# ALASKA
# PipelineProject

# Draft Resource Report 6 – Rev 0
# Geological Resources

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TransCanada ExxonMobil

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**Notes:**

Yellow highlighting is used throughout this draft resource report to highlight selected information that is pending or subject to change in the final report.

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## LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| § | Section |
| ADNR | Alaska Department of Natural Resources |
| ADOTPF | Alaska Department of Transportation and Public Facilities |
| AEIC | Alaska Earthquake Information Center |
| AMP | Alaska Mainline milepost |
| APP | Alaska Pipeline Project |
| ARD | acid rock drainage |
| AVO | Alaska Volcano Observatory |
| BLM | U.S. Bureau of Land Management |
| C.F.R. | Code of Federal Regulations |
| DEM | Digital Elevation Model |
| DGGS | Alaska Division of Geological & Geophysical Surveys |
| DOI | U.S. Department of the Interior |
| FERC | Federal Energy Regulatory Commission |
| FSZ | Fairbanks Seismic Zone |
| *g* | gravity |
| GTP | Gas Treatment Plant |
| LiDAR | light detection and ranging |
| LNG | liquefied natural gas |
| ML | metal leaching |
| MLBV | mainline block valve |
| MMMI | Maximum Modified Mercalli Intensity |
| MP | milepost |
| MSZ | Minto Flats Seismic Zone |
| PMP | Point Thomson Gas Transmission Pipeline milepost |
| PT Pipeline | Point Thomson Gas Transmission Pipeline |
| PTU | Point Thomson Unit |
| SSZ | Salcha Seismic Zone |
| TAPS | Trans-Alaska Pipeline System |
| USGS | U.S. Geological Survey |

# 6.0 RESOURCE REPORT 6 – GEOLOGICAL RESOURCES

The location information, facility descriptions, resource data, construction methods, and mitigation measures presented in this report are preliminary and subject to change. APP is conducting engineering studies, environmental resource surveys, agency consultations, and stakeholder outreach efforts to further refine and define the details of the Project.

The Project described in this resource report is being designed and developed based on estimated volumes of natural gas from projected shipper commitments. If final shipper commitments are significantly different from those estimated, the Project may be adjusted accordingly.

## 6.1 INTRODUCTION

TransCanada Alaska Company, LLC and Foothills Pipe Lines Ltd., working with ExxonMobil Alaska Midstream Gas Investments LLC, are developing a joint project to treat, transport, and deliver natural gas from the Alaska North Slope (ANS) to pipeline facilities in Alberta, Canada for markets in the contiguous United States and North America. This joint project is referred to as the Alaska Pipeline Project (APP or Project)[1].

As required by Title 18 Code of Federal Regulations (C.F.R.) Section (§) 380.12 and consistent with the Alaska Natural Gas Pipeline Act of 2004 (ANGPA), APP has prepared this draft resource report in support of its application to the U.S. Federal Energy Regulatory Commission (FERC) for a Certificate of Public Convenience and Necessity (CPCN) under Section 7(c) of the Natural Gas Act (NGA) to construct, own, and operate the portion of the Project in Alaska. This draft resource report pertains only to that portion of the Project in Alaska, and unless the context otherwise requires, references in this draft resource report to APP refer only to the Alaska portion of the Project[2].

As shown in Figure 1.1-1 of Resource Report 1, APP will comprise the following major components[3,4]:

- The Point Thomson Gas Transmission Pipeline (PT Pipeline)[5], consisting of approximately 58.4 miles of buried 32-inch-diameter pipeline from the Point Thomson Unit (PTU) to an APP Gas Treatment Plant (GTP) and associated facilities near Prudhoe Bay;

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1 Depending on the context, the term APP refers to the joint project or, collectively, to the sponsoring entities.

2 The Canadian Section refers to the portion of the Project from the Yukon border to the pipeline facilities in Alberta, Canada.

3 In previous FERC filings, the Point Thomson Gas Transmission Pipeline was referred to as Zone 1, the Gas Treatment Plant was referred to as Zone 2, and the Alaska Mainline was referred to as Zone 3 of the Alaska-Canada Pipeline.

4 As part of the Project, APP proposes to construct compressor stations, meter stations, various mainline block valves (MLBVs), pig launcher and receiver facilities, as well as associated ancillary and auxiliary infrastructure, including additional temporary workspace, access roads, helipads, construction camps, pipe storage areas, contractor yards, borrow sites, and dock modifications at Prudhoe Bay.

5 The origin of the PT Pipeline is assumed to be located at an outlet from the PTU. The final length may vary depending on the final gas development plan for the PTU.

- The GTP, which will have the capacity to process gas received from the Point Thomson Unit and the existing Central Gas Facility (CGF) on the Prudhoe Bay Unit (PBU) in order to deliver an annual average capacity up to 4.5 billion standard cubic feet per day (bscfd) (standard conditions: 14.73 pounds per square inch absolute and 60º Fahrenheit) of sales quality gas; and
- The Alaska Mainline, consisting of approximately 745.1 miles of 48-inch-diameter pipeline, all of which is buried except as otherwise described in this Resource Report. The Alaska Mainline extends from the GTP to the Alaska-Yukon border east of Tok, Alaska, and includes provisions for intermediate gas delivery points within Alaska.

Table 6.1-1 lists the FERC's filing requirements and additional information applicable to Resource Report 6 taken from FERC's Guidance Manual for Environmental Report Preparation.

TABLE 6.1-1

**Alaska Pipeline Project**
**Resource Report 6 Filing Requirements Checklist**

| Requirement | Where Found in Document |
|---|---|
| FERC REQUIREMENTS FROM 18 C.F.R. § 380.12 | |
| 1. Identify the location (by milepost [MP]) of mineral resources and any planned or active surface mines crossed by the proposed facilities. (§380.12[h][1&2])<br>• Describe hazards to the facilities from mining activities, including subsidence, blasting, slumping, or landsliding or other ground failure. | Section 6.3 |
| 2. Identify any geologic hazards to the proposed facilities. (§ 380.12[h][2])<br>• For the offshore this information is needed on a mile-by-mile basis and will require completion of geophysical and other surveys before filing. | Section 6.4 |
| 3. Discuss the need for and locations where blasting may be necessary in order to construct the proposed facilities. (§ 380.12[h][3]) | Section 6.5 |
| 4. For liquefied natural gas (LNG) projects in seismic areas, the materials required by "Data Requirements for the Seismic Review of LNG Facilities," NBSIR84-2833. (§ 380.12[h][5]) | Not Applicable |
| 5. For underground storage facilities, how drilling activity by others within or adjacent to the facilities would be monitored, and how old wells would be located and monitored within the facility boundaries. (§ 380.12[h][6]) | Not Applicable |
| OTHER INFORMATION OFTEN MISSING AND RESULTING IN DATA REQUESTS PER FERC'S GUIDANCE MANUAL FOR ENVIRONMENTAL REPORT PREPARATION | |
| • Identify any sensitive paleontological resource areas crossed by the proposed facilities (usually only if raised in scoping or required by land-managing agency). | Section 6.6 |
| • Briefly summarize the physiography and bedrock geology of the project. | Section 6.2 |
| • If the application is for underground storage facilities:<br>o Describe monitoring of potential effects of the operation of adjacent storage or production facilities on the proposed facility, and vice versa;<br>o Describe measures taken to locate and determine the condition of old wells within the field and buffer zone and how the applicant would reduce risk from failure of known and undiscovered wells; and<br>o Identify and discuss safety and environmental safeguards required by state and federal drilling regulations. | Not Applicable |

Mileposts (MPs) are commonly used markers along linear projects, such as APP. Where necessary to distinguish the PT Pipeline from the Alaska Mainline, APP has prefixed its MP identifier with a PT Pipeline MP (PMP) or an Alaska Mainline MP (AMP). This convention is used in APP's application and supporting maps and alignment sheets (refer to Appendix 1O of Resource Report 1) to identify resources and features along the respective pipeline routes.

The purpose of Resource Report 6 is to describe the geological resources crossed by the Project or that are in the Project vicinity, and the potential impacts and mitigation measures that will be implemented to reduce impacts on these resources. Section 6.2 describes the geology and physiography; Section 6.3 describes the known mineral resources; Section 6.4 describes existing and potential geologic hazards; Section 6.5 discusses the potential for blasting to occur during Project activities; Section 6.6 addresses paleontological resources in the vicinity of the Project; Section 6.7 addresses cumulative impacts. References are provided in Section 6.8.

## 6.2 PHYSIOGRAPHIC AND GEOLOGIC SETTING

Most of Alaska forms a large peninsula or extension at the northwestern corner of the North American continent between the Arctic Ocean and the Pacific Ocean. The southeastern part of the state is on the main body of the continental land mass and includes an archipelago. Large areas of high, rugged mountains in northern and southern Alaska are extensions of mountain systems in Canada. The Brooks Range in northern Alaska is the northern terminus of the Rocky Mountain System. Only small valley glaciers are present in the eastern Brooks Range. Many of the summits and upper slopes of the southern mountain ranges are glaciated. Low mountains, plateaus, and highlands flank the high mountains and are, in turn, bounded by lowland areas. The lowlands are primarily along the courses of major streams and in coastal areas, where most Alaskan cities, towns, and villages in Alaska are located (U.S. Geological Survey [USGS] 2010).

There are two major physiographic large-scale regions of North America that extend into Alaska: The Interior Plains and the North America Cordillera (Wahrhaftig 1965). The Arctic Coastal Plain province is the continuation of the Interior Plains in Alaska. In Alaska, the North American Cordillera consists of three major divisions: The Rocky Mountain System, the Intermontane Plateaus, and the Pacific Mountain System. These divisions form three parallel belts from the conterminous United States through Canada to Alaska. Within the physiographic regions, geomorphic processes have modified the landscape to its present form and character through erosion, deposition, and mass wasting by the actions of glaciers, flowing water, wind, and gravity. In the Project area[6], the exposed bedrock and unconsolidated deposits range in age from Precambrian to Holocene in age (USGS 2010). Glacial drift deposited during several Pleistocene glaciations mantles mountain flanks and adjacent lowland areas in most mountainous areas. In some unglaciated areas, residual soil (decomposed bedrock) is present. Permafrost (perennially frozen ground) is encountered along much of the pipeline route and is discussed in more detail in Resource Report 7. Alaska has been divided into physiographic provinces[7] on the basis of topography and geomorphic processes by Wahrhaftig (1965). More recent publications divided Alaska into ecoregions on the primary parameters of lithology, soil type, surficial geology, and land cover (Nowacki et al. 2002). Secondary parameters utilized include climate, terrain roughness, and permafrost. Each province and ecoregion crossed by the Project, with associated MPs, is listed in Table 6.2-1. Province and ecoregion physiography

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[6] The terms “Project area” and “Project footprint” are defined to include the project facilities and land requirements for construction and operation. The term “Project vicinity” is used to mean the area or region near or surrounding the Project area, and is subject to the context in which the term is used.

[7] Provinces are distinctive areas having common topography, rock types and structure, and geologic and geomorphic history.

and geology characteristics are summarized in the following paragraphs. Figure 6.2-1 presents the location of the physiographic province types (mountains, uplands, lowlands, etc.) and ecoregions relative to the Project area.

TABLE 6.2-1

**Alaska Pipeline Project**
**Physiographic Provinces and Ecoregions Crossed by the Alaska Mainline Route** [a]

| Milepost | | Physiographic Province Number | Physiographic Province Name/Type | Ecoregion Number | Ecoregion Name |
|---|---|---|---|---|---|
| Begin | End | | | | |
| 0.0 | 62.8 | 1 | Arctic Coastal Plan Province | 1A | Beaufort Coastal Plain Ecoregion |
| 62.8 | 145.9 | 2 | Arctic Mountains Province | 2A | Brooks Range Foothills Ecoregion |
| 145.9 | 254.5 | 2 | Arctic Mountains Province | 2B | Brooks Range Ecoregion |
| 254.5 | 259.8 | 2 | Arctic Mountains Province | 2C | Kobuk Ridges and Valleys Ecoregion |
| 259.8 | 418.2 | 3 | Interior Lowlands and Uplands Province | 3A | Ray Mountains Ecoregion |
| 418.2 | 468.6 | 3 | Interior Lowlands and Uplands Province | 3B | Yukon Tanana Uplands Ecoregion |
| 468.6 | 494.0 | 3 | Interior Lowlands and Uplands Province | 3C | Tanana-Kuskokwim Lowlands Ecoregion |
| 494.0 | 502.0 | 3 | Interior Lowlands and Uplands Province | 3B | Yukon Tanana Uplands Ecoregion |
| 502.0 | 508.7 | 3 | Interior Lowlands and Uplands Province | 3C | Tanana-Kuskokwim Lowlands Ecoregion |
| 508.7 | 523.7 | 3 | Interior Lowlands and Uplands Province | 3B | Yukon Tanana Uplands Ecoregion |
| 523.7 | 535.8 | 3 | Interior Lowlands and Uplands Province | 3C | Tanana-Kuskokwim Lowlands Ecoregion |
| 535.8 | 537.5 | 3 | Interior Lowlands and Uplands Province | 3B | Yukon Tanana Uplands Ecoregion |
| 537.5 | 668.8 | 3 | Interior Lowlands and Uplands Province | 3C | Tanana-Kuskokwim Lowlands Ecoregion |
| 668.8 | 675.3 | 3 | Interior Lowlands and Uplands Province | 3B | Yukon Tanana Uplands Ecoregion |
| 675.3 | 676.3 | 3 | Interior Lowlands and Uplands Province | 3B | Yukon Tanana Uplands Ecoregion |
| 675.3 | 676.3 | 3 | Interior Lowlands and Uplands Province | 3C | Tanana-Kuskokwim Lowlands Ecoregion |
| 676.3 | 676.6 | 3 | Interior Lowlands and Uplands Province | 3C | Tanana-Kuskokwim Lowlands Ecoregion |
| 676.6 | 679.6 | 3 | Interior Lowlands and Uplands Province | 3B | Yukon Tanana Uplands Ecoregion |
| 679.6 | 681.1 | 3 | Interior Lowlands and Uplands Province | 3C | Tanana-Kuskokwim Lowlands Ecoregion |
| 681.1 | 681.3 | 3 | Interior Lowlands and Uplands Province | 3B | Yukon Tanana Uplands Ecoregion |
| 681.3 | 689.6 | 3 | Interior Lowlands and Uplands Province | 3C | Tanana-Kuskokwim Lowlands Ecoregion |
| 689.6 | 696.0 | 3 | Interior Lowlands and Uplands Province | 3B | Yukon Tanana Uplands Ecoregion |
| 696.0 | 696.0 | 3 | Interior Lowlands and Uplands Province | 3C | Tanana-Kuskokwim Lowlands Ecoregion |
| 696.0 | 696.4 | 3 | Interior Lowlands and Uplands Province | 3B | Yukon Tanana Uplands Ecoregion |
| 696.4 | 706.0 | 3 | Interior Lowlands and Uplands | 3C | Tanana-Kuskokwim Lowlands Ecoregion |

TABLE 6.2-1

**Alaska Pipeline Project**
**Physiographic Provinces and Ecoregions Crossed by the Alaska Mainline Route [a]**

| Milepost Begin | Milepost End | Physiographic Province Number | Physiographic Province Name/Type | Ecoregion Number | Ecoregion Name |
|---|---|---|---|---|---|
| | | | Province | | |
| 706.0 | 706.7 | 3 | Interior Lowlands and Uplands Province | 3B | Yukon Tanana Uplands Ecoregion |
| 706.7 | 712.2 | 3 | Interior Lowlands and Uplands Province | 3C | Tanana-Kuskokwim Lowlands Ecoregion |
| 712.2 | 712.4 | 3 | Interior Lowlands and Uplands Province | 3B | Yukon Tanana Uplands Ecoregion |
| 712.4 | 712.5 | 3 | Interior Lowlands and Uplands Province | 3C | Tanana-Kuskokwim Lowlands Ecoregion |
| 712.5 | 713.5 | 3 | Interior Lowlands and Uplands Province | 3B | Yukon Tanana Uplands Ecoregion |
| 713.5 | 713.8 | 3 | Interior Lowlands and Uplands Province | 3C | Tanana-Kuskokwim Lowlands Ecoregion |
| 713.8 | 713.9 | 3 | Interior Lowlands and Uplands Province | 3B | Yukon Tanana Uplands Ecoregion |
| 713.9 | 714.0 | 3 | Interior Lowlands and Uplands Province | 3C | Tanana-Kuskokwim Lowlands Ecoregion |
| 714.0 | 714.1 | 3 | Interior Lowlands and Uplands Province | 3B | Yukon Tanana Uplands Ecoregion |
| 714.1 | 714.7 | 3 | Interior Lowlands and Uplands Province | 3C | Tanana-Kuskokwim Lowlands Ecoregion |
| 714.7 | 715.3 | 3 | Interior Lowlands and Uplands Province | 3B | Yukon Tanana Uplands Ecoregion |
| 715.3 | 727.9 | 3 | Interior Lowlands and Uplands Province | 3C | Tanana-Kuskokwim Lowlands Ecoregion |
| 727.9 | 728.5 | 3 | Interior Lowlands and Uplands Province | 3B | Yukon Tanana Uplands Ecoregion |
| 728.5 | 731.3 | 3 | Interior Lowlands and Uplands Province | 3C | Tanana-Kuskokwim Lowlands Ecoregion |
| 731.3 | 731.8 | 3 | Interior Lowlands and Uplands Province | 3B | Yukon Tanana Uplands Ecoregion |
| 731.8 | 732.5 | 3 | Interior Lowlands and Uplands Province | 3C | Tanana-Kuskokwim Lowlands Ecoregion |
| 732.5 | 738.9 | 3 | Interior Lowlands and Uplands Province | 3B | Yukon Tanana Uplands Ecoregion |
| 738.9 | 742.8 | 3 | Interior Lowlands and Uplands Province | 3C | Tanana-Kuskokwim Lowlands Ecoregion |
| 742.8 | 745.1 | 3 | Interior Lowlands and Uplands Province | 3B | Yukon Tanana Uplands Ecoregion |

[a] The PT Pipeline and GTP facilities fall entirely within Physiographic Province 1, Ecoregion 1A.
Source: Nowacki et al. 2002; Wahrhaftig 1965.

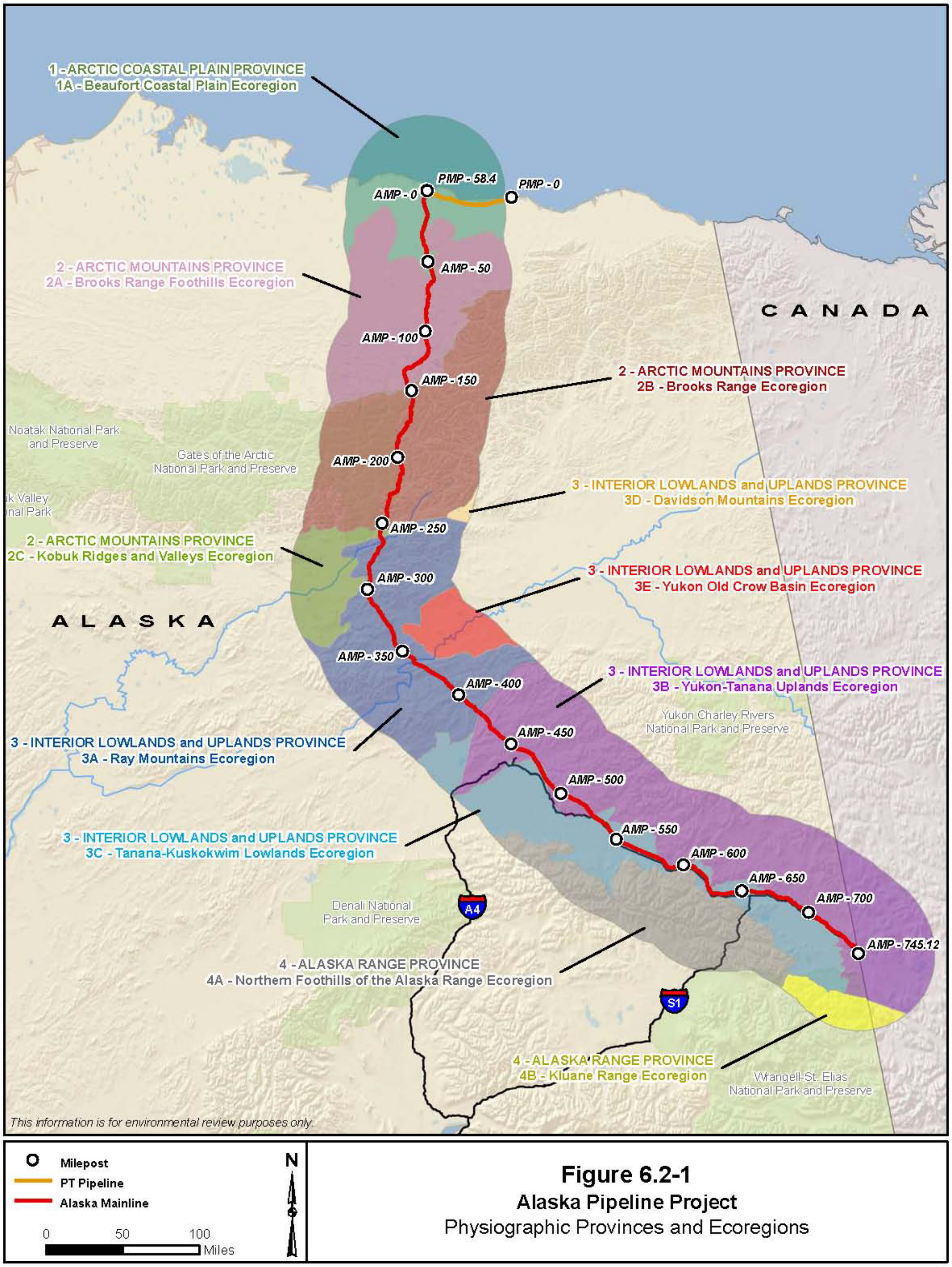


**Figure 6.2-1**
**Alaska Pipeline Project**
Physiographic Provinces and Ecoregions

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Several Project components (West Dock, dredge channel, dredge material disposal area) also extend north onto the Beaufort Sea Shelf as part of the Arctic Coastal Plain, Beaufort Coastal Plain Ecoregion. The shelf is characterized by a gentle slope from sea level to shelf break at about 200 feet below sea level, with an average gradient of about 4 feet per mile. The Beaufort Sea Shelf is about 50 miles wide in the Project vicinity, and is underlain by a thick sequence of Quaternary strata that is a continuation of those that underlie the Arctic Coastal Plain. These deposits are several hundreds of feet thick and consist of glaciofluvial deposits, braided stream alluvium, peat, and deltaic sediments, combined with shallow marine fine sand, silt, clay, and ice-rafted boulders deposited during sea level transgressions. Superimposed on these deposits are a number of large bodies of coarse-grained surface sediments, which form constructional islands and shoals such as Reindeer Island located about 8 miles offshore of Prudhoe Bay. The Quaternary deposits beneath the shelf are underlain by Paleozoic to Tertiary sedimentary rocks which are the target of oil and gas development in this region (U.S. Department of the Interior [DOI], Minerals Management Service 2003). Shallow marine sediment beneath the inner shelf contains relict ice-bonded permafrost, the top of which lies within a few feet of the seafloor near the shoreline and deepens to more than 50 feet below the sea floor within about 0.5mile of shore (Osterkamp and Harrison 1976).

In the vicinity of the PT Pipeline, GTP, and northern part of the Alaska Mainline, the tundra-covered Arctic Coastal Plain Province, Beaufort Coastal Plain Ecoregion has elevations that range from sea level at Prudhoe Bay to about 750 feet above sea level. This area is characterized by networks of polygonal ground between oriented thaw lakes in low areas. Other than streambanks and scattered pingos (small ice-cored hills), there is little topographic relief. The smooth plain is poorly drained and rises to the south at an average gradient of about 10 feet per mile. The coastal plain is mantled with Quaternary deposits of marine, alluvial, fluvial, and aeolian origins, and the underlying bedrock consists of northward-dipping and poorly consolidated Tertiary and Cretaceous shale, siltstone, and sandstone at depths ranging from several feet to more than 100 feet. The pipeline route generally follows the northward-flowing Sagavanirktok River and crosses perennially frozen Quaternary sediments that become progressively thinner to the north. The Sagavanirktok River is the dominant drainage in the region, with a wide, braided, and coarse-grained floodplain. The river has a meandering channel in its upper reach and is braided in the lower reach.

The Arctic Mountains Province, Brooks Range Foothills Ecoregion is characterized by broad uplands that increase in elevation southward, with east- to west-trending ridges and mesas in the north. In the south are irregular buttes, mesas, and long, linear ridges of Devonian and Cretaceous sandstone and shale with intervening low-relief plains and plateaus that are underlain by Quaternary alluvial, colluvial, aeolian, and glacial moraine deposits. Devonian and Cretaceous sandstone and shale underlie these unconsolidated deposits.

The Arctic Mountains Province, Brooks Range Ecoregion, and Kobuk Ridges and Valleys Ecoregion consist of several groups of rugged, deeply dissected mountains consisting of uplifted sedimentary and volcanic rocks that have been carved by glaciers. Portions of the summits and upper slopes of the mountain ranges and chains are covered with glaciers, and smaller glaciers are present in valleys of the Brooks Range, however, no active glaciers have been identified in the Project vicinity.

Near AMP 150 the Brooks Range rises abruptly from foothills to elevations reaching 8,000 feet above sea level. Folded and faulted stratified Paleozoic and Mesozoic sedimentary rock, including limestone, sandstone, shale, and some deformed Paleozoic metamorphic rocks are exposed on the northern flank of the range and in the central Brooks Range. Proterozoic to Paleozoic metamorphic rocks with some granitic intrusions are present in the southern Brooks Range. The range trends east to west, forming the continental divide, with major drainages flowing north or south in broad valleys that have been repeatedly glaciated. The pipeline route crosses the continental divide at Atigun Pass, the highest point along the Alaska Mainline route near AMP 173, with an elevation about 4,900 feet above sea level. North of the pass the pipeline route traverses the Atigun River Valley, a broad U-shaped valley with steep walls rising 2,000 to 3,000 feet above the river. Talus slopes, alluvial fans, moraines, and outwash terraces and fans are present at the base of steep slopes and in the river valleys. Lower elevations are covered with deep colluvial and coarse-grained floodplain deposits. Recent avalanche and slushflow (failure of high-water-content snow) deposits form distinctively humped colluvial fans covered with scattered boulders and cobbles at the mouths of higher tributary valleys.

South of Atigun Pass, the Alaska Mainline quickly descends 1,200 feet in elevation to the head of the Chandalar River basin before descending another 700 feet to the headwaters of the Dietrich-Koyukuk River system. The upper Dietrich River Valley is narrow, with a steep gradient and steep, coalescing alluvial and colluvial fans at the mouths of tributary valleys. Landslides and rock glaciers are present on both valley walls, but the most common forms of mass wasting are solifluction and flow slides. Solifluction forms widespread sheets and aprons on lower valley walls, especially where local bedrock is shale, phyllite, or siltstone. In the middle and lower reaches, the Dietrich River valley widens and becomes distinctly U-shaped with the floodplain becoming wider and braided. Thick stream icings develop annually in these braided reaches. Frozen till and fan deposits exist on the side slopes with frozen alluvium and lake deposits in the valley bottom (Brown and Kreig 1983). Drainages in the northern Brooks Range discharge into the Arctic Ocean, and drainages in the southern Brooks Range discharge into the Bering Sea. Most of the major drainages in the Brooks Range flow across flat-floored, U-shaped valleys that were scoured by Pleistocene glaciers.

In Alaska, the Interior Lowlands and Uplands Province correlate with the Ray Mountains, Yukon Tanana Uplands, and the Tanana-Kuskokwim Lowlands Ecoregions. The Ray Mountains Ecoregion consists of rounded ridges rising generally to 2,000 to 4,000 feet above sea level surmounted by isolated rugged mountains. Peaks in these isolated areas reach up to 5,700 feet in elevation. Elevations along the pipeline route range from 350 to 2,100 feet above sea level. Valleys are floored by thick, discontinuously frozen alluvial fills, which are locally ice-rich, to within a few miles of their heads. Highlands are underlain chiefly by Paleozoic and Precambrian schist and gneiss with a northeast-trending structural grain cut by several granitic intrusions. Along the pipeline alignment, the terrain has not been glaciated, except near the very northern margin. Unconsolidated deposits generally consist of frozen colluvial silts, sands, and rock fragments, glaciofluvial sand and gravel, windblown silt and sand, fine-grained lake sediments, and alluvium.

The Yukon-Tanana Upland Ecoregionis located south of the Yukon River. The landscape is characterized by gentle ridges and hills with elevations ranging between 350 and 1,900 feet above sea level. Lowlands are underlain by ice-rich silt and fine-grained alluvium, and uplands are mantled with colluvium and windblown silt.

The northern portion of the Tanana-Kuskokwim Lowland Ecoregion is characterized by rounded ridges with gentle side slopes and broad, slightly irregular divides and terraced spurs. The pipeline route generally follows ridge crests between major east- to west-trending valleys. In the western part, these rounded ridges trend northeast to east and have elevations up to 2,200 feet, as much as1,500 feet above adjacent valley floors. Valleys are generally flat, alluvium floored, and measure 0.25- to 0.5-mile-wide to within a few miles of their headwaters.

Moving south, the topography consists of small basins among scattered, low hills of Precambrian schist and Mesozoic granitic intrusions. The basins are floored with coarse outwash alluvium, silt, morainal deposits, aeolian sand blankets, and dunes in places. Elevations range from 1,000 to 1,500 feet above sea level. Farther to the south, elevations can reach 2,900 feet above sea level. Coalescing outwash fans from the Alaska Range slope 20 to 50 feet-per-mile northward to floodplains located along the axial streams in the lowlands. End moraines form semicircular belts on some upper fan surfaces. Scattered, low knobs of granite, ultramafic rocks, and Precambrian schist stand above the outwash. A short segment of the Project near Dot Lake (AMPs 605 to 610) is characterized by Tertiary sedimentary bedrock and Quaternary deposits uplifted and deformed by thrust faults and folds to form a distinct tectonic region referred to as the Northern Fold and Thrust Belt (Carver et al. 2008).

## 6.3 MINERAL RESOURCES

A wide variety of exploitable and potentially exploitable mineral resources occur in the vicinity of the Project including industrial (sand/gravel, rock, dimension stone) and metallic (gold, silver, lead, zinc) minerals and energy resources (oil and gas, coal, peat). Mineral resources within 1,500 feet of the construction right-of-way for the pipeline route and within 0.5 mile of Aboveground Facilities[8] and their Associated Infrastructure[9] have been identified. The following sections detail where these resources are located relative to the Project and the mitigation measures that will reduce potential impacts on metals, industrial minerals, and energy resources.

### 6.3.1 INDUSTRIAL AND METALLIC MINERAL RESOURCES

The total value of Alaska's mineral industry in 2009 was estimated at approximately $3.0 billion. In 2009, state mineral rents and royalties amounted to $6.4 million and sales of rock, sand, and gravel amounted to $4.7 million. Exploration expenditures were $180 million, with at least 62 Alaska projects spending more than $100,000 each on exploration. These projects included copper/gold/molybdenum porphyry systems, which were the major exploration target in 2009, followed by intrusion-related gold deposits. Exploration was also conducted on various gold, quartz-vein deposits; base metal rich, polymetallic massive sulfide deposits; platinum-group-element, nickel/copper, ultramafic-hosted deposits; and rare earth-element, diamond, tin, coal, placer gold, and other deposit types (Szumigala et al. 2010).

Szumigala et al. (2010) maps the state with seven mineral industry regions. The Northern and Eastern Interior regions are crossed by the Project. Within the Northern Region, the Nolan Creek Mine– a gold/antimony lode property is the only mine mapped. It is depicted by

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8 Aboveground Facilities include the GTP, eight compressor stations, three custody meter stations, various MLBVs, pig launchers, pig receivers, provisions for intermediate gas delivery points, and cathodic protection facilities as discussed in Section 1.3.2 of Resource Report 1.

9 Associated Infrastructure and land required to construct and operate APP include additional temporary workspace (ATWS), access roads, helipads, airstrips, construction camps, pipe storage areas, contractor yards, borrow sites, and dock modifications, as discussed in Section 1.3.3 of Resource Report 1.

Szumigala et al. (2010) as approximately 25 miles west of AMP 200[10]. In the Eastern Interior Region, the Fairbanks District (consisting of four mining projects – Fort Knox, Golden Summit, Coffee Dome, and Gil) and the Tushtena mining project are mapped by Szumigala et al. (2010) within the vicinity of the Project. APP completed a more detailed review of these mine locations relative to the Alaska Mainline and PT pipelines. The review indicates that:

- The Fort Knox mining project has operations located about 2 to 3 miles northeast of AMP460,however, it appears that the Alaska Mainline route crosses or is very near the southwest corner of this mineral holding;
- The Golden Summit mining project is located approximately 5 miles northeast of AMP455;
- The Coffee Dome mining project is located about 13 miles northeast of AMP464;
- The Gil mining project, which lies within the Fort Knox property, is located about 7miles northeast of AMP 465; and
- The Tushtena mining project is approximately 6 miles southwest of AMP 630.

Szumigala et al. (2010) also notes that minor placer gold exploration activities, including prospecting, trenching, drilling, and geophysical surveys, were reported by 126 individuals and companies, and work was performed in most mining districts across the Eastern Interior Region. Lode exploration in the region was also conducted to partially fulfill annual labor requirements to maintain mining claims in good standing. According to the Alaska Department of Natural Resources (ADNR), mining claims are locatable mineral rights which have been discovered. Claims may be converted or required to be converted to an Upland Mining Lease before minerals can be extracted if other resources are affected.

APP is currently evaluating the Project for active mineral claims and leases that could potentially be within 1,500 feet of the Pipeline Facilities[11] or within 0.5 mile of Aboveground Facilities and Associated Infrastructure. APP's evaluation includes completing landowner consultations, reviewing public records (such as those recorded by ADNR– Land Records Information Section and State Mining Claims and U.S. Bureau of Land Management [BLM] Mining Claims in Alaska), researching mineral resource maps, and conducting field reconnaissance.

A total of approximately 60 aggregate material borrow sites currently exist within the Project area. A list of these is provided in Resource Report 1, Appendix 1G. Existing sites include those used by the oil industry on the North Slope, as well as Alaska Department of Transportation and Public Facilities (ADOTPF) sites along the road system that are used for road and airstrip construction and maintenance. Existing sites on the North Slope extract sand and gravel from buried outwash deposits or alluvium in floodplains and river terraces (Rawlinson 1990). ADOTPF sites in the Brooks Range contain either rock of marginal quality, glacial moraine material, or alluvial fan deposits. Along the Dalton Highway south of the Brooks Range and along the Richardson Highway from Fairbanks to Delta Junction, existing borrow sites

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10 Because the mines referenced in this section are mapped on a state-wide scale, the MP crossings are estimated to the nearest whole number.

11 The Pipeline Facilities will consist of the PT Pipeline and the Alaska Mainline, as discussed in Section 1.3.1 of Resource Report 1.

contain floodplain alluvium, weathered or fractured bedrock, glacial till, and colluvium. Existing sites along the Alaska Highway south of Delta Junction contain mostly gravelly glacial outwash, alluvial fan and floodplain deposits, and in the region southeast of Northway, eolian sand over weathered bedrock (ADOTPF 2009).

Table 6A-1 provides a preliminary summary of the active federal and state mineral claims and leases within 1,500 feet of the Alaska Mainline. APP has determined that there are no active non-energy resource leases or claims along the PT Pipeline construction right-of-way or within the footprint of the GTP, including any associated Aboveground Facilities and infrastructure. [Note: APP will provide an update of this assessment of industrial mineral holdings within 1,500 feet of the Pipeline Facilities and within 0.5 mile of Aboveground Facilities and Associated Infrastructure in the final report.]

### 6.3.2 ENERGY RESOURCES

ADNR (2008) provides a digitized map of oil and gas basins in Alaska adapted from Ehm (1983). The most northern of the basins crossed by the Project, the Colville Basin, lies beneath the Project on the North Slope, and is crossed by the Pipeline Facilities between PMP 0 to PMP 58 and AMP 0 to AMP 150[12]. The Colville Basin contains approximately 25 percent of U.S. oil reserves (ADNR 2011). ADNR lands in the greater Prudhoe Bay area have produced more than 15 billion barrels of oil since the late 1970s. Hydrocarbons are being developed and produced from the Prudhoe Bay Field, the largest oil field in North America, the 2.5-billion-barrel Kuparuk Field, and from numerous smaller fields such as the 500-million-barrel Alpine field, which lies within the Colville River Unit west of Prudhoe Bay and Kuparuk. Other petroleum fields on state lands, both onshore and offshore (within the 3-mile limit), include Arctic Fortitude, Badami, Beechey Point, Dewline, Duck Island (Endicott), Milne Point, Nikaitchuq, Northstar, and Ooguruk (ADNR 2011). The Project crosses the Badami, Prudhoe Bay, and Arctic Fortitude units (refer to Table 6.3.2-1). Hydrocarbon generation in this area commonly correlates with deposition of the Cretaceous to Tertiary Brookian sequence and the Late Paleozoic to Cretaceous Ellesmerian and Beaufortian sequences. The rocks include marine and nonmarine deltaic sandstone, siltstone, shale, conglomerate, coal, and carbonates. Potential reservoir rocks include sandstone, conglomerate, and limestone (ADNR 2011; BLM 2005).

The BLM has held lease sales on federal lands in the Colville Basin (west of the state lands) in 1999, 2002, and 2004, resulting in the drilling of 20 exploratory wells and the discovery of 3 oil and gas fields. Exploration also indicates there is added potential for producing coal bed natural gas. Gas discoveries south of Barrow are produced for local consumption. Prospects for additional discoveries are projected by BLM as excellent (BLM 2005).

South of the Brooks Range lies a basin referred to as the “Kobuk flysch belt of Kirschner” (ADNR 2008; Troutman and Stanley 2003a) which is crossed between AMPs 253 and 300. The potential for oil/gas at this location was based on the report of three naturally occurring oil seeps located near Allakaket on the Koyukuk River in 1988. Troutman and Stanley (2003a) conclude these seeps are doubtful because the reports were based on observations “made by a

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12 As these features are regional in scale, exact MP crossings are subjective and thus estimated to the nearest whole number.

prospector many years ago, and seeps have not been seen by, or reported to, geologists who have recently been in Allakaket."

The western edge of the Yukon Flats Basin is depicted by Ehm (1983) and the ADNR (2008) as approximately 20 miles east of approximate AMP 350. Troutman and Stanley (2004, 2003a, and 2003b) document several occurrences of oil shale outcrops, oil seeps, and exploratory wells drilled in this basin more than 100 miles northeast of the Alaska Mainline. The wells encountered solid bitumen and minor gas shows, but no oil.

The Nenana/Middle Tanana Basin, crossed between AMPs 532 and 579, underlies swampy lowland areas near Fairbanks (ADNR 2008; Bailey 2010; Ehm 1983). The overall basin (approximately 8,500 square miles) consists of two sub-basins separated by a saddle with varying thicknesses of Tertiary nonmarine fill. Although some rock samples from the basins contain material conducive to oil formation, the nonmarine rocks in most of the basins contain coal and other material that would more likely favor the production of natural gas. It was estimated that the entire basin has the potential to hold one trillion to six trillion cubic feet of natural gas. Exploration of the basin has been very limited. Unocal, in 1962, and ARCO, in 1984,each drilled a well in the basin, however, neither found oil or gas. Troutman and Stanley (2003a) report that no commercial petroleum production has been obtained from central Alaska. Nevertheless, confirmed indications of petroleum in central Alaska include gas in wells that penetrate Tertiary coal-bearing strata in the Nenana basin and gas in water wells and test holes in the Fairbanks area. Bailey (2010) reports that in 2004,the Usibelli Coal Mine applied for a state exploration license for coal bed methane in the Healy area about 70 miles southwest of AMP 500. The proposal ran into local opposition, and ADNR has yet to issue the license. From 2002 to 2007, Andex Resources continued evaluation of resources in the area as well as oil and gas leasing. In 2009, Rampart Energy initiated drilling in the basin. The final results of the drilling were not reported. Bailey (2010) concludes that coal beds and lake-formed shales are the most likely source of hydrocarbons. Coal beds in the sediments have probably created gas and could act as a future source of coal bed methane in this basin.

Troutman and Stanley (2003a) and Miller et al. (1959) describe a sedimentary basin from Tok to the U.S.-Canada border (approximate AMPs 640 to 744), referred to as the Northway Lowlands or Upper Tanana basin. Two wells were drilled in this area in 1955 with reported gas shows. The first was drilled in unconsolidated Quaternary deposits by the Alaska Propane Company, Inc. near AMP 730. The second was in unconsolidated Quaternary deposits in a well drilled for water at Seaton Roadhouse near AMP 733. No commercial petroleum production was reported in this area.

APP completed a preliminary search of ADNR (2009a), BLM (2011), and USGS (2008) databases for energy resource claims and leases in the vicinity of the Project. The results of the search are identified in Table 6.3.2-1 below. The GTP footprint is within the oil and gas lease ADL 28303. [Note: APP will provide an update of this assessment of energy resource claims and leases within 1,500 feet of the Pipeline Facilities and 0.5 mile of Aboveground Facilities and Associated Infrastructure in the final report.]

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TABLE 6.3.2-1

**Alaska Pipeline Project**
**Oil and Gas Leases Potentially Within 1,500 Feet of the Pipeline Facilities**

| Milepost Begin | Milepost End | Distance and Direction from the Construction Right-of-Way to the Lease [a] | ID Number |
|---|---|---|---|
| POINT THOMSON GAS TRANSMISSION LINE | | | |
| 0.0 | 1.9 | 385 feet North of right-of-way | ADL 47559 |
| 10.0 | 12.0 | right-of-way traverses through Lease | ADL 390997 |
| 12.0 | 14.0 | right-of-way traverses through Lease | ADL 390998 |
| 12.0 | 14.0 | 450 feet South of right-of-way | ADL 391000 |
| 14.0 | 14.9 | right-of-way traverses through Lease | ADL 390825 |
| 14.9 | 16.0 | right-of-way traverses through Lease | ADL 391001 |
| 16.0 | 19.0 | right-of-way traverses through Lease | ADL 365535 |
| 18.0 | 20.0 | 550 feet South of right-of-way | ADL 391432 |
| 19.0 | 20.0 | right-of-way traverses through Lease | ADL 375093 |
| 20.0 | 21.2 | right-of-way traverses through Lease | ADL 375094 |
| 21.2 | 22.1 | right-of-way traverses through Lease | ADL 367011 |
| 22.1 | 24.1 | right-of-way traverses through Lease | ADL 367010 |
| 23.1 | 24.1 | 500 feet South of right-of-way | ADL 391769 |
| 24.1 | 26.1 | right-of-way traverses through Lease | ADL 390994 |
| 24.1 | 26.1 | 500 feet South of right-of-way | ADL 390996 |
| 26.1 | 28.1 | right-of-way traverses through Lease | ADL 391534 |
| 28.1 | 30.3 | right-of-way traverses through Lease | ADL 390993 |
| 37.8 | 39.1 | right-of-way traverses through Lease | ADL 390838 |
| 39.1 | 41.4 | right-of-way traverses through Lease | ADL 391021 |
| 41.4 | 42.4 | right-of-way traverses through Lease | ADL 391018 |
| 42.4 | 43.4 | right-of-way traverses through Lease | ADL 391017 |
| 43.4 | 45.5 | right-of-way traverses through Lease | ADL 28344 |
| 43.4 | 45.5 | 775 feet South of right-of-way | ADL 391019 |
| 45.5 | 47.9 | right-of-way traverses through Lease | ADL 28345 |
| 45.5 | 47.9 | 1,250 feet South of right-of-way | ADL 28346 |
| 47.9 | 49.0 | right-of-way traverses through Lease | ADL 28327 |
| 49.0 | 50.0 | right-of-way traverses through Lease | ADL 28324 |
| 50.0 | 52.7 | right-of-way traverses through Lease | ADL 28325 |
| 52.7 | 54.6 | right-of-way traverses through Lease | ADL 28326 |
| 54.6 | 55.9 | right-of-way traverses through Lease | ADL 28308 |
| 55.9 | 57.7 | right-of-way traverses through Lease | ADL 28307 |
| 57.7 | 58.0 | right-of-way traverses through Lease | ADL 28306 |
| 58.0 | 58.4 | right-of-way traverses through Lease | ADL 28303 |
| ALASKA MAINLINE | | | |
| 0.0 | 0.4 | right-of-way traverses through Lease | ADL 28303 |
| 0.4 | 2.8 | 1,050 feet West of right-of-way | ADL 28305 |
| 0.4 | 2.8 | right-of-way traverses through Lease | ADL 28306 |
| 2.8 | 3.1 | right-of-way traverses through Lease | ADL 28309 |
| 3.1 | 5.0 | right-of-way traverses through Lease | ADL 28310 |
| 5.0 | 7.0 | right-of-way traverses through Lease | ADL 28313 |
| 7.0 | 9.1 | right-of-way traverses through Lease | ADL 47475 |
| 9.1 | 11.1 | right-of-way traverses through Lease | ADL 389179 |
| 11.1 | 13.1 | right-of-way traverses through Lease | ADL 391766 |
| 13.1 | 14.0 | right-of-way traverses through Lease | ADL 391768 |
| 14.0 | 15.1 | right-of-way traverses through Lease | ADL 391767 |
| 23.9 | 27.1 | right-of-way traverses through Lease | ADL 391706 |
| 27.1 | 28.2 | right-of-way traverses through Lease | ADL 391707 |
| 28.2 | 30.4 | right-of-way traverses through Lease | ADL 391704 |
| 30.4 | 33.5 | right-of-way traverses through Lease | ADL 391678 |
| 33.5 | 36.6 | 450 feet East of right-of-way | ADL 391683 |

TABLE 6.3.2-1

**Alaska Pipeline Project**
**Oil and Gas Leases Potentially Within 1,500 Feet of the Pipeline Facilities**

| Milepost | | Distance and Direction from the Construction Right-of-Way to the Lease [a] | ID Number |
|---|---|---|---|
| Begin | End | | |
| 33.5 | 36.6 | right-of-way traverses through Lease | ADL 391680 |
| 36.6 | 37.3 | right-of-way traverses through Lease | ADL 391660 |
| 37.3 | 39.9 | right-of-way traverses through Lease | ADL 391663 |

[a] Straight-line distance and direction from the site to the pipeline. The actual distance by road or trail from site to the pipeline will be longer.

### 6.3.3 CONSTRUCTION AND OPERATION IMPACTS AND MITIGATION

The potential impacts of the Project on industrial and metallic mineral rights and energy resource claims and leases, access, and commercial viability include:

- Restrictions on exploration and development within a certain distance to the pipeline for activities deemed a safety hazard;
- Short-term restrictions to access of claims or leases within the construction right-of-way during construction activities in a specific area;
- Short-term disruption of the land surface within the construction right-of-way during construction activities, which may disturb surface or subsurface mineral resources;
- Limitations on the mining process that can be used to recover minerals because of considerations of pipeline safety (e.g., vibration impacts on the pipeline); and
- Limitations on the recovery of mineral sources because of the physical presence of the Project, this impact depends on the location of the Project within the boundaries of the lease relative to the location of the mineral resources.

The Project does not cross any known active or abandoned underground mines, and the area is not known to be undergoing regional subsidence due to petroleum or excessive groundwater withdrawal (USGS 2010).

#### 6.3.3.1 Industrial and Metallic Mineral Resources

**Construction and Operations Impacts and Mitigation**

Appendices 6A and 6B provide the list of industrial and metallic mineral resources within 1,500 feet of the Pipeline Facilities and 0.5 mile of Aboveground Facilities and Associated Infrastructure. APP will make a reasonable effort to maintain communications with parties affected by construction activities to reduce adverse effects of the Project on mineral resources and mineral extraction activities. APP will work with parties associated with future mineral leases in an attempt to preserve the commercial viability of such leases and permit the mining of these resources while protecting the integrity of the Project.

The Project could cross unknown or abandoned mines. Potential hazards associated with abandoned mines could include, but are not limited to, ground subsidence, contaminated water or soils, toxic gas, mud pits, tailings, open boreholes, and the presence of waste chemicals and shock-sensitive materials and explosives. Evaluation of the potential hazards associated with abandoned mines within the Project area suggests that only tailings will be a potential hazard on this Project. This evaluation identified periodic accumulations of tailings from dredge and sluice box mining operations in the vicinity of AMPs 453 to 456. This generally coincides with the Fairbanks Mining District, noted previously. APP has further reviewed these locations and believes that these mining residuals are related to historic (circa late-1800s/early 1900s) placer operations in the valleys along the Steese and Elliot highways. Therefore, regional subsidence or the local collapse of structures is not expected to impact the Project. If tailings are found to be present within the Project area during construction, or if APP determines that runoff from these deposits could impact the Project, APP will report their presence to the appropriate federal and/or state regulatory agency, and comply with further actions as necessary (Resource Report 8).

The Project will use granular material, such as gravel and sand, during construction. Appendix 1G of Resource Report 1 provides a list of existing and proposed borrow sources, and Section 1.6.5.5 provides a description of activities associated with resource extraction. Resource Report 8 provides a list of impacts by land use type (Section 8.2.2 and Appendix 8C). During construction, the Project will temporarily impede access to roughly half of the existing borrow sites where the route crosses existing access roads to the sites. As described in Resource Report 1 (Section 1.6.3.3), roads will be crossed by the pipeline using conventional horizontal boring or open-cut techniques, and will be reclaimed using the same type of sub-bed and surface material as the original construction. Thus, these impacts are expected to be short-term in duration. The Project will impede future use at six existing borrow sites (located near AMPs 457.7, 521.2, 590.2, 681.5, 688.2, and 738.5; Appendix 1G) where the route passes through part of the borrow site itself, precluding use of the resource beneath the right-of-way for the life of the pipeline.

#### 6.3.3.2 Energy Resources

**Construction and Operations Impacts and Mitigation**

Table 6.3.2-1 provides the list of energy resource claims and leases within 1,500 feet of the Pipeline Facilities. Based on a preliminary assessment, APP has determined that the Project does not impact the subsurface estate of energy resources, and that the Project footprint does not currently overlap with any entry points. Although APP crosses areas currently utilized or that can be potentially utilized for oil and gas development, the Project is not anticipated to inhibit development because the pipeline will not be buried deep enough to directly or indirectly impact an oil and gas field. APP will make a reasonable effort to maintain communications with parties affected by construction activities to reduce adverse effects of the Project on energy resources. APP will work with parties associated with energy resource claims and leases in an attempt to preserve the mining and commercial viability of these resources while protecting the integrity of the Project. Prior to ground-disturbing activities, APP will identify underground utilities in the construction area by contacting Alaska's One-Call system. If facilities are located within construction work areas, APP will either avoid well or pipeline sites or take appropriate precautions to protect the integrity of such facilities.

## 6.4 GEOLOGIC HAZARDS

Geologic hazards are natural physical conditions that can, when active, result in damage to land and structures or injury to people. Due to the rugged and varying terrain and level of seismic activity in some areas, geologic hazards occur in the Project area. The State Hazard Mitigation Plan prepared by the Department of Military and Veteran Affairs, Division of Homeland Security and Emergency Management (2010), evaluated hazard risk in Alaska during the period between1978 to 2009. This plan notes the following geologic hazards:

- Approximately 11 percent of all earthquakes worldwide occur in Alaska, and typically, an earthquake of magnitude 7 occurs annually in Alaska. Several seismically active areas of the state are crossed by the Project between the Brooks Range and the U.S.-Canada border;
- A number of volcanoes are considered active in Alaska, one of which is located in the east-central region of Alaska crossed by the Project;
- Of the types of ground failure (mass movement, land subsidence, failure related to seasonal frozen ground and permafrost) present in Alaska, mass movement is the greatest threat;
- Numerous snow avalanche events have occurred in Alaska in the past 200 years. For regions crossed by the Project, the Brooks Range in particular is considered to have high avalanche potential; and
- Flooding is the most widespread geologic hazard in Alaska, with many Alaska communities and transportation corridors located along rivers subject to flooding.

APP completed a preliminary geohazard assessment of the Project right-of-way using a number of Project-specific datasets, imagery, and other resources. The Project will continue to evaluate geohazards to support the basis for design and construction. Several generalized categories were considered in the assessment and include:

- Earthquakes (fault rupture displacement, and soil liquefaction, seismic wave propagation);
- Volcanism;
- Landslides/mass movements (landslides, avalanches, rock glaciers, and subsidence);
- Acid rock drainage (ARD);
- Erosion and scour; and
- Ground freezing, frost heave, and permafrost thawing (refer to Resource Report 7).

APP assessed each type of geohazard in the Project area and developed a preliminary susceptibility ranking based on a semi-quantitative index-based approach adapted from Rizkalla (2008). This methodology will provide a common framework to evaluate the potential severity of both individual and multiple geohazards and a basis for developing mitigation options.

### 6.4.1 EARTHQUAKES

Nearly the entire State of Alaska is seismically active. The greatest concentration of earthquakes is along the Pacific margin where the Pacific plate is being subducted beneath southern Alaska and the Aleutian Islands. Three of the ten largest earthquakes in the world since 1900 have occurred in Alaska along the boundary between the Pacific and North American plates. Approximately 75 percent of the detected earthquakes occur in the Anchorage, Cook Inlet, Alaska Peninsula, and the Aleutian Islands. About 15 percent of the earthquakes occur in southeast Alaska, and the remaining 10 percent occur in the interior region where much of the Project is located (Alaska Earthquake Information Center [AEIC] 2011).

A portion of the APP pipeline route traverses areas of seismicity with fairly frequent earthquake activity. The AEIC (2011) lists more than 1,400 earthquake events with magnitude greater than 4.0 since 1898 for the general geographic area encompassing the Project (61$^{o}$ to 63$^{o}$ north latitude, 141$^{o}$ to 146$^{o}$ west longitude and 63$^{o}$ to 70.5$^{o}$ north latitude, 145$^{o}$ to 152$^{o}$ west longitude).

Earthquake size is commonly measured by the Moment Magnitude Scale, and ground-shaking intensity at specific locations is often indicated by the Maximum Modified Mercalli Intensity (MMMI) scale. Table 6.4.1-1 lists typical damage resulting from various magnitude events. Table 6.4.1-2 lists typical human perception and structural responses arising from the select MMMI intensity levels.

TABLE 6.4.1-1

**Alaska Pipeline Project**
**Summary of Earthquake Effects in Relation to Magnitude**

| Magnitude | Earthquake Perception or Effect |
|---|---|
| Less than 2.0 | Micro earthquakes, not felt. |
| 2.0–2.9 | Generally not felt, but recorded. |
| 3.0–3.9 | Often felt, but rarely causes damage. |
| 4.0–4.9 | Noticeable shaking of indoor items, rattling noises. Significant damage unlikely. |
| 5.0–5.9 | Can cause major damage to poorly constructed buildings over small regions. At most slight damage to well-designed buildings. |
| 6.0–6.9 | Can be destructive in areas up to about 100 miles across in populated areas. |
| 7.0–7.9 | Can cause serious damage over larger areas. |
| 8.0–8.9 | Can cause serious damage in areas several hundred miles across. |
| 9.0–9.9 | Devastating in areas many hundreds to several thousand miles across. |
| 10.0+ | Never recorded, widespread devastation across very large areas |

Source: USGS 2009

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TABLE 6.4.1-2

**Alaska Pipeline Project**
**Summary of Human Perceptions or Structure Responses to Maximum Modified Mercalli Intensities**

| Maximum Modified Mercalli Intensity | Human Perception or Structural Response |
|---|---|
| IV | Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably. |
| V | Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop. |
| VI | Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight. |
| VII | Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken. |
| VIII | Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. |

Source: USGS 2009

DOI (2011) identified 28 earthquakes, having a MMMI of IV or greater, that have occurred within approximately 100 miles of APP since 1904. Table 6.4.1-3 summarizes this data. All of these earthquakes have occurred within a region between AMPs 300 to 744[13]. Nine earthquakes of intensity VI to VII have occurred since 1898. Four of these earthquakes occurred in the Fairbanks, Alaska vicinity. The DOI reports that strong shaking caused minor damage in the Fairbanks area, but there were no identified surface fault ruptures during these events. No reported earthquake had a MMMI intensity greater than VIII.

TABLE 6.4.1-3

**Alaska Pipeline Project**
**Earthquakes Greater Than Maximum Modified Mercalli Intensity IV Within 100 Miles of the Alaska Pipeline Project Route**

| | | | Location | | Scale | | | |
|---|---|---|---|---|---|---|---|---|
| Approximate Nearest Milepost | Epicenter Direction and Distance (miles) from Right-of-Way | Event Month/Day/Year | West Longitude | North Latitude | Body Wave Magnitude | Surface Wave Magnitude | Maximum Modified Mercalli Intensity | Depth (miles) |
| YUKON-KOYUKUK CENSUS AREA | | | | | | | | |
| AMP 300 | 80 W | 6/14/1986 | 152º 32’ | 65º37’ | 5.2 | 4.7 | V | 6 |
| AMP 300 | 5 E | 3/9/1985 | 149º 56’ | 66º12’ | 5.9 | 6.0 | V | 6 |
| AMP 300 | 50 SE | 2/7/1991 | 147º 56’ | 66º 22’ | 5.5 | 4.8 | IV | 6 |
| AMP 350 | 110 W | 6/4/2001 | 152º 29’ | 66º 44’ | 5.0 | 4.5 | IV | 6 |
| AMP 350 | 100 W | 5/11/1958 | 152º.01’ | 65º 01’ | NV | NV | V | 0 |
| AMP 350 | 100 W | 5/10/1958 | 152º 09’ | 65º 06’ | NV | NV | V | 0 |
| AMP 360 | 50 W | 1/30/1961 | 150º 07’ | 65º 12’ | NV | NV | V | 0 |
| AMP 360 | 40 W | 10/29/1968 | 150º 08’ | 65º 28’ | 6.0 | 6.5 | VII | 4 |
| AMP 410 | 12 W | 10/6/1995 | 148º 36’ | 65º 11’ | 5.7 | 5.8 | VI | 5 |

13 As the features discussed in this section are regional to state-wide in scale, exact MP crossings are subjective and thus estimated to the nearest whole number.

TABLE 6.4.1-3

**Alaska Pipeline Project**
**Earthquakes Greater Than Maximum Modified Mercalli Intensity IV Within 100 Miles of the Alaska Pipeline Project Route**

| Approximate Nearest Milepost | Epicenter Direction and Distance (miles) from Right-of-Way | Event Month/Day/Year | Location: West Longitude | Location: North Latitude | Scale: Body Wave Magnitude | Scale: Surface Wave Magnitude | Scale: Maximum Modified Mercalli Intensity | Depth (miles) |
|---|---|---|---|---|---|---|---|---|
| FAIRBANKS NORTH STAR BOROUGH | | | | | | | | |
| AMP 430 | 50 W | 1/7/1990 | 148º 56' | 64º 48' | 4.9 | 4.6 | V | 12 |
| AMP 440 | 2 W | 8/14/1970 | 147º 57' | 65º 03' | 5.0 | 5.0 | V | 10 |
| AMP 450 | 100 W | 11/29/2000 | 150º 09' | 63º 54' | 5.5 | 5.3 | V | 14 |
| AMP 450 | 25 W | 8/27/1904 | 148º 04' | 64º 41' | NV | NV | VI | NV |
| AMP 460 | 45 W | 10/16/1947 | 148º 17' | 64º 17' | NV | NV | VIII | 41 |
| AMP 470 | 1 W | 6/21/1967 | 147º 26' | 64º 46' | 5.6 | 5.9 | VII | 10 |
| AMP 480 | 1 W | 7/22/1937 | 147º 06' | 64º 35' | 7.3 | NV | VII | NV |
| AMP 490 | 1 W | 12/29/1993 | 146º 55' | 64º 26' | 3.9 | NV | VI | 6 |
| AMP 510 | 90 W | 3/2/1956 | 149º 16' | 63º 36' | NV | NV | IV | 49 |
| SOUTHEAST FAIRBANKS CENSUS AREA | | | | | | | | |
| AMP 525 | 75 W | 11/8/2002 | 148º 19' | 63º 30' | 5.5 | 4.6 | IV | 3 |
| AMP 530 | 75 W | 7/28/1947 | 147º 50' | 63º 22' | NV | NV | IV | NV |
| AMP 530 | 75 W | 10/23/2002 | 147º 58' | 63º 31' | 6.0 | 6.7 | VII | 2 |
| AMP 535 | 70 W | 11/3/2002 | 147º 26' | 63º 31' | 7.0 | 7.9* | VIII | 3 |
| AMP 560 | 2 W | 2/11/1948 | 145º 21' | 63º 48' | NV | NV | IV | NV |
| AMP 590 | 50 W | 11/3/2002 | 145º 35' | 63º 18' | 5.6 | NV | IV | 2 |
| AMP 595 | 45 W | 10/22/1996 | 145º 22' | 63º 21' | 5.7 | 5.4 | V | 2 |
| AMP 600 | 30 W | 11/3/2002 | 145º 06' | 63º 25' | 5.2 | NV | V | 3 |
| AMP 630 | 30 W | 8/31/1958 | 144º 18' | 63º 14' | NV | NV | V | 10 |
| AMP 744 | 70 SW | 11/23/1987 | 141º 22' | 61º 36' | 5.7 | 5.0 | IV | 3 |

N - North
E - East
S - South
W - West
NV - No Value Reported.
* To be verified and updated in the final report.
Source: DOI 2011

The USGS has developed national maps of earthquake shaking hazards (DOI 2011; Frankel et al. 1996 and 2002; Wesson et al. 1999). These maps are used to assess probabilistic seismicity and provide information used to create and update seismic design provisions of building codes in the United States. The codes provide design standards for buildings, bridges, highways, industrial facilities, and other public infrastructure, but do not explicitly address pipeline design standards. Values on these seismic hazard maps are expressed as a percentage of the acceleration due to gravity (*g*). The USGS maps show peak horizontal acceleration values with a 10 percent exceedance probability in 50 years for Alaska. Values in Alaska range between 1 and 80 percent *g*. The majority of APP is located in areas of 10 percent *g* or less. The currently highest design acceleration values are located in the Fairbanks area, peaking to 20 percent *g*, approximately between AMPs 430 to 475.

Other resources used to assess seismic hazard include seismic deaggregation software available online at the USGS web site (http://eqint.cr.usgs.gov/deaggint/1996/index.php). This software provides a detailed breakdown of seismic source magnitude and distance in relation to a particular point of interest, along with other spectral analysis parameters. This information can be used in conjunction with empirical relations for seismic effects to assess specific geologic hazard mechanisms such as liquefaction-induced lateral spreading (Youd et al. 2002). This approach was used by APP.

While the DOI (2011) earthquake database based on Mercalli intensity (refer to Table 6.4.1-3) suggests that the North Slope is relatively aseismic, possibly due to lack of historic population centers in this area, AEIC (2011) indicates that several moderate earthquakes have been recorded in the eastern part of northern Alaska associated with active surface faults in Camden Bay and a diffuse scattering of seismicity at depth extending north-northeast from the eastern Interior (refer to Figure 6.4.1-1). ADNR summarized the earthquake potential for this area, located east-northeast of the start of the PT Pipeline, in its “Beaufort Sea Areawide Lease Sale” ADNR (2009b). Key findings from this report include:

- Fifty-nine earthquakes with a magnitude four or greater have been recorded in the area, with the majority of these events being shallow (indicating near-surface faulting) and clustering along the axis of the Camden anticline;
- The largest earthquake recorded in the area was a magnitude 5.3 event 18.6 miles north of Barter Island (Kaktovik) in 1968;
- Wesson and others estimate a 10-percent probability of exceeding a 0.07 *g* earthquake-generated peak ground acceleration in bedrock during a 50-year period (ADNR Division of Geologic and Geophysical Surveys, 2008 citing to Wesson and others 2007); for perspective, the peak ground acceleration in Anchorage during the 1964 earthquake was estimated at 0.16 g (Division of Geologic and Geophysical Surveys 2008 citing Algemissen and others 1991); and
- The thick permafrost underlying the Point Thomson onshore area may cause the earthquake response of sediments to behave more like bedrock, which will limit amplification effects and will also tend to prevent earthquake-induced ground failure, such as liquefaction.

AEIC (2011) identifies the seismic area of the Interior as between 63$^{o}$ to 66$^{o}$ north latitude and 146.5$^{o}$ to 152$^{o}$ west longitude. Within this area some of the earthquakes are associated with the Denali strike-slip fault system to the south and the Kaltag/Tintina strike-slip fault systems in the north, however, the majority of the earthquake events are located in a zone of distributed shear deformation between these two fault systems. These earthquakes are aligned in three major north- to northeast-trending seismic belts that intersect the Alaska Mainline route. They are specified as follows:

- Minto Flats Seismic Zone (MSZ);
- Fairbanks Seismic Zone (FSZ); and
- Salcha Seismic Zone (SSZ).

Many of the earthquakes in the region are deep (greater than 25 miles) and originate in the subducted Pacific plate, however, shallow crustal earthquakes also occur. These shallow earthquakes define several distinct northeast-trending, linear seismic zones. Prior to the studies for this Project, no active faults had been identified in these seismic zones, however, an active fault centered in the SSZ was discovered and mapped during the field investigations for the Project. Because of the shallow depth of the earthquakes in the zone it is possible the seismicity in the other seismic zones is generated on undiscovered faults that extend to the surface. These seismic belts include earthquakes with left-lateral focal mechanism solutions. They have been interpreted to be generated on left-lateral, strike-slip faults bounding long, narrow crustal blocks that are undergoing clockwise horizontal rotation driven by right-lateral shear between the Denali and Tintina faults. In 2010, APP conducted a helicopter reconnaissance survey of these seismic belts to search for previously unmapped faults. Some of the preliminary findings from this reconnaissance survey included the following.

- The MSZ is a prominent northeast-trending alignment of earthquakes that extends from the Alaska Range northeast of Denali to near Livengood, a distance of about 100 miles. The southern 50-mile-long section of the zone between the Alaska Range and the Tanana River is about 5 miles wide and trends about north 35° east. Northeast of the Tanana River the zone of seismicity continues beneath the Minto Flats for an additional 50 miles to the vicinity of the Alaska Mainline route, a few miles southeast of Livengood. This section of the zone, about 50 miles long, is wider (about 15 miles wide) than the southern section and includes two parallel alignments of earthquakes, one on each side of the zone. MSZ has generated earthquakes up to magnitude 6.

  The 2010 APP field reconnaissance covered the northern section of the MSZ, with special emphasis on the southeast margin of the northern Minto Flats where a fault had been previously mapped. The geology of this area includes extensive nearly flat valley fill along the Tolovana River. The valley floor is bordered by broad, gently sloping alluvial aprons at the base of the low mountains on the southeast side of the valley. Both the surfaces of the flat-floored valley and the extensive alluvial apron provided a geomorphic datum for assessing the presence of active faults. No visual evidence of surface faults was observed. APP found no evidence of Holocene activity for the Minto fault.

- The FSZ comprises a broad (15-mile-wide) diffuse northeast-trending zone of earthquakes that extends for about 75 miles from the foothills of the Alaska Range to near the Alaska Mainline route northeast of Fairbanks at approximate AMP 450. The zone includes a prominent cluster of numerous earthquake epicenters at its northeast corner. The Alaska Mainline route crosses the north margin of this cluster. The southern section of the FSZ traverses the broad, nearly flat-floored Tanana River Valley. No evidence of active faults associated with the FSZ was found in the valley by APP in 2010, nor was any indication of youthful surface faults found in the area of the prominent cluster of epicenters near the pipeline route. APP has concluded that no active faults in the FSZ extend to the surface and intersect the pipeline route.

- The SSZ comprises a 75-mile-long, narrow, linear, northeast-trending alignment of seismicity. The southern part of the SSZ extends across the Tanana River Valley from the foothills of the Alaska Range to near the confluence of the Tanana River and the Salcha and Little Salcha rivers. The northern section of the zone continues up the Salcha and Little Salcha River valleys into the Yukon-Tanana Uplands. Shallow earthquakes with magnitudes as large as 7.3 have occurred historically in the area of the SSZ. The 1937 magnitude 7.3 Salcha earthquake, located in the SSZ on the northern margin of the Tanana River Valley, is the largest instrumentally recorded earthquake in the Interior north of the Denali fault. One of the two fault plane solutions from the focal mechanism for the 1937 earthquake indicates it may have been generated by left-lateral slip on a northeast-trending high-angle fault, compatible with focal mechanisms for other earthquakes in the SSZ. The 1937 earthquake was large enough to have generated appreciable surface displacement. The 2011 APP field investigations, supported with light detection and ranging (LiDAR) imaging of the Salcha River Valley, found a youthful surface fault extending from Harding Lake northeast along the seismic zone to the vicinity of the Alaska Mainline route. This Salcha River Fault is considered active, but no evidence of historic surface displacement was identified on this fault. Thus it is concluded that the 1937 earthquake probably was not generated by a fault in the SSZ. It is possible that the 1937 event was associated with rupture along the Blair Hills fault. The location and northwest orientation of this fault is compatible with the alternate northwest trending focal plane solution for the 1937 event. Field reconnaissance of this fault in 2010 found an approximate 3- to 7-foot-high steep facet along the base of the scarp associated with this fault. This facet may be the result of surface displacement generated during the 1937 earthquake.

Faults were identified along or within the vicinity of the Project that APP considered critical for potential pipeline strain and stress from dynamic ground motion associated with earthquakes. Earthquake-related geohazards include fault rupture displacement, soil liquefaction, seismic wave propagation, and mass movements. These geohazards are discussed in Section 6.4.1.1 through 6.4.1.3, and 6.4.3, respectively, and the mitigation of these geohazards on the pipeline is addressed in Section 6.4.6.

#### 6.4.1.1 Fault Rupture Displacement

Fault displacement hazards are an important consideration for pipeline routing and design. Pipelines crossing fault zones must deform longitudinally and in flexure to accommodate ground surface offsets. Fault crossing design is limited to crossings of active faults. A fault is considered active in this context if it has shown evidence of geologic displacement during the Holocene Epoch (approximately 10,000 years ago to present) and/or, based on its history of seismicity, has a relatively high potential for future rupture.

APP completed a route inventory of potentially active Holocene faults in proximity to the GTP and PT Pipeline portion of the Project. The study found that no surface faults were identified along the PT Pipeline route and that the nearest active fault is approximately 30 to 40 miles northeast of the start of the PT Pipeline route (Craig et al. 1985; Plafker et al. 1994). APP has concluded surface faulting at this distance will not impact the PT Pipeline system or GTP.

APP undertook a desktop review of the Alaska Mainline and adjacent areas, and consulted geologists familiar with the neotectonics, seismicity, and paleoseismology of the region in Alaska. This desktop study identified potential Holocene-active faults and estimated fault attributes based on available published information. In 2010, APP completed a field study of potential Holocene-active faults. The field study included two principal components.

- As discussed in Section 6.4.1, the first study component was a comprehensive helicopter-supported field reconnaissance survey to identify and locate active and potentially active faults that cross or project toward the pipeline. The field reconnaissance focused on known and suspected active faults identified in the pre-field program desktop studies. Additionally, the Alaska Mainline was examined from the air by a field team that included two senior paleoseismologists with extensive experience in the application of helicopter reconnaissance for identification and delineation of active surface-breaking fault systems. Extensive use was made of LiDAR imagery, digital elevation models, topographic maps, geologic maps, aerial photographs, and orthophotographs covering the entire pipeline route and adjacent areas to be used in the helicopters during the reconnaissance.

- The second component included on-ground field investigations of faults of interest that were identified during literature review, photograph and remote-sensed imagery analysis, and field reconnaissance. The field investigations were directed toward detailed mapping of the faults at the crossing locations and measurement of the displacement parameters required for special pipeline design at each confirmed Holocene-active fault crossing. Design parameters include near-surface fault geometry, estimated fault displacement per event, and mode and direction of expected fault displacement.

The 2010 field studies identified a number of suspected or potentially active fault crossings by APP in Alaska. Table 6.4.1-4 summarizes the locations of seven potentially active fault crossings.

TABLE 6.4.1-4

**Alaska Pipeline Project**
**Potentially Active Fault Crossings**

| Ref. No. | Fault Location/Name | Approximate Location of Fault or Zone (AMP) Begin | End | Closest Community | Crossing Location |
|---|---|---|---|---|---|
| FAIRBANKS NORTH STAR BOROUGH | | | | | |
| 1 | Salcha River / Salcha River Fault | 501.6 | 503.5 | Harding Lake | Poorly defined |
| SOUTHEAST FAIRBANKS CENSUS AREA | | | | | |
| 2 | Blair Hills / Clear Creek Fault | 541.0 | 545.0 | Delta Junction | Undefined |
| 3 | Sears Creek / Dot T Johnson Fault | 593.0 | 593.5 | Dry Creek | Defined |
| 4 | Billy Creek / Billy Creek Fault | 599.0 | 601.0 | Dot Lake Village | Undefined |
| 5 | Bear Creek / Bear Creek Fault | 611.7 | 612.0 | Dot Lake Village | Defined |
| 6 | Cathedral Rapids West 2 traces / Cathedral Rapids Fault | 633.0 | 633.0 | Tanacross | Defined |
| 7 | Cathedral Rapids East / Cathedral Rapids Fault | 639.5 | 639.5 | Tanacross | Defined |

AMP - Alaska Mainline Milepost
[Note: The major fault locations will be further evaluated after additional field data has been acquired and analyzed, and may be updated in the final report.]

Additional information regarding mitigation and techniques for crossing potentially active faults is provided in Section 6.4.6 and in Resource Report 1.

#### 6.4.1.2 Soil Liquefaction

Earthquake ground shaking may trigger liquefaction of some loose, saturated cohesionless soils. The liquefied condition is temporary, with the material reverting to a solid state usually in hours to days depending on the hydraulic conductivity of the material. The most susceptible soils are generally granular, cohesionless soils that remain loose and uncemented after deposition during recent geologic time (modern or late-Holocene). Liquefaction occurs only in saturated, unfrozen soils. Susceptible areas are typically found along rivers, streams, lake shorelines, and in areas with relatively shallow groundwater (less than 30 feet from the ground surface).

During earthquake-induced liquefaction, the saturated granular soils lose strength as a result of the shaking and act like a viscous fluid. Damage generally occurs when liquefaction leads to some form of ground displacement or ground failure. The liquefaction mechanisms that may affect the pipeline include: Lateral spread, flow slides, buoyant rise, settlement, and ground oscillation. Of these, lateral spread and ground oscillation are related to pipe integrity whereas the other mechanisms are unlikely to appreciably damage the pipeline. APP assumed that liquefaction in relatively level areas poses little hazard to the pipeline or other engineered structures in the Project vicinity. For steeper terrain, earthquake-induced landslides (mass movements) pose a higher risk to the pipeline. Landslides are discussed in Section 6.4.3.

Lateral spread is defined as the lateral displacement of liquefied soil material on gentle slopes typically between 0.1 percent and 10 percent, or in areas near a free face such as an incised river channel. The depth of the shear plane can generally range from about 3 to about 30 feet and is controlled by the depth and continuity of the liquefiable layer. Displacements typically range up to a few feet, but larger displacements may occur where vulnerable ground conditions are subjected to strong-intensity ground shaking.

Ground oscillation is a phenomenon that may occur on flat terrain in response to inertial forces acting on decoupled soil materials above a liquefied zone. The decoupling allows large transient ground motions of ground waves to develop in response to earthquake shaking, but permanent displacements are usually small and chaotic. APP concluded that the likelihood of damage to steel pipelines due to ground oscillation is considered relatively low compared to liquefaction-induced effects on other types of structures.

APP determined that seismicity near the GTP is low, and that seismicity along the PT Pipeline is low to moderate. Liquefaction and lateral spread are not anticipated to be a concern for the PT Pipeline. Therefore, a detailed liquefaction assessment was not conducted for this part of the Project.

APP conducted a preliminary review of the Alaska Mainline and identified areas or specific locations potentially susceptible to liquefaction. Seismic hazard mapping, geologic maps, hydrogeologic reports, and topographic maps were reviewed to assess the potential liquefaction hazard area for ground movement or failure. In areas with seismic potential and ground conditions likely to be conducive to liquefaction, a lateral spreading analysis was undertaken using information derived from USGS seismic deaggregation calculations in combination with empirical relations for lateral spread displacement (Youd et al. 2002).

Generally, the potential for liquefaction is greatest along floodplains associated with watercourses that:

- Have average summer flow greater than 15 cubic feet per second;

- Have bank heights greater than 3 feet where the pipeline route crosses;
- Have fine-grained cohesionless, saturated soils loosely deposited over the past 500 years; and
- Are coupled with areas prone to earthquakes with magnitude five or greater.

Further analysis was conducted by APP to assess potential for liquefaction on shallow, non-permafrost cross slopes crossed by the cold pipeline and its associated frost bulb. This analysis screened the route for conditions that could lead to lateral loading of the pipe and associated frost bulb over a critical length of pipe. Less than 2 miles of moderate-high potential liquefaction on long cross slopes were identified from the preliminary screening assessment between AMPs 636 and 714. In addition, APP identified that the Tetlin Junction Compressor station is currently located in an area of potential soil liquefaction.

APP concluded the likelihood of liquefaction-induced buoyancy or settlement of the pipe in relatively level areas is likely non-existent owing to the development of a frost bulb around the pipe in non-permafrost soils. Liquefaction potential of permafrost soils is considered non-existent. Based on seismic screening, results of the analyses indicate that potential liquefaction-induced effects of buoyancy or settlement are limited to locations on the Alaska Mainline between AMPs 533 and 745 where the seismic potential is high enough to initiate liquefaction in certain soil conditions. Seismic potential for the PT Pipeline was considered too low to initiate liquefaction.

Liquefaction is unlikely in sediment beneath permafrost that is more than 30 feet thick because of high overburden pressure; however, susceptibility may exist in a thawed, saturated active layer where drainage may be restricted by the underlying permafrost and in the fall by an overlying frozen cap. In this case, the soil layer susceptible to liquefaction is typically located above the pipe, so there will likely be no impact on the integrity of the pipeline. Earthquake-induced liquefaction in these areas is unlikely for the remainder of the year.

#### 6.4.1.3 Seismic Wave Propagation

Body waves propagate radially from the source of earthquake energy release (hypocenter) into the surrounding rock and soil medium. When the body waves are reflected by interaction with the ground surface, surface waves are generated. Except at very large distances from the epicenter, the magnitudes of surface waves are much less than body waves.

A pipeline buried in soil that is subject to the passage of these surface waves will incur longitudinal and bending strains as it conforms to the associated ground strains. In most cases, welded pipelines typically do not incur damage from these relatively small strains. Propagating seismic waves also give rise to hoop membrane strains and shearing strains in buried pipelines, but these strains are even smaller. APP's anticipates very small strains in the pipe as a result of seismic wave propagation.

### 6.4.2 VOLCANISM

Several volcanic features have been mapped (Alaska Volcano Observatory [AVO] 2011; DOI 2011) in the vicinity of the Project that are considered historically active or active within the Holocene period. Table 6.4.2-1, below, provides a brief overview of these features, their location relative to Aboveground Facilities, and notes recent activity.

TABLE 6.4.2-1

**Alaska Pipeline Project**
**Volcanic Features[a] Within the Vicinity of Aboveground Facilities**

| Volcanic Feature Name | Closest Facility[b] | Approximate Distance and Direction from Milepost | Longitude | Latitude | Volcano Type | Recent Activity |
|---|---|---|---|---|---|---|
| FAIRBANKS NORTH STAR BOROUGH | | | | | | |
| Buzzard Creek | Johnson Road Compressor Station (AMP 494) | 60 miles SW | 148° 15' 10" W | 64° 03' 06" N | Tuff Rings | Holocene |
| SOUTHEAST FAIRBANKS CENSUS AREA | | | | | | |
| Klawesi Group | George Lake Compressor Station (AMP 579) | 115 miles S | 145° 05' 07" W | 62° 5' 7" N | Mud Volcanoes | Holocene |
| | Tetlin Junction Compressor Station (AMP 670) | 115 miles SW | | | | |
| Mount Wrangell | Tetlin Junction Compressor Station (AMP 670) | 100 miles SW | 144° 02' 50" W | 61° 59' 56" N | Shield Volcano | Historic |
| Bona-Churchill | Tetlin Junction Compressor Station (AMP 670) | 130 miles SE | 141° 41' 01" W | 61° 23' 40" N | Stratovolcano | Holocene |

[a] Source: AVO 2011; DOI 2011.
[b] These features are regional in scale; therefore, the closest facilities are estimated to nearest whole number.
[c] The closest volcanic feature to the GTP lies about 250 miles to the southeast.

DOI (2011), AVO (2011), and Smithsonian National Museum of Natural History (2011) provide additional details on these volcanic features as follows.

- The Buzzard Creek tuff rings are two shallow craters containing small lakes which last erupted about 3,000 years ago. An ejecta blanket from this eruption extends about 1 mile from the larger of the two vents.
- The Klawesi Group is composed of three large mud volcanoes near the west slope of Mount Drum, a volcano last active about 200,000 years ago. These features rise several hundred feet above the surrounding terrain and are composed of glaciolacustrine sediments of the Copper River basin. Two of the three features have historically experienced relatively constant low-level mud eruptions and minor gas emissions. The most dormant of the three experienced activity in 1997 consisting of a vigorous eruption of $CO_2$-rich gas and warm saline mud. While these types of emissions are not considered volcanic eruptions, they lend suspicion to the area having been volcanically active within the Holocene.
- Mount Wrangell, a 14,163-foot-high andesitic shield volcano, is the only volcano in the Wrangell volcanic field to have had documented historical activity. Two large calderas truncate the summit; the inner ice-filled caldera contains three craters. Minor, possibly phreatic, eruptions have occurred during the 20th century. The field includes Mount Zanetti, a 13,009-foot-tall flank cone; and the flank cone of the neighboring Pleistocene-age Mount Drum volcano. Researchers have listed three reports of eruptive activity at

Mount Wrangell (1784, 1884 to 1885, and 1900 to 1930), but at least the first two of these are suspect. Historical activity has been limited to fumaroles and minor phreatic eruptions in the summit craters. Although major eruptions and lava flows have been reported on Wrangell in the past, none have ever been confirmed.

- Mount Churchill is part of the Bona-Churchill massif in the St. Elias Mountains. It forms the highest Quaternary-age volcano in the United States with a 1.7- by 2.6-mile-wide caldera capping the summit at 15,637 feet. Mount Churchill is now known to be the source of the White River Ash, produced during two of the largest explosive eruptions in North America during the past 2,000 years. The 16,421-foot-high summit of Mount Bona lies 2.5 miles across a high saddle from the younger Mount Churchill. The source vent of the widespread White River Ash deposit, which blankets more than 211,266 square miles of eastern Alaska and northwest Canada, was initially thought to be a pumice mound that is mostly buried beneath the Klutlan Glacier northeast of the Mount Churchill volcano. More recent work has revealed thick, young pumice deposits, mineralogical and chemically similar to the White River Ash deposits, along the rim of the Mount Churchill caldera. Radiocarbon dating indicates the period of most recent volcanic activity was approximately 800 AD ± 100 years.

Several other Quaternary-age volcanic features lie in the vicinity of the Alaska Mainline but are listed as inactive by AVO (2011). These include Jumbo Dome in the Interior near the Buzzard Creek craters; and Capital Mountain, Mount Drum, Mount Gordon, Mount Jarvis, Mount Sanford, Skookum Peak, and Tanada Peak in the Wrangell Volcanic Field. Two of these, Gordon and Sanford, are suspected of Holocene activity, but existing evidence is insufficient to regard them as active within the Holocene Period.

Volcanic hazards include eruptions, lahars (debris and mudflows), landslides, lava flows, pyroclastic flows (high-density mixtures of hot, dry rock fragments and hot gases that move away from the vent that erupted them at high speeds), and tephra (typically ash fall). Volcanic dust particles from ash falls, such as those that have been experienced in Southcentral Alaska in recent years, are particularly abrasive, corrosive, and pervasive. They can damage engine components and electronics, and reduce compressor performance (Labadie 1983). Of the volcanic features noted, however, historical activity was present only at Mount Wrangell and it suggests minor volcanic activity.

### 6.4.3 MASS MOVEMENTS

#### 6.4.3.1 Landslides

The term “landslide” refers to the downward and outward movement of slope-forming materials reacting under the force of gravity. A landslide generally is comprised of natural soil, rock, artificial fill, or a combination of those materials along with ground ice and/or water. The term covers a range of mechanisms, including deep-seated landslides, slope creep, rockfalls/rock avalanches, debris flows, and debris slumps in non-permafrost ground. Thaw-related landslides in permafrost include thawed-layer detachment (or skin flows) and solifluction. Briefly, the following describes landslide movement associated with these different mechanisms:

- Slides: A downslope displacement of material along one or many failure surfaces; shallow slides may be referred to as slumps; large masses of broken rock may be referred to as rock avalanches; and typically includes deep-seated landslides, rock avalanches, debris slumps, and thawed-layer detachment;

- Flows: A mixture of soil, rock, air, water, and possibly organic material with a potentially long run-out distance; and typically includes debris flows and mudflows (a subset of debris flows). The ratio of mass thickness to length is usually small;
- Falls: Falls occur when rock or other material breaks free from a cliff or slope and moves by free-fall, bouncing, or rolling; falls may be initiated as material topples or rotates forward on a slope, depending on the nature of the rock mass; and includes rock falls; and
- Creep: Gradual downslope movement of material on a slope resulting from changes in moisture and material properties; may result in creep rupture leading to sudden downslope movement as a slide; and includes slope creep and some occurrences of deep-seated landslides.

DOI (2011) maps landslide incidence in the Project area as “low,” occurring in less than 1.5 percent of the area involved. Terrain mapping completed by APP of the Project area in 2009 was used in conjunction with other available datasets and imagery for the pipeline corridor to identify existing landslides of various types (results tabulated in Appendix 7A of Resource Report 7). Mudflows were also identified using the same approach. This evaluation concluded that there are no existing landslides or mudflows for the PT Pipeline, Aboveground Facilities, or Associated Infrastructure. Tables 6.4.3-1 and 6.4.3-2, below, summarize these features and their locations for the Alaska Mainline.

TABLE 6.4.3-1

**Alaska Pipeline Project**
**Existing Landslides[a] Within the Vicinity of the Alaska Mainline**

| Alaska Mainline Milepost | | Offset Distance from Centerline | Active Landslide [b] | Probable Mass Movement Type [c] | Terrain Symbol [d] |
|---|---|---|---|---|---|
| Begin | End | | | | |
| NORTH SLOPE BOROUGH | | | | | |
| 66.8 | 66.9 | 1.1 miles North | No | Thawed layer detachment and thermal erosion | Cl |
| 171.9 | 171.9 | 0.1 mile West | No | Deep Seated Rock Landslide | Cl |
| 172.1 | 172.2 | 0.1 mile West | No | Deep Seated Rock Landslide | Cl |
| 175.7 | 175.8 | 0.4 mile West | No | Creep | Cl/Gt |
| 181.4 | 181.5 | 0.2 mile North | No | Creep | Bu + [C+Bu) |
| 181.9 | 182.5 | 0.1 mile North | Yes | Shallow Creep on Bedrock | Cl |
| YUKON-KOYUKUK CENSUS AREA | | | | | |
| 186.2 | 186.3 | 0.7 mile West | Yes | Shallow Creep on Bedrock | Cl |
| 186.9 | 187.3 | 0.2 mile West | Yes | Shallow Creep on Bedrock | Cl |
| 187.5 | 187.8 | 0.3 mile West | Yes | Shallow Creep on Bedrock | Cl |
| 188.7 | 189.3 | 0.1 mile West | Yes | Shallow Creep on Bedrock | Cl |
| 190.2 | 190.4 | 0.7 mile west | Yes | Shallow Creep on Bedrock | Cl |
| 196.7 | 197.4 | 0.9 mile West | Yes | Shallow Creep on Bedrock | Cl |
| 201.0 | 201.2 | <0.1 mile East | Probable | Shallow Creep on Bedrock | Cg |
| 202.6 | 202.7 | 0.3 mile East | Yes | Shallow Creep on Bedrock | C/Bw |
| 206.1 | 206.2 | 0.5 mile East | Yes | Shallow Creep on Bedrock | Cg |
| 206.4 | 206.5 | 0.1 mile East | Probable | Shallow Creep on Bedrock | Gt-It/Bw |
| 208.2 | 208.3 | 0.5 mile East | Probable | Shallow Creep on Bedrock | [C/Bw]+Bw |
| 209.7 | 209.8 | 0.5 mile East | Probable | Creep | Cs/GtIt |

TABLE 6.4.3-1

**Alaska Pipeline Project**
**Existing Landslides[a] Within the Vicinity of the Alaska Mainline**

| Alaska Mainline Milepost | | Offset Distance from Centerline | Active Landslide [b] | Probable Mass Movement Type [c] | Terrain Symbol [d] |
|---|---|---|---|---|---|
| Begin | End | | | | |
| 219.4 | 219.7 | 0.7 mile West | Probable | Creep | Cg |
| 279.6 | 280.0 | 0.1 mile North | Yes | Creep | Cl |
| 299.7 | 300.0 | <0.1 mile East | No | Shallow Creep on Bedrock | Cl |
| 300.0 | 300.0 | <0.1 mile East | No | Shallow Creep on Bedrock | Cl |
| 377.3 | 377.4 | 0.3 mile East | No | Shallow Creep on Bedrock | Cl-f |
| 377.6 | 378.0 | 0.3 mile West | No | Shallow Creep on Bedrock | Cl-f |
| 379.6 | 379.7 | 0.4 mile East | No | Creep | Cl-f |
| 429.2 | 429.7 | 0.2 mile West | Yes | Shallow Creep on Bedrock | Cl |
| FAIRBANKS NORTH STAR BOROUGH | | | | | |
| 431.8 | 432.2 | <0.1 mile East | Yes | Shallow Creep on Bedrock | Cl |
| 432.2 | 432.3 | 0.4 mile East | Yes | Shallow Creep on Bedrock | Cl |
| 432.4 | 432.8 | 0.2 mile East | Possible | Shallow Creep on Bedrock | Cl |
| 436.3 | 436.6 | 0.4 mile East | Possible | Creep | Cl |
| 447.1 | 447.5 | Crosses centerline | Yes | Deep-seated creep? | C/Bx |
| 448.5 | 448.8 | Crosses centerline | Yes | Deep-seated creep | Cr/Es |
| 463.7 | 463.9 | 0.6 mile East | Possible | Shallow Creep on Bedrock | Cl |
| 500.2 | 500.4 | 0.6 mile Southwest | Possible | Shallow Creep on Bedrock | Cl |
| 500.7 | 500.8 | 0.7 mile East | Possible | Shallow Creep on Bedrock | Cl |
| 500.8 | 500.9 | <0.1 mile west | Probable | Shallow Creep on Bedrock | Cl |
| 501.2 | 501.2 | <0.1 mile West | Probable | Creep | Cl |
| SOUTHEAST FAIRBANKS CENSUS AREA | | | | | |
| 615.9 | 616.3 | <0.1 mile West | No | Creep | Cl |
| 638.9 | 639.4 | Crosses centerline | No | Creep | Cl |
| 639.4 | 639.4 | Crosses centerline | No | Shallow Creep | Cl |
| 675.4 | 675.4 | Crosses centerline | No | Shallow detachment | Ess/Bw |
| 679.7 | 679.7 | Crosses centerline | No | Shallow Landslide | Ess/Bw |
| 679.7 | 679.8 | Crosses centerline | No | Shallow Landslide | Fpc/Bw |
| 680.7 | 680.8 | 0.4 mile North | No | Shallow Landslide | Cl |
| 684.2 | 684.2 | Crosses centerline | No | Shallow Creep on Bedrock | Ess/Bw |
| 684.2 | 684.3 | Crosses centerline | No | Shallow Creep on Bedrock | Bw |
| 684.3 | 684.3 | Crosses centerline | No | Shallow Landslide | Bw |
| 684.4 | 684.5 | Crosses centerline | No | Shallow Creep on Bedrock | Ess/Bw |
| 684.5 | 684.6 | Crosses centerline | No | Shallow Creep on Bedrock | Cr/Es |
| 684.6 | 684.7 | Crosses centerline | No | Shallow Landslide | Cr/Es |
| 686.5 | 686.7 | Crosses centerline | No | Shallow Creep on Bedrock | Ess/Bw |
| 686.9 | 687.0 | Crosses centerline | No | Shallow Creep on Bedrock | Ess/Bw |
| 687.0 | 687.0 | Crosses centerline | No | Shallow Landslide | Ess/Bw |
| 687.0 | 687.1 | Crosses centerline | No | Shallow Landslide | Ff/Es |
| 687.1 | 687.1 | Crosses centerline | No | Shallow Creep on Bedrock | Es |
| 690.1 | 690.6 | 0.4 mile North | No | Shallow Creep on Bedrock | Es/Bw |
| 691.5 | 691.6 | <0.1 mile South | No | Shallow Creep on Bedrock | Es/Bw |
| 696.2 | 696.2 | Crosses centerline | No | Shallow Creep on Bedrock | Es/Bw |
| 696.2 | 696.5 | Crosses centerline | No | Shallow Landslide | Es |
| 697.5 | 697.7 | <0.1 mile North | No | Shallow Landslide | Es |

TABLE 6.4.3-1

**Alaska Pipeline Project**
**Existing Landslides[a] Within the Vicinity of the Alaska Mainline**

| Alaska Mainline Milepost | | Offset Distance | Active | Probable Mass | |
|---|---|---|---|---|---|
| Begin | End | from Centerline | Landslide [b] | Movement Type [c] | Terrain Symbol [d] |
| 699.7 | 700.0 | Crosses centerline | No | Shallow Landslide | Es |
| 701.0 | 701.0 | Crosses centerline | Yes | Deep seated Landslide | Es/Bw |
| 701.0 | 701.3 | Crosses centerline | Yes | Deep seated Landslide | Es |
| 710.6 | 710.7 | <0.1 mile North | No | Shallow Creep on Bedrock | Es/Bw |
| 710.7 | 710.7 | <0.1 mile North | No | Shallow Landslide | Es |
| 710.7 | 710.8 | <0.1 mile North | No | Shallow Landslide | Cr-s |
| 710.8 | 710.9 | <0.1 mile North | No | Shallow Landslide | Es |
| 711.3 | 711.4 | Crosses centerline | No | Shallow Landslide | Es |
| 711.4 | 711.4 | Crosses centerline | No | Shallow Landslide | Fpc/Es |
| 711.6 | 711.7 | Crosses centerline | No | Shallow Landslide | Es |
| 711.8 | 711.8 | Crosses centerline | No | Shallow Landslide | Es |
| 711.8 | 711.8 | Crosses centerline | No | Shallow Landslide | Cr-s |

[a] Results are based on review of Project datasets including terrain mapping, LiDAR digital elevation models (DEMs), aerial photography, and available reports.
[b] Active landslide indicates possible ongoing movement.
[c] Probable mass movement type identified where possible; otherwise the estimated depth of failure is described (shallow or deep-seated landslide).
[d] Terrain Symbols are defined in Rawlinson 1990.
? - Denotes uncertainty in landform interpretation.

TABLE 6.4.3-2

**Alaska Pipeline Project**
**Existing Mudflow* Occurrences Within the Vicinity of the Alaska Mainline**

| Alaska Mainline Milepost | | Offset Distance from | |
|---|---|---|---|
| Begin | End | Centerline | Description and Comment |
| NORTH SLOPE CENSUS AREA | | | |
| 154.3 | 154.4 | 0.1 mile Southeast | Mudflow fan outside route right-of-way. |
| 154.4 | 154.5 | <0.1 mile Southeast | Mudflow fan outside route right-of-way. |
| 154.8 | 154.9 | <0.1 mile Southeast | Mudflow fan outside route right-of-way. |
| 155.1 | 155.2 | Crosses centerline | Mudflow Depositional Area. Not a problem for buried pipeline. |
| 155.3 | 156.2 | Crosses centerline | Mudflow Depositional Area. Not a problem for buried pipeline. |
| 156.3 | 156.6 | Crosses centerline | Mudflow Depositional Area. Not a problem for buried pipeline. |
| 157.1 | 157.5 | Crosses centerline | Mudflow Depositional Area. Not a problem for buried pipeline. |
| 158.0 | 159.1 | Crosses centerline | Mudflow Depositional Area. Not a problem for buried pipeline. |
| 159.1 | 159.4 | 0.2 mile Southwest | Mudflow fan outside Alaska Mainline route right-of-way. |
| 159.5 | 159.8 | Crosses centerline | Mudflow Depositional Area. Not a problem for buried pipeline. |
| 161.1 | 162.4 | Crosses centerline | Multiple overlapping mudflow fans (6). Mudflow Depositional Area. Not a problem for buried pipeline. |
| 164.8 | 165.1 | 0.2 mile Southeast | Multiple overlapping mudflow fans outside Alaska Mainline route right-of-way. |
| 166.2 | 166.5 | 0.5 mile East | Multiple overlapping mudflow fans located on opposite side of the Trans-Alaska Pipeline System (TAPS), Dalton Highway, and Atigun River from Alaska Mainline route. |
| 167.1 | 167.4 | 0.4 mile East | Probable mudflow fan located on opposite side of TAPS, Dalton Highway |

TABLE 6.4.3-2

**Alaska Pipeline Project**
**Existing Mudflow* Occurrences Within the Vicinity of the Alaska Mainline**

| Alaska Mainline Milepost | | Offset Distance from Centerline | Description and Comment |
|---|---|---|---|
| Begin | End | | |
| | | | and Atigun River from Alaska Mainline route. |
| 176.5 | 177.3 | 0.2 mile Southeast | Probable multiple overlapping mudflow fans outside route right-of-way. |
| 177.6 | 178.2 | 0.2 mile Southeast | Probable multiple overlapping mudflow fans opposite side of Chandalar River from Alaska Mainline route. |

* Results are based on review of Project datasets including terrain mapping, LiDAR DEMs, aerial photography, and available reports.

Based on the results provided in Tables 6.4.3-1 and 6.4.3-2, there are four active deep-seated landslides and seven mudflows that cross the Alaska Mainline.

Preliminary slope stability assessment was conducted for longitudinal slopes along the Alaska Mainline and PT Pipeline. Based on the screening assessment, for each slope that exceeds 5 percent grade, an instability hazard rating was assigned based on anticipated effects of pipeline construction. Factors considered in assigning the hazard rating include slope geometry, subsurface conditions, permafrost and ice condition, geothermal status, and existing geohazards on or near the slopes. Seismic events can trigger some types of slope instability and, therefore, the proximity of each slope to a seismically active zone is considered a factor when assigning a hazard rating to slopes. The proximity of slopes to potential liquefaction zones and possibility of toe erosion at watercourses are also considered in assigning hazard ratings to individual slopes.

Table 6.4.3-3 provides locations where the potential for slope instability (both cross slope and longitudinal slope, as appropriate) along the pipeline route creates a potential risk to the pipelines. [Note: APP will provide an update of potential slope instability data in Table 6.4.3-3 in the final report.]

TABLE 6.4.3-3

**Alaska Pipeline Project**
**Potential Slope Instability within the Pipeline Facilities**

| Milepost | | Slope Grade (percent) | Slope Angle (°) | Instability Potential |
|---|---|---|---|---|
| Begin | End | | | |
| POINT THOMSON GAS TRANSMISSION PIPELINE | | | | |
| TBD | TBD | TBD | TBD | TBD |
| ALASKA MAINLINE | | | | |
| TBD | TBD | TBD | TBD | TBD |

Note: Values specified as TBD will be updated for the final report.

### 6.4.3.2 Avalanche

Snow avalanches are rapid down slope movements of snow, ice, and associated debris such as soil, rocks, and vegetation. Most avalanches of dangerous size originate on slopes between 30 and 45 degrees. They rarely occur on slopes of less than 25 degrees or more than 45 degrees (U.S. Department of Agriculture 2004). An avalanche will not pose a hazard to the underground pipeline, but could damage Aboveground Facilities and Associated Infrastructure, and could pose a risk to construction and operations staff working in the affected area.

Slushflows represent a special type of wet-snow avalanche that develops in arctic and subarctic mountains during spring breakup, when accelerating rates of meltwater production cause saturation of snowpacks on low to moderate slopes and in gentle valley bottoms (Onesti 1985). Once released, slurries of ice, snow, water, and debris flow down chutes, which may have gradients as low as 1 to 5 degrees and are capable of developing considerable momentum. Fans often occur at the mouths of slushflow chutes associated with tributary valleys in the upper Atigun valley, Atigun Pass, and on the Chandalar Shelf. The northernmost and southernmost slushflow fans crossed by APP are near AMPs 166 and 182, respectively. Table 6.4.3-4 identifies snow and slushflow avalanche occurrences within the vicinity of Aboveground Facilities and Associated Infrastructure. Section 6.4.6 provides a discussion on the potential impacts of both snow and slushflow avalanche to the Project. [Note: This evaluation will be updated in the final report.]

TABLE 6.4.3-4

**Alaska Pipeline Project**
**Snow and Slushflow Avalanche Occurrences in the Vicinity of the Alaska Pipeline Project**

| Milepost | | Offset from Route (miles) | Snow Avalanche | Slushflow Avalanche | Description and Comment |
|---|---|---|---|---|---|
| Begin (AMP) | End (AMP) | | | | |
| NORTH SLOPE CENSUS AREA | | | | | |
| 166.1 | 166.2 | Crosses centerline | X | | Chute and upper fan crossing centerline (potential high impacts, scour, and deposition). Not a problem for buried pipeline with adequate cover depth. |
| 166.7 | 167.0 | Crosses centerline | X | X | Chute and upper fan crossing centerline (potential high impacts, scour, and deposition). Not a problem for buried pipeline with adequate cover depth. |
| 167.3 | 167.5 | Crosses centerline | X | | Chute and upper fan crossing centerline (potential high impacts, scour, and deposition). Not a problem for buried pipeline with adequate cover depth. |
| 168.0 | 168.5 | Crosses centerline | X | X | Two chutes and complex fan crossing centerline (potential high impacts, scour, and deposition). Not a problem for buried pipeline with adequate cover depth. |
| 168.2 | 168.3 | Crosses centerline | | X | Eastern fan margin (along edge of deposition zone). |
| 168.4 | 168.7 | Crosses centerline | X | X | Chute and upper fan crossing centerline (potential high impacts, scour, and deposition). Not a problem for buried pipeline with adequate cover depth. |
| 170.6 | 170.7 | Crosses centerline | X | X | Upper fan crosses centerline (potential high impacts, scour, and deposition). Not a problem for buried pipeline with adequate cover depth. |
| 170.8 | 172.1 | Crosses centerline | X | X? | Possible slushflow fan crosses centerline (potential high impacts and deposition). Not a problem for buried pipeline with adequate cover depth. |
| 172.2 | 172.5 | 0.1 mile East | X | X | Slushflow fan crosses route centerline (likely high impacts, scour, and deposition). |
| 172.5 | 173.6 | Crosses centerline | X | | High potential for snow avalanches through Atigun Pass. |
| 173.6 | 173.8 | Crosses centerline | X | X | Slushflow fan crosses route centerline (likely high impacts, scour, and deposition). Not a problem for buried pipeline with adequate cover depth. |

TABLE 6.4.3-4

**Alaska Pipeline Project**
**Snow and Slushflow Avalanche Occurrences in the Vicinity of the Alaska Pipeline Project**

| Milepost | | Offset from | | | |
|---|---|---|---|---|---|
| Begin (AMP) | End (AMP) | Route (miles) | Snow Avalanche | Slushflow Avalanche | Description and Comment |
| 173.8 | 174.4 | Crosses centerline | X | X | Pipeline centerline follows northwestern margin of slushflow chute. |
| 174.4 | 174.7 | Crosses centerline | | X | Slushflow fan crosses route centerline (likely high impacts, scour, and deposition). Not a problem for buried pipeline with adequate cover depth. |
| 174.9 | 175.0 | Crosses centerline | | X | Toe of slushflow fan reaches pipe centerline from northwest. |
| 175.4 | 175.6 | <0.1 mile East | | X | Margin of slushflow fan. |
| 175.8 | 176.0 | 0.2 mile Southeast | | X | Toe slushflow fan. |
| 176.2 | 176.3 | 0.1 mile Southeast | | X? | Toe of possible slushflow fan. |
| 176.3 | 176.7 | 0.1 mile west | | X | Toe slushflow fan. |
| 177.0 | 177.1 | <0.1 mile Southeast and 0.2 mile Northwest | | X? | Toes of two possible slushflow fans. |
| 177.2 | 177.4 | 0.1 mile Southeast | | X | Toe slushflow fan. |
| 178.0 | 178.1 | 0.2 mile Northwest | | X | Toe slushflow fan diverted around old Chandalar Camp. |
| 181.6 | 181.8 | <0.1 mile Northeast | | X | Toe slushflow fan. |

Results are based on review of Project datasets including terrain mapping, Light Ranging and Distance DEMs, aerial photography, and available reports.
? - denotes some uncertainty in the landform interpretation.

Based on the information in Table 6.4.3-4, there are 10 snow avalanche chutes and 10 slushflow avalanche chutes (some of which are co-located) that cross the Alaska Mainline route.

#### 6.4.3.3 Rock Glaciers

In addition to snow and slushflow avalanches, rock glaciers and associated slow-moving ice-rich mass-movement features were also identified in the Project area. APP terrain mapping was used in conjunction with other available datasets and imagery for the Project area to identify existing rock glaciers. These are summarized in Table 6.4.3-5, below (results tabulated in Appendix 7A of Resource Report 7). The results indicate that there are two rock glaciers or similar ice-rich mass movement features that cross the Alaska Mainline centerline and there are no rock glaciers along the PT Pipeline.

TABLE 6.4.3-5

**Alaska Pipeline Project**
**Existing Rock Glacier Occurrences on the Alaska Mainline**

| Milepost Begin (AMP) | Milepost End (AMP) | Offset Distance from Centerline (miles) | Interpretation | Probable Mass Movement Type | Terrain Symbol | Description |
|---|---|---|---|---|---|---|
| NORTH SLOPE CENSUS AREA | | | | | | |
| 154.5 | 154.8 | <0.1 mile East | Ice-rich colluvium/till and avalanche/mudflow deposits | Creep | Cg | Appears to be colluvium deposited from avalanche chutes (one showing mudflow track). If ice-rich, could be creeping down slope like a rock glacier. Is not obvious as a rock glacier. |
| 158.4 | 158.6 | 0.2 mile East | Rock Glacier | Creep | C/Bu | Active rock glacier. |
| 164.8 | 164.9 | 0.5 mile West | Rock Glacier | Creep | Ct | Active rock glacier located on opposite side of the Trans-Alaska Pipeline System (TAPS), Dalton Highway, and Atigun River from Alaska Mainline route. |
| 165.1 | 165.2 | 0.4 mile West | Rock Glacier | Creep | Ct | Active rock glacier located on opposite side of TAPS, Dalton Highway, and Atigun River from Alaska Mainline route. |
| 167.4 | 167.5 | <0.1 mile West | Rock Glacier | Creep | Bu | Probable Rock Glacier. |
| 168.3 | 168.5 | 0.4 mile East | Rock Glacier | Creep | Cg | Active rock glacier located on opposite side of TAPS, Dalton Highway, and Atigun River from Alaska Mainline route. |
| 169.0 | 169.2 | 0.3 mile East | Rock Glacier | Creep | Cs | Active rock glacier located on opposite side of TAPS, Dalton Highway, and Atigun River from Alaska Mainline route. Terrain map suggests typo in symbol. |
| 169.1 | 169.2 | 0.5 mile West | Rock Glacier | Creep | Cg | Rock Glacier. |
| 169.8 | 170.0 | 0.1 mile East | Rock Glacier | Creep | Cg | Active rock glacier located on opposite side of TAPS, Dalton Highway, and Atigun River from Alaska Mainline route. |
| 170.4 | 170.5 | 0.2 mile East | Rock Glacier | Creep | Cg | Active rock glacier located on opposite side of TAPS, Dalton Highway, and Atigun River from Alaska Mainline route. |
| 170.4 | 170.5 | <0.1 mile West | Rock Glacier | Creep | Ct | Active rock glacier. |
| 170.6 | 170.7 | 0.6 mile West | Rock Glacier or Protalus Rampart | Creep | [C/Bw]+Bw | Rock Glacier or Protalus Rampart. |
| 170.7 | 171.0 | 0.1 mile East | Rock Glacier | Creep | Cg | Active rock glacier located on opposite side of TAPS, Dalton Highway, and Atigun River from Alaska Mainline route. |
| 171.2 | 171.2 | <0.1 mile west | Rock Glacier | Creep | Cg | Active rock glacier. |
| 171.2 | 171.5 | 0.2 mile East | Rock Glacier | Creep | Cg | Active rock glacier located on opposite side of TAPS, Dalton Highway, and Atigun River from Alaska Mainline route. |
| 171.6 | 171.6 | Crosses centerline | Colluvium and Till | Creep? | Cg | Colluvium and till. May be locally ice-rich and subject to downslope creep. |
| 171.5 | 171.6 | 0.1 mile South | Rock Glacier or Protalus Rampart | Creep | Ct | Rock Glacier or Protalus Rampart. Angular rock fragments in ice may exist and is subject to slow creep. |
| 172.0 | 172.2 | <0.1 mile | Rock Glacier | Creep | Cg | Active rock glacier located on opposite |

TABLE 6.4.3-5

**Alaska Pipeline Project**
**Existing Rock Glacier Occurrences on the Alaska Mainline**

| Milepost Begin (AMP) | Milepost End (AMP) | Offset Distance from Centerline (miles) | Interpretation | Probable Mass Movement Type | Terrain Symbol | Description |
|---|---|---|---|---|---|---|
| | | South | | | | side of TAPS from Alaska Mainline route. |
| 173.2 | 173.2 | 0.4 mile South | Rock Glacier | Creep | Cg | Active rock glacier located on opposite side of TAPS from Alaska Mainline route. |
| 173.2 | 173.4 | Crosses centerline | Colluvial Apron similar to Rock Glacier | Creep | Cl | Colluvial Apron composed of angular rock fragments with interstitial ice allowing creep downslope. Acts same as a rock glacier. Surface cracking on slope. |
| 173.6 | 173.7 | 0.4 mile North | Rock Glacier | Creep | Cg | Active rock glacier located on opposite side of Dalton Highway from Alaska Mainline route. |
| 174.9 | 175.1 | 0.2 mile West | Rock Glacier | Creep | Cg | Active rock glacier located on opposite side of TAPS, Dalton Highway, and Chandalar River from Alaska Mainline route. |
| 175.2 | 175.3 | 0.3 mile North | Rock Glacier | Creep | Cg | Active rock glacier located on opposite side of TAPS, Dalton Highway, and Chandalar River from Alaska Mainline route. |
| 175.6 | 175.9 | 0.2 mile North | Rock Glacier | Creep | Cg | Active rock glacier located on opposite side of TAPS, Dalton Highway, and Chandalar River from Alaska Mainline route. |
| YUKON-KOYUKUK CENSUS AREA | | | | | | |
| 185.9 | 186.0 | 0.5 mile Northwest | Rock Glacier | Creep | Cg | Active rock glacier located on opposite side of TAPS, Dalton Highway, and Dietrich River from Alaska Mainline route. |
| 186.6 | 186.7 | <0.1 mile East | Flow-slide* | Creep | Cg | Flow-slide (Hamilton 1978), described as unsorted, non-stratified, angular to sub-angular rubble in a fine-grained matrix. Apparently subject to slow downslope creep. |
| 188.2 | 188.3 | 0.1 mile East | Flow-slide* | Creep | Cg | Flow-slide (Hamilton 1978), described as unsorted, non-stratified, angular to sub-angular rubble in a fine-grained matrix. Apparently subject to slow downslope creep. |
| 195.9 | 196.4 | 0.3 mile East | Rock Glacier | Creep | Cg | Inactive rock glacier. |
| 196.0 | 196.0 | 0.7 mile West | Rock Glacier | Creep | Cg | Active rock glacier located on opposite side of TAPS, Dalton Highway, and Dietrich River from Alaska Mainline route. |
| 197.0 | 197.3 | 1.2 mile West | Rock Glacier | Creep | Cg | Active rock glacier located on opposite side of TAPS, Dalton Highway, and Dietrich River from Alaska Mainline route. |
| 198.8 | 198.9 | 0.2 mile East | Flow-slide* | Creep | Cg | Flow-slide (Hamilton 1978), described as unsorted, non-stratified, angular to sub-angular rubble in a fine-grained matrix. Apparently subject to slow downslope creep. |
| 199.1 | 199.3 | <0.1 mile East | Flow-slide* | Creep | Cg | Flow-slide (Hamilton 1978), described as unsorted, non-stratified, angular to sub- |

TABLE 6.4.3-5

**Alaska Pipeline Project**
**Existing Rock Glacier Occurrences on the Alaska Mainline**

| Milepost | | Offset Distance from Centerline (miles) | Interpretation | Probable Mass Movement Type | Terrain Symbol | Description |
|---|---|---|---|---|---|---|
| Begin (AMP) | End (AMP) | | | | | |
| | | | | | | angular rubble in a fine-grained matrix. Apparently subject to slow downslope creep. |
| 199.6 | 199.8 | <0.1 mile east | Flow-slide* | Creep | Cg | Flow-slide (Hamilton 1978), described as unsorted, non-stratified, angular to sub-angular rubble in a fine-grained matrix. Apparently subject to slow downslope creep. |
| 201.1 | 201.4 | 0.3 mile east | Rock Glacier | Creep | Cg | Active rock glacier. |
| 214.3 | 214.8 | 0.3 mile East | Rock Glacier | Creep | Cg | Active rock glacier. |
| 215.4 | 215.4 | 0.4 mile East | Rock Glacier | Creep | Cg | Active rock glacier. |
| 215.6 | 215.9 | 0.3 mile east | Rock Glacier | Creep | Cg | Active rock glacier. |
| 218.0 | 218.1 | 0.5 mile east | Rock Glacier | Creep | Cg | Active rock glacier. |
| 222.9 | 223.0 | 0.8 mile West | Rock Glacier | Creep | Cg | Active rock glacier located on opposite side of TAPS, Dalton Highway, and Koyukuk River from Alaska Mainline route. |
| 223.2 | 223.4 | 0.7 mile West | Rock Glacier | Creep | Cg | Active rock glacier located on opposite side of TAPS, Dalton Highway, and Koyukuk River from Alaska Mainline route. |
| 224.0 | 224.5 | 0.5 mile west | Rock Glacier | Creep | Cg | Active rock glacier located on opposite side of TAPS, Dalton Highway, and Koyukuk River from Alaska Mainline route. |

* Flow slides identified from Hamilton 1978

Results are based on review of Project datasets including terrain mapping, Light Ranging and Distance DEMs, aerial photography, and available reports.

Terrain Symbols are defined in Resource Report 7, Appendix 7A.

#### 6.4.3.4 Subsidence

Subsidence is the loss of surface elevation due to removal of subsurface support. Subsidence ranges from small, local collapses to broad, regional lowering of the land surface. Causes of subsidence can include thawing of ice-rich permafrost (thermokarst[14]), dissolution in carbonate or gypsum rock (karst topography), past and present underground mining, and withdrawal of fluids (groundwater, petroleum, and geothermal).

The Project area is underlain by sedimentary bedrock formations that include carbonate units that could be subject to dissolution (i.e., karst formation). There is a potential for karst where

[14] Permafrost in soils and associated effects on subsidence and slope failure are discussed in Resource Report 7, Section 7.3.

surficial deposits are less than 30 feet thick and the underlying carbonate rocks occur at depths at or just above the water table. Surface subsidence and sinkhole development occur most commonly in areas where groundwater levels are altered by excessive pumping or by diversion of surface drainage. This form of subsidence generally involves the collapse of weathered bedrock and soils that bridge caverns, subterranean galleries, and dome pits. The collapse is caused by loss of support resulting from the reduction of hydrostatic pressure of groundwater, by sapping, and by piping (Davies et al. 1984). These types of occurrences are relatively rare[15] in Arctic environments compared to other more temperate and tropical climates.

DOI (2011) and Davies et al. (1984) provide a general map of karst features on a statewide scale for Alaska. This map depicts two general areas where karst features may be proximate to the Project: Near Atigun Pass (AMP 173) and north of Fairbanks (AMP 425). DOI (2011) describes these two areas as potentially having fissures, tubes, and caves generally less than 1,000 feet long and 50 feet or less in vertical extent occurring in moderately to steeply dipping beds of carbonate rock with a thin cover of glacial till and frost-derived residual soil. The bedrock formations near Atigun Pass are most likely associated with Baird Group rocks in the Southern Brooks Range. Mull and Adams (1989) describe the Baird Group as including the Skajit Limestone, Kugururok Formation, and other shallow-marine, carbonate-platform rocks. Wilson et al. (1998) describes a number of rock units that are present north of Fairbanks that have a carbonate rock component and, therefore, have the potential for karst formation. They include the Cascaden Ridge Formation and Wickershim Grit, which are described as containing limestone, the Amy Creek Formation consisting chiefly of dolostone and dolomitic mudstone, and the Tolovana Limestone. These rock units are not described as containing secondary solution cavities.

### 6.4.4 ACID ROCK DRAINAGE

Acid rock may occur naturally as part of the rock-weathering process or could possibly be exposed to some degree by large-scale earth disturbances characteristic of mining and other construction activities such as transportation corridor work for pipelines and highways.

APP completed a preliminary desktop study of the surficial geology that might be crossed by the Project and concluded that only a low percentage of the Project area has geologic conditions that could potentially create ARD conditions. Pleistocene-age glaciers formed in the mountainous areas of Alaska and generally extended some tens of miles north and south of the mountain fronts. The glaciers left deposits of glacial till and glaciofluvial sediment in the mountains and the adjacent lowlands. In addition, many areas of Alaska are covered with loess (windblown silt) or sand dunes. The Alaska Mainline traverses extensive glacial till and glaciofluvial sediment north and south of the Brooks Range and adjacent to the Alaska Range south of Delta Junction and Tok. The Alaska Mainline also crosses dune fields north of Delta Junction and near the U.S.-Canada border. These units are generally considered to be of negligible ARD potential.

[15] APP will evaluate subsidence potential of the expanded West Dock area during/after construction in Section 6.4.4 of the final report.

The APP desktop study assessed bedrock and surficial geology of the Project area to identify rock units with potential metal leaching (ML)/ARD that might be exposed during construction. APP's desktop study determined the following:

- Shallow bedrock is not present along the PT Pipeline route; therefore, ML/ARD is not a concern for the PT Pipeline.
- For the Alaska Mainline, APP determined that the rocks with the highest potential for sulphide mineral concentration are Mesozoic and Cenozoic-age continental and marine deposits. They include shale, mudstone, claystone, and coal shale. Rock units with moderate potential for sulphide mineral concentration are Precambrian to Cenozoic rocks of igneous, metamorphic, and sedimentary origin. Rock units with a low potential for sulphide mineral concentrations are Precambrian, Paleozoic, and Mesozoic igneous and metasedimentary rocks.
- The Brooks Range and the northern foothills are dominated by sedimentary rocks. North of the Brooks Range, in the foothills, the Alaska Mainline crosses shale, sandstone, and coal. Progressing south, the Brooks Range is largely limestone, shale, and conglomerate. In this area, from an ARD standpoint, the shale is a potential consideration, however, the extensive limestone units have buffering capacity that will mitigate ARD.
- From the Brooks Range to the Yukon River, the geology is dominated by metamorphic rock, mafic igneous rock, and felsic intrusive rock. Metamorphic rocks include various types of schist and the mafic igneous rocks commonly seen are gabbro and basalt. The felsic intrusive rocks are comprised of coarse-grained granitic rock. The rocks along this portion of the Alaska Mainline tend to be largely inert with few iron sulphides, little carbonate, and minimal metallic mineralization. These rocks, therefore, are generally of low priority from an ML/ARD perspective.
- South of the Yukon River to just north of Fairbanks, the geology is complex. Extensive large-scale faulting has resulted in the juxtaposition of many rock types. There are also a number of mineral occurrences in this area. Some of this mineralization is due to mineral-laden waters circulating in the faulted rocks, which can precipitate iron sulphides, calcium carbonate or both. The ML/ARD potential is variable in this section.
- From north of Fairbanks south to the U.S.-Canada border, the Alaska Mainline crosses metamorphic rocks, usually schist, with some metamorphosed granitic rock. As with the area north of Fairbanks, the ML/ARD potential of this area is variable.

APP completed a non-intrusive field reconnaissance of 61 of 78 potential ML/ARD sites in August and September of 2010. This study did not evaluate the Aboveground Facilities and infrastructure associated with the Alaska Mainline. Based on the 2010 field reconnaissance, APP identified 5.5 miles of bedrock with ML/ARD potential at the 61 sites investigated. Many of sites lacked bedrock exposure and other areas had restricted access. Conclusions from the reconnaissance are as follows.

- For the majority of the Alaska Mainline, the pipeline crosses rocks that generally have low diagenetic ML/ARD potential. The rocks tend to be intrusive rocks such as granite, and moderate grade metamorphic rocks such as schist. Exceptions to this exist, such as in the Brooks Range area where sedimentary rocks including sandstone, conglomerate, limestone, shale, and coal are found. Other areas, such as the coal-bearing formations north of the Alaska Range, are generally not of concern either because the Alaska Mainline does not cross these formations or because they are under thick surficial deposits.

- The most common type of ML/ARD potential was from secondary iron sulphides introduced by fluids moving in faults and fractures. This type of occurrence is somewhat unpredictable. Plotting of known mineral occurrences may identify areas where this type of occurrence is possible.
- The majority of the Alaska Mainline has negligible ML/ARD potential because the bedrock is covered by surficial deposits of sufficient thickness where excavation will not reach the underlying rock. The surficial deposits are generally considered to have no or negligible ML/ARD potential.

Information from the field reconnaissance and the desktop study were integrated to provide an estimate of ML/ARD potential for the Alaska Mainline as summarized in Table 6.4.4-1.

TABLE 6.4.4-1

**Alaska Pipeline Project**
**Results of Additional Studies Relating to Potential Acid Rock Drainage Hazards Within the Vicinity of the Alaska Mainline**

| Alaska Mainline Milepost | | | Acid Rock Drainage | |
|---|---|---|---|---|
| Begin | End | Geologic Description | Hazard Rating | Comments on Hazard Rating |
| NORTH SLOPEBOROUGH | | | | |
| 64.3 | 71.2 | Claystone, Siltstone, Sandstone, Conglomerate, and Coal | High | No assessment on bedrock available in area at this time. |
| 71.2 | 74.7 | Sandstone, Conglomerate, Shale, Clay, Silt, and Bentonite | High | No assessment on bedrock available in area at this time. |
| 87.3 | 97.7 | Shale, Sandstone, and Conglomerate (coal layers) | Low to Moderate | ARD potential high if coal layers and shale is present. |
| 148.4 | 148.8 | Sandstone, Siltstone, and Shale | Low | No assessment on bedrock available in area at this time. |
| 149.5 | 149.5 | Limestone, Conglomerate, Shale, Dolomite, and Chert | None | No assessment on bedrock available in area at this time. |
| 150.5 | 150.8 | Conglomerate, Shale, Limestone, Chert, and Dolomite | None | No assessment on bedrock available in area at this time. |
| 160.2 | 185.2 | Shale, Sandstone, Chert, Conglomerate, Quartzite, Limestone, and Dolomite | None | No assessment on bedrock available in area at this time. |
| YUKON-KOYUKUKCENSUS AREA | | | | |
| 185.2 | 185.5 | Shale, Sandstone, Chert, Conglomerate, Quartzite, Limestone, and Dolomite | None | No assessment on bedrock available in area at this time. |
| 185.7 | 221.3 | Metasedimentary and Metaigneous Rock including Metacarbonate Rock, Metasiliciclastics, Metamorphosed Calcareous Sedimentary Rock, minor Mafic Metagabbro, and Metafelsite | Very Low | ARD potential low if metagabbro is encountered. |
| 244.2 | 244.3 | Metasedimentary and Metaigneous Rock including Quartz Mica Schist, Calcareous Schist, Marble, Mafic Schist, and Granitic Orthogneiss | Very Low | ARD potential low if mafic schist is encountered. |

TABLE 6.4.4-1

**Alaska Pipeline Project**
**Results of Additional Studies Relating to Potential Acid Rock Drainage Hazards**
**Within the Vicinity of the Alaska Mainline**

| Alaska Mainline Milepost | | | | |
|---|---|---|---|---|
| Begin | End | Geologic Description | Acid Rock Drainage Hazard Rating | Comments on Hazard Rating |
| 252.3 | 252.6 | Igneous and Sedimentary Rocks including Ultramafic, Mafic extrusive and intrusive, Andesitic and Dacitic to Rhyolitic Igneous Rocks; Chert and Limestone are interbedded with the Mafic Igneous Rock; Argillite, Shale, Greywacke, rare Limestone, and oil Shale form Sedimentary units; all Rock is slightly Metamorphosed | Very Low | ARD potential moderate if ultramafic and mafic rock and shale is encountered. |
| 262.1 | 262.7 | Conglomeratic Sandstone, Greywacke, Sandstone, Mudstone, Shale, Calcareous Sandstone, Siltstone, Shale, and Coal | None | ARD potential high if carbonaceous shale or coal is encountered. |
| 278.0 | 283.9 | Igneous and Sedimentary Rocks including Ultramafic, Mafic extrusive and intrusive, Andesitic and Dacitic to Rhyolitic Igneous Rocks; Chert and Limestone are interbedded with the Mafic Igneous Rock; Argillite, Shale, Greywacke, rare Limestone, and oil Shale form Sedimentary units; all Rock is slightly Metamorphosed | Very Low | ARD potential moderate if ultramafic and mafic rock and shale is encountered. |
| 285.6 | 289.0 | Metamorphosed Sedimentary Rocks including deformed Shale, Siltstone, Sandstone, Greywacke, Quartz, and Chert wacke; minor Conglomerate, Carbonate, and Mafic Rock | Very Low | ARD potential low if mafic rock is encountered. |
| 289.1 | 291.5 | Granite | Very Low | |
| 291.7 | 292.9 | Metasedimentary and Metaigneous Rock including Quartz Mica Schist, Calcareous Schist, Marble, Mafic Schist, and Granitic Orthogneiss | Very Low | ARD potential low if mafic schist is encountered. |
| 293.6 | 296.8 | Metamorphosed Sedimentary Rocks including deformed Shale, Siltstone, Sandstone, Greywacke, Quartz and Chert wacke; minor Conglomerate, Carbonate, and Mafic Rock | Very Low | ARD potential low if mafic rock is encountered. |
| 296.9 | 301.6 | Metasedimentary and Metaigneous Rock including Quartz Mica Schist, Calcareous Schist, Marble, Mafic Schist, and Granitic Orthogneiss | Very Low | ARD potential low if mafic schist is encountered. |
| 302.1 | 309.8 | Igneous and Sedimentary Rocks including Ultramafic, Mafic extrusive and intrusive, Andesitic and Dacitic to Rhyolitic Igneous Rocks; Chert and Limestone are interbedded with the Mafic Igneous Rock; Argillite, Shale, Greywacke, rare Limestone, and oil Shale form Sedimentary units; all Rock is slightly Metamorphosed | Very Low | ARD potential moderate if ultramafic and mafic rock and shale is encountered. |
| 309.8 | 312.5 | Granite | Very Low | |
| 314.6 | 322.0 | Metamorphosed Sedimentary Rocks including deformed Shale, Siltstone, Sandstone, Greywacke, Quartz and Chert wacke; minor Conglomerate, Carbonate and Mafic Rock | Very Low | |
| 322.1 | 326.2 | Metasedimentary and Metaigneous Rock including Quartz Mica Schist, Calcareous Schist, Marble, Mafic Schist and Granitic Orthogneiss | None to Very Low | ARD potential low if mafic schist is encountered. |

TABLE 6.4.4-1

**Alaska Pipeline Project**
**Results of Additional Studies Relating to Potential Acid Rock Drainage Hazards**
**Within the Vicinity of the Alaska Mainline**

| Alaska Mainline Milepost | | | | |
|---|---|---|---|---|
| Begin | End | Geologic Description | Acid Rock Drainage Hazard Rating | Comments on Hazard Rating |
| 327.3 | 343.1 | Granite | Low | |
| 344.3 | 346.6 | Metamorphosed Sedimentary Rocks including deformed Shale, Siltstone, Sandstone, Greywacke, Quartz and Chert wacke; minor Conglomerate, Carbonate and Mafic Rock | Very Low | ARD potential low if mafic rock is encountered. |
| 346.9 | 369.3 | Igneous and Sedimentary Rocks including Ultramafic, Mafic extrusive and intrusive, Andesitic and Dacitic to Rhyolitic Igneous Rocks; Chert and Limestone are interbedded with the Mafic Igneous Rock; Argillite, Shale, Greywacke, rare Limestone, and oil Shale form Sedimentary units; all Rock is slightly Metamorphosed | Low | ARD potential moderate if ultramafic and mafic rock and shale is encountered. |
| 370.4 | 373.2 | Clastic Sedimentary Rock including Mudstone, Coal, Sandstone, and Conglomerate | Low | ARD potential high if mudstone and/or coal is encountered. |
| 373.4 | 379.9 | Igneous and Sedimentary Rocks including Ultramafic, Mafic extrusive and intrusive, Andesitic and Dacitic to Rhyolitic Igneous Rocks; Chert and Limestone are interbedded with the Mafic Igneous Rock; Argillite, Shale, Greywacke, rare Limestone, and oil Shale form Sedimentary units; all Rock is slightly Metamorphosed | Low | ARD potential moderate if ultramafic and mafic rock and shale is encountered. |
| 383.1 | 388.5 | Igneous and Sedimentary Rocks including Ultramafic, Mafic extrusive and intrusive, Andesitic and Dacitic to Rhyolitic Igneous Rocks; Chert and Limestone are interbedded with the Mafic Igneous Rock; Argillite, Shale, Greywacke, rare Limestone, and oil Shale form Sedimentary units; all Rock is slightly Metamorphosed | Moderate | |
| 391.8 | 392.6 | Igneous and Sedimentary Rocks including Ultramafic, Mafic extrusive and intrusive, Andesitic and Dacitic to Rhyolitic Igneous Rocks; Chert and Limestone are interbedded with the Mafic Igneous Rock; Argillite, Shale, Greywacke, rare Limestone, and oil Shale form Sedimentary units; all Rock is slightly Metamorphosed | Moderate to High | |
| 396.1 | 404.4 | Sedimendary and Igneous Rocks including Argillite, Phyllite, Quartzite Greywacke, Siltite, Grit and Limestone; Mafic extrusive and intrusive rocks and fine grained Sedimentary Rocks interlayered with Serpentinite; also Chert, Sedimentary Breccias, Siliceous Slate, Rare Greenstone, Limestone, and Mafic flows. | None to Low | ARD potential low if mafic rock is encountered. |
| 408.2 | 417.8 | Quartzite, Argillite, Conglomerate, and Hornfels | Low | No assessment on bedrock available in area at this time. |
| 419.9 | 430.2 | Sedimentary and Igneous Rocks | Low | No assessment on bedrock available in area at this time. |
| FAIRBANKS NORTH STAR BOROUGH | | | | |
| 430.2 | 437.7 | Sedimentary and Igneous Rocks | Low | No assessment on bedrock available in area at this time. |

TABLE 6.4.4-1

**Alaska Pipeline Project**
**Results of Additional Studies Relating to Potential Acid Rock Drainage Hazards**
**Within the Vicinity of the Alaska Mainline**

| Alaska Mainline Milepost | | | | |
|---|---|---|---|---|
| Begin | End | Geologic Description | Acid Rock Drainage Hazard Rating | Comments on Hazard Rating |
| 438.7 | 453.2 | Metamorphic Rocks | None | No assessment on bedrock available in area at this time. |
| 453.2 | 455.4 | Quartzite, Greenschist facies Argillite | None | No assessment on bedrock available in area at this time. |
| 456.2 | 463.1 | Granite | None | No assessment on bedrock available in area at this time. |
| 463.6 | 464.2 | Quartzite, Greenschist facies, Argillite | None | No assessment on bedrock available in area at this time. |
| 473.4 | 498.6 | Phyllite, Meta-Argillite, Quartzite, and Metachert | Low | No assessment on bedrock available in area at this time. |
| 499.9 | 501.6 | Schist, Argillite, and Amphibolite | Moderate | No assessment on bedrock available in area at this time. |
| 509.3 | 518.2 | Gneiss | None | No assessment on bedrock available in area at this time. |
| SOUTHEAST FAIRBANKS CENSUS AREA | | | | |
| 518.2 | 519.1 | Gneiss | None | No assessment on bedrock available in area at this time. |
| 537.8 | 605.8 | Schist, Argillite, and Amphibolite | Moderate | No assessment on bedrock available in area at this time. |
| 605.9 | 610.1 | Granite | None | No assessment on bedrock available in area at this time. |
| 634.7 | 634.7 | Metasedimentary and Metaigneous Schist, Gneiss, and Amphibolite | Moderate | No assessment on bedrock available in area at this time. |
| 666.2 | 689.7 | Granite to Granodiorite | None | No assessment on bedrock available in area at this time. |
| 690.8 | 698.3 | Metasedimentary and Metaigneous Schist, Gneiss, and Amphibolite | Moderate | No assessment on bedrock available in area at this time. |
| 698.7 | 704.7 | Metamorphic Rocks - Hornfels, Schist, Amphibolite, minor Marble also Gneiss, Schist, and Phyllite | Low to Moderate | ARD potential moderate if hornfels and amphibolite is encountered. |
| 705.1 | 714.1 | Granite to Granodiorite | None | No assessment on bedrock available in area at this time. |
| 727.9 | 745.1 | Metamorphic Rocks - Hornfels, Schist, Amphibolite, minor Marble also Gneiss, Schist, and Phyllite | Low to Moderate | ARD potential moderate if hornfels and amphibolite is encountered. |

Hazard ratings of Very Low, None to Very Low, None to Low considered negligible for the purposes of the assessment of ARD potential.

The AMPs shown are for the interval associated with the geologic description, of which only a portion may be associated with ARD potential.

Based on the preliminary desktop study and field reconnaissance of the route, APP concluded that 75.8 miles of the Alaska Mainline has the potential for ML/ARD. Of the 75.8 miles, 9.1 miles have a high potential, 13.8 miles have a moderate potential, and 52.9 miles have a low potential for ML/ARD. The remaining approximately 669.3 miles have no or negligible potential for ARD owing either to the rock type or depth of soil cover overlying the bedrock[16].

### 6.4.5 EROSION AND SCOUR

Seasonal and flash flooding and aufeis (surface icings) have the potential to expose the pipeline at or near waterbodies. Resource Report 2, Appendix 2B, provides a list of waterbodies crossed by the Project, and Resource Report 8 provides a discussion of flood zones. Although flooding itself does not present a risk to Pipeline Facilities, bank erosion, scour, and/or channel migration could expose or cause sections of pipe to become unsupported (free-stress). The pipeline route crosses numerous waterbodies that have potential for flood scour during large excessive runoff events (e.g., spring breakup). The pipeline will be buried at a depth that is sufficient to protect against erosion and scour.

Terrain mapping completed by APP for the Alaska Mainline in 2009 was used in conjunction with other available datasets (including Federal Emergency Management Agency defined flood zones) and imagery for the pipeline corridor to identify existing landforms (as tabulated in Resource Report 7, Appendix 7A) that may be associated with flooding. It is noted that flooding does not always result in scour, and that many of these locations may be old deposits that are no longer subject to flooding or are not defined waterbody crossings. Table 6.4.5-1 summarizes the distribution of the landforms that may be subject to flooding along the Alaska Mainline by general area. In addition to the Alaska Mainline, APP determined that the Atigun River and Sears Creek storage yards and the Little Chena and Tok construction camps may be subject to flooding.

TABLE 6.4.5-1

**Alaska Pipeline Project**
**Potential Flooding Hazards within the Vicinity of the Alaska Mainline***

| Area | Location of First Occurrence (milepost) | Location of Last Occurrence (milepost) | Total Length (Miles) of Occurrences within Area |
|---|---|---|---|
| North Slope Borough | 0.1 | 184.8 | 10.4 |
| Yukon-Koyukuk Census Area | 185.8 | 428.9 | 24.2 |
| Fairbanks North Star Borough | 430.6 | 517.4 | 9.7 |
| Southeast Fairbanks Census Area | 518.6 | 744.9 | 25.2 |

* Scour potential not included in table.

Based on the results in Table 6.4.5-1, a potential flooding hazard exists for 69.5 miles of the Alaska Mainline.

16 See Appendix 7B of Resource Report 7 for detailed listing of surficial geologic units and location of bedrock exposures.

### 6.4.6 CONSTRUCTION AND OPERATION IMPACTS AND MITIGATION

Adverse effects to the pipeline and other Project facilities resulting from geologic hazards will be avoided or greatly reduced through route selection, engineering design, and monitoring. In the event that the Project encounters geohazards, APP will implement the appropriate mitigation measures to reduce potential impacts.

[Note: APP will complete a Project-wide facility-specific geohazard evaluation and include an update of the results of this assessment in the final report.]

#### 6.4.6.1 Earthquakes

**Fault Rupture Displacement**

Based on studies of seismic hazards, APP identified fault zones along or within the vicinity of the Project that APP considered critical for potential pipeline strain and stress from dynamic ground motion associated with earthquakes. APP will realign the pipeline along segments that are parallel or coincident with major faults to increase the separation distance from the fault to the pipeline. APP will design the pipeline and the Aboveground Facilities to withstand the predicted levels of ground deformation and incorporate current seismological engineering standards where applicable. During operations, APP will develop or arrange for monitoring of seismic ground motions in accordance with the Integrity Management Program.

**Soil Liquefaction**

Less than 7.5 miles of potential lateral spreading was identified within the Project area. These areas are primarily in floodplains associated with waterbodies. The mitigation options selected by APP to address lateral spread at watercourse crossings may involve modified burial depth and crossing geometry at conventional trenched crossing locations.

APP identified less than 2 miles of potentially liquefiable materials on long cross slopes. To address these areas, mitigation may include techniques such as interceptor ditches and vertical drains. Other techniques may be developed as engineering design progresses.

The Tetlin Junction Compressor station is currently located in an area of potential soil liquefaction; APP will continue to evaluate the location of this compressor station and provide updates in the final report.

**Seismic Wave Propagation**

APP predicts very small strains on the pipeline from seismic wave propagation, and APP has not identified a need to mitigate this potential geohazard.

#### 6.4.6.2 Volcanism

Of the volcanic features near the Project area, only Mount Wrangell has been historically active. Given its distance from the nearest Aboveground Facility (approximately 100 miles) and the low level of activity at Mount Wrangell, adverse effects of volcanism are not expected.

#### 6.4.6.3 Mass Movements

**Landslides**

To reduce the effects from landslides, the pipeline route selection criteria includes avoiding steep slopes, minimizing exposure to unstable landforms, and following the fall line (perpendicular to the slope contour) when traversing a slope, as discussed in Section 10.5

of Resource Report 10. By following existing or previously studied corridors, the large majority of potential slope instability hazards have been avoided. Based on studies of the Project area, there are four active deep-seated landslides and seven mudflows that cross the Alaska Mainline. APP will further investigate the deep-seated landslides to assess the hazard. The mudflows are depositional in nature where they cross the Alaska Mainline and, therefore, are not considered a threat to the pipeline and require no additional investigation. [Note: Results of any new or updated landslide studies will be incorporated into the final report.]

In accordance with the APP Erosion Control, Revegetation, and Maintenance Plan (Plan), the Project will install appropriate erosion control measures during and following construction to mitigate landslides and slope instability (refer to Appendix 1J in Resource Report 1). During operations, APP will implement an Integrity Management Program as identified in Section 11.4 of Resource Report 11.

Avalanche

APP will consider the potentially large run-out distances for snow avalanches during selection of sites for Aboveground Facilities, parking and storage areas, and materials sites in mountainous terrain.

A total of 10 snow avalanche chutes and 10 slushflow avalanche chutes (some of which are collocated) cross the Project area as identified in Table 6.4.5-1. Specific areas such as Atigun Pass will be addressed in the design process to incorporate appropriate mitigation measures.

Rock Glaciers

Based on preliminary assessments, APP has determined that known rock glaciers in the Project area will not have an impact due to the slow rate of movement.

Subsidence

Based on preliminary assessment, no karst collapse hazards occur in the vicinity of the Project; therefore karst collapse within the Project area is unlikely.

Regional subsidence is unlikely to occur in the Project area and the potential for localized collapse features to develop in the Project area is low. In the unlikely event of a collapse structure developing beneath the pipeline, the strength and ductility of the pipeline will allow it to span a considerable distance without threatening the integrity of the pipeline. Thaw-settlement may occur in localized areas, as discussed in Section 7.4 of Resource Report 7.

#### 6.4.6.4 Acid Rock Drainage

Based on desktop study and field reconnaissance, ML/ARD is not a concern for the PT Pipeline, but 75.8 miles of the Alaska Mainline has the potential for ML/ARD. Of these 75.8 miles, 9.1 miles have high potential, 13.8 miles have moderate potential, and 52.9 miles have low potential. The remaining 669.3 miles of the Alaska Mainline have no or negligible potential.

ARD is a geohazard that might affect surface and groundwater by increasing the acidity and the concentration of heavy metals, and can promote corrosion to exposed metal. APP pipelines will be protected with a corrosion coating and a corrosion protection system to reduce this potential effect on the pipeline.

#### 6.4.6.5 Erosion and Scour

Within the Project area, there is a potential flooding hazard for 69.5 miles of the Alaska Mainline and within the vicinity of the Atigun River and Sears Creek storage yards and the Little Chena and Tok construction camps. APP will design and construct Pipeline Facilities in accordance with 49 C.F.R. § 192 to provide adequate protection from bank erosion, scour, and/or channel migration.

## 6.5 BLASTING

### 6.5.1 BLASTING ACTIVITIES

Blasting will be required in areas where competent shallow bedrock or boulders and permafrost are encountered that cannot be removed by conventional mechanical excavation with a trackhoe trencher, bulldozer, hydraulic hammer, or rocksaw. Blasting will be employed to create an excavated water reservoir impoundment southwest of the GTP. Blasting will be conducted to break up the existing frozen rock and gravel. Blasting will be conducted in accordance with the Blasting Plan in Appendix 6B. [Note: Refer to Appendix 6B of this draft resource report for an outline of the Blasting Plan. A draft Blasting Plan will be provided in the final report.]

Appendix 6C lists areas where shallow or exposed bedrock is expected to be encountered along the APP facilities and may require blasting. In addition, certain soil conditions with boulders, cobbles, or gravel/granular materials in permafrost may require blasting depending on the proportion of coarse granular materials and the nature of the permafrost. These locations are also summarized in this table. Also listed in Appendix 6C are waterbody crossings that may require blasting, depending on specific conditions such as the pipe burial depth and construction mode and the proposed crossing method at these sites. Blasting may also be used at some borrow sites to loosen material that may be frozen or in a dense, consolidated state.

The locations where bedrock is expected to be encountered on the prepared right-of-way or in the pipeline ditch were identified as “Probable Blasting” in a summary of ditch and/or grade rock[17] intervals (refer to Table 6C-1 of Appendix 6C). The estimated total length of “Probable Blasting” associated with ditch and/or grade rock intervals along the Alaska Mainline route is 173.4 miles; of which, approximately 0.5 mile is anticipated within waterbodies. No bedrock is anticipated along the PT Pipeline route based on the available information.

Permafrost soil locations containing frequent cobbles and/or boulders were identified as “Probable Blasting” whereas those containing few cobbles and/or boulders, gravel, or granular material were identified as “Potential Blasting” (refer to Table 6C-1 of Appendix 6C). For the Alaska Mainline route, respective lengths of 245.1 miles of “Probable Blasting” and 56.7 miles of “Potential Blasting” were estimated. For the PT Pipeline, respective lengths of 11 miles of “Probable Blasting” and 8.5 miles of “Potential Blasting” were estimated[18].

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17 Grade rock is shallow or surface bedrock intersected during right-of-way preparation prior to pipeline ditch excavation, and ditch rock is shallow or surface bedrock intersected during pipeline ditch excavation.

18 [Note: Preliminary blasting locations and estimated miles of blasting will be updated in Appendix 6C of the final report. The need for blasting at all Aboveground Facilities and Associated Infrastructure locations has not been assessed. These will also be determined at a preliminary level and incorporated into the final report.]

### 6.5.2 CONSTRUCTION AND OPERATION IMPACTS AND MITIGATION

Blasting has the potential to damage nearby structures including buildings, wells, unstable slopes, undiscovered paleontological resources, and existing third-party pipelines and facilities. Prior to the start of construction, APP will prepare and file a Blasting Plan that notes all potential blasting locations. [Note: Refer to Appendix 6B of this draft resource report for an outline of the Blasting Plan. A draft Blasting Plan will be provided in the final report.] Blasting activities will be performed in accordance with manufacturers' prescribed safety procedures, industry practices, and comply with applicable laws, regulations, and permits. The Blasting Plan also will specify measures for proper storage, transport, and handling of explosives.

APP will identify its proposed blasting procedures in its Blasting Plan. These procedures will include:

- Identification and compliance with applicable blasting regulations;
- Provisions for pre-blast geotechnical investigations;
- Procedures to avoid impacts associated with flyrock and vibration;
- Determination of appropriate charge type, weight, and configuration;
- Depth and spacing of charges;
- Detonation delays;
- Procedures for notifying and evacuating nearby residents; and
- Procedures for pre- and post-blasting monitoring and blast mat placement.

All blasting operations will be implemented in accordance with federal, state, and local regulations using approved procedures for conducting safe blasting. The subcontractor performing the blasting will be responsible for obtaining blasting permits.

## 6.6 PALEONTOLOGIC RESOURCES

Paleontological resources are any physical evidence of past life, including fossilized remains, imprints, and traces of plants and animals. Fossilized plants of marine and terrestrial origin, as well as invertebrate and vertebrate animal remains, may be present in the Project area. These fossils document non-human life in Alaska during the last 570 million years. As non-renewable resources, no matter how common or rare they may be, fossils of scientific value are protected by the Antiquities Act. Fossils on federal lands also are protected by the Federal Land Policy and Management Act. Two other federal laws, the Archaeological Resources Protection Act and the Federal Cave Resources Protection Act, protect fossils in archaeological context and fossils from caves, respectively. Paleontological resources are protected in Alaska under the state's Alaska Historic Preservation Act.

The Project will cross varying sedimentary bedrock formations and unconsolidated materials of varying age and depth that are known to contain or have the potential to contain paleontological resources in Alaska. Fossils potentially present range from single-celled organisms to large vertebrates, including Mesozoic dinosaurs and Pleistocene mammoths. Vertebrate fossils tend to be rare and fragmentary, and thus have greater scientific importance than the more common invertebrate and plant fossils; therefore, they are considered to be scientifically significant.

In the Project area, the unconsolidated materials that are potentially fossil-bearing include glaciofluvial, alluvial, fluvial, and eolian deposits. These unconsolidated deposits may overlie igneous, metamorphic, or sedimentary rock of varying age and depth. Although many consolidated and unconsolidated geologic formations have the potential to contain fossils, those that could potentially contain vertebrate fossils are of the greatest concern to the Project.

The amount of paleontological evidence in Alaska varies, and with respect to APP can be broadly characterized by location. Beginning at the northern end of the Project, the North Slope and portions of the Brooks Range contain and are underlain by sedimentary rocks. Most of the limestone, sandstone, siltstone, and shale are marine in origin. The earliest fossils are found in Middle Devonian-age rocks. Common fossils in these rocks include brachiopods, cephalopods, gastropods, pelecypods, sponges, bryozoans, corals, and crinoids. Post-Devonian sedimentation on the North Slope has, in some cases, developed up to 20,000 feet of fossil-bearing strata. Fossils of post-Devonian marine invertebrates include bryozoans, brachiopods, pelecypods, gastropods, ostracods, cephalopods, crinoids, trilobites, and coral. Marine plants also occur in these sedimentary rocks. By the Middle Jurassic and continuing into the Cretaceous, terrestrial plant fossils appear in the North Slope geologic deposits, indicating episodic retreats and advances of the sea. Twelve types of dinosaurs, from Late Cretaceous beds, have been found on the North Slope and Trans-Alaska Pipeline System (TAPS) (2002) reports its right-of-way parallels Late Cretaceous sandstones for approximately 11 miles of the North Slope, though no dinosaur fossils have been found near the TAPS right-of-way. Bones from adult and young hadrosaur, tyrannosaur, and troodon dinosaurs, however, have been discovered along the Colville River about 50 miles west of Prudhoe Bay and the Alaska Mainline route. Tertiary fossils represented primarily by invertebrate fossils are common in beds along the Arctic Coastal Plain. The post-Eocene fossil record on the North Slope does not resume until the Pliocene and Pleistocene. Marine and terrestrial mammals (such as otter, seal, whale, mammoth, moose, caribou, musk ox, bison, antelope, camel, horse, lion) and birds have been found in Quaternary glaciofluvial deposits along the Colville River, approximately 90 miles west of APP and the TAPS right-of-way. Possibly because of the effects of later glacial activities, no Pleistocene faunal remains have been reported in the part of the North Slope occupied by the Alaska Mainline.

The Brooks Range contains mountains composed of sedimentary rocks, interspersed with metamorphic and igneous strata. Glacial, colluvial, alluvial, lacustrine, and aeolian deposits overlie weathered bedrock. Upthrusts and faulting have exposed fossil-bearing strata at the ground surface. Concentrations of invertebrate fossils from sedimentary and metamorphic rocks are found along mountainous stretches that will parallel the Alaska Mainline (TAPS 2002).

South of the Brooks Range, the Alaska Mainline crosses major river drainages and numerous smaller rivers and creeks. The underlying bedrock associated with these river drainages is usually metamorphic, with sedimentary and igneous episodes. The bedrock often is deeply buried by Quaternary glacial, glaciofluvial, outwash, lacustrine, alluvial, and eolian deposits, and derived from flanking mountainous zones. The older metamorphic, igneous, or rapidly deposited sedimentary rocks predominate, and pre-Quaternary fossils are either very uncommon or absent. However, Pleistocene-age fossils are present in locations and generally preserved in glaciofluvial or fluvial gravel or re-transported sediments. Fossils of freshwater mollusks, insects, and vertebrates are common in the Fairbanks area. Fossils of extinct Pleistocene animals, including mammoth, mastodon, bison, Siberian steppe antelope, horse, musk oxen, blue ox, and birds have also been found in placer mining operations in the Fairbanks area (TAPS 2002).

In general, paleontological resources could be affected by construction of the pipeline and associated Aboveground Facilities, as well as by the resulting increased public access to these resources. Both federal and state laws mandate the protection of significant paleontological resources on federally-administrated or state-owned lands. Without mitigation, excavation during construction could cause direct physical impact on paleontological resources. Indirect impact on fossil beds could result from erosion caused by slope grading, vegetation clearing, and unauthorized collection. If scientifically significant fossil deposits are encountered during trenching and earthmoving activities, measures identified in the Significant Paleontological Resources Component of Construction Unanticipated Discoveries Plan will be implemented. Scientifically significant fossils are identified in BLM Circular H-8270-1 (BLM 1998). [Note: Refer to Appendix 6D of this draft resource report for an outline of the Significant Paleontological Resources Component of Construction Unanticipated Discoveries Plan. The Construction Unanticipated Discovery Plan will be updated after consultation with ADNR and BLM and will be provided in the final report. The final Construction Unanticipated Discovery Plan will be submitted for approval prior to construction-related ground disturbance activities.]

The data for locations and types of scientifically significant fossil finds is generally confidential and not publicly available. TAPS (2002) lists known paleontological resources that have been recorded in the vicinity of the TAPS right-of-way, including 20 invertebrate sites, 3 vertebrate, and 2 plant fossil localities. The Alaska Paleontological Database (2011) was reviewed to determine if significant paleontological finds have been reported in the area of the Project. The database contains detailed information on fossils and fossil localities in Alaska derived from unpublished USGS fossil reports, published literature, and industry data. The database cites at least 40 locations, many with multiple finds per location. One find was reported to be within 1,500 feet the route. It's location is cited as west of AMP 68.9 and the find was reported as a microfossil found in the Sagavanirktok Formation. With the exception of one vertebrate find, all fossil remains reported in this database are not considered significant. This vertebrate find is cited as approximately 3,370 feet east of AMP 187.8 and is not expected to be impacted by APP construction.

"Lowland loess" is the landform with the greatest potential to contain vertebrate fossils. Table 6.6-1, below, provides the lowland loess locations along the Alaska Mainline. [Note: Table 6.6-1 will be updated with an evaluation of the PT Pipeline, Aboveground Facilities, and Associated Infrastructure and after consultation with ADNR and BLM and provided in the final report.]

TABLE 6.6-1

**Alaska Pipeline Project**
**Lowland Loess Locations in the Vicinity of the Alaska Mainline**

| Pipeline/Borough or Census Area | Milepost Begin (AMP) | Milepost End (AMP) | Total Length (miles) |
|---|---|---|---|
| North Slope Borough | 0.0 | 0.1 | 0.1 |
| North Slope Borough | 0.7 | 1.4 | 0.7 |
| North Slope Borough | 1.7 | 2.8 | 1.0 |
| North Slope Borough | 5.5 | 6.3 | 0.8 |
| North Slope Borough | 6.4 | 7.0 | 0.6 |
| North Slope Borough | 7.2 | 8.9 | 1.6 |
| North Slope Borough | 9.2 | 9.3 | 0.1 |
| North Slope Borough | 9.5 | 9.7 | 0.2 |
| North Slope Borough | 10.1 | 11.1 | 1.0 |
| North Slope Borough | 11.7 | 11.8 | 0.1 |
| North Slope Borough | 12.2 | 15.9 | 3.7 |
| North Slope Borough | 16.4 | 16.8 | 0.4 |
| North Slope Borough | 16.9 | 17.8 | 0.9 |
| North Slope Borough | 27.0 | 27.0 | 0.1 |
| North Slope Borough | 27.1 | 27.1 | <0.1 |
| North Slope Borough | 35.1 | 35.2 | 0.1 |
| North Slope Borough | 47.2 | 53.9 | 6.7 |
| North Slope Borough | 53.9 | 54.3 | 0.4 |
| North Slope Borough | 54.4 | 55.4 | 1.1 |
| North Slope Borough | 55.4 | 55.8 | 0.4 |
| North Slope Borough | 55.9 | 55.9 | 0.1 |
| North Slope Borough | 55.9 | 56.2 | 0.3 |
| North Slope Borough | 56.5 | 57.6 | 1.0 |
| North Slope Borough | 58.1 | 59.2 | 1.1 |
| North Slope Borough | 59.2 | 63.7 | 4.5 |
| North Slope Borough | 63.7 | 63.9 | 0.2 |
| North Slope Borough | 63.9 | 64.2 | 0.2 |
| North Slope Borough | 111.4 | 111.5 | 0.1 |
| Yukon-Koyukuk Census Area | 369.6 | 369.9 | 0.3 |
| Yukon-Koyukuk Census Area | 370.0 | 370.4 | 0.4 |
| Yukon-Koyukuk Census Area | 379.9 | 380.1 | 0.1 |
| Yukon-Koyukuk Census Area | 380.2 | 381.0 | 0.8 |
| Fairbanks North Star Borough | 492.2 | 492.3 | 0.1 |
| Fairbanks North Star Borough | 492.3 | 492.6 | 0.3 |
| Fairbanks North Star Borough | 492.6 | 492.7 | 0.1 |
| Fairbanks North Star Borough | 497.1 | 497.1 | <0.1 |
| Fairbanks North Star Borough | 507.1 | 507.3 | 0.2 |
| Fairbanks North Star Borough | 507.3 | 507.4 | 0.1 |
| Southeast Fairbanks Census Area | 524.4 | 524.8 | 0.4 |
| Southeast Fairbanks Census Area | 524.9 | 525.2 | 0.3 |
| Southeast Fairbanks Census Area | 525.2 | 526.1 | 0.8 |
| Southeast Fairbanks Census Area | 527.0 | 528.1 | 1.1 |
| Southeast Fairbanks Census Area | 529.4 | 530.4 | 1.0 |
| Southeast Fairbanks Census Area | 587.6 | 587.8 | 0.1 |

### 6.6.1 CONSTRUCTION AND OPERATION IMPACTS AND MITIGATION

The Alaska Mainline crosses no known significant paleontological resources and the Project is not anticipated to inhibit any future exploration of these resources.

## 6.7 CUMULATIVE IMPACTS

[Note: Field surveys and agency consultation are ongoing. Cumulative impacts will be updated in the final report.]

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