative 3B – Diesel Pipeline	Alternative 4 – BTC Port	Alternative 5A – Dry Stack Tailings	Alternative 6A – Dalzell Gorge Route
Paleontology	Potential impacts within project footprint at locations having fossil potential: pre-Quaternary and Quaternary deposits along roughly 262 miles of ROW (out of 316 mile total ROW), 80 miles of shoofly roads, and material sites covering about 1,000 acres.	Same as Alternative 2.	Little additional impacts.	Same as Alternative 2.	Same as Alternative 2.	Same as Alternative 2.

Notes: *The No Action Alternative would have no new impacts.