# 3.7 WATER QUALITY

**SYNOPSIS**

This section describes existing and projected surface water quality, groundwater quality, and sediment quality in the proposed project area. The section begins by discussing applicable laws and water quality criteria; then covers existing conditions in the potentially affected environment. The geochemistry of the proposed mine site is described in relation to surface water quality, groundwater quality, and sediment quality. Existing conditions are described for each component of the proposed project. The section then presents expected effects of the proposed action and alternatives.

**Summary of Existing Conditions:**

Regulatory Framework: The Clean Water Act (CWA) requires the establishment and maintenance of water quality standards and is the primary law governing surface water quality in the United States. The CWA provides EPA, the Corps, and the States with a variety of programs and tools to protect and restore the Nation's waters. One such program is called the Alaska Pollutant Discharge Elimination System (APDES) Program, which is administered by the Alaska Department of Environmental Conservation (ADEC) and regulates point source discharges, including stormwater, in Alaska. The CWA also contains requirements that water quality standards (WQS) must be established, and that water quality must be monitored to determine compliance relative to the established standards. ADEC is responsible for setting and regulating WQS for the State of Alaska.

Groundwater quality is protected for a variety of uses, including drinking, culinary, and food processing; agriculture, including irrigation and stock watering; aquaculture; and industrial uses. ADEC regulates contaminated sites, underground storage tanks, and establishes water quality standards to serve to protect groundwater. But the department does not regulate groundwater directly. While there are no regulations in force for chemical concentrations in sediment, the sediment quality guidelines recommended by ADEC to establish clean-up levels at contaminated sites are used as a basis for evaluation of impacts to sediment quality.

General Background: By breaking up and exposing previously solid, buried rock to air and water and microbes, mining increases the rates of physical and chemical processes such as weathering and chemical dissolution of rocks and minerals. During weathering, the minerals in mined rock come into contact and react with air and water and may potentially release some of their constituents (in the mobile forms of ions, compounds, and colloids) into the surrounding environment, including surface water, groundwater, and sediment.

*Mine Site* – Prior to any mining activity, a study of natural background water quality was conducted. Among several constituents potentially present naturally at concentrations in excess of the applicable standards, are mercury and arsenic. Naturally elevated mercury levels are found

sporadically in surface and groundwater within and surrounding the proposed mine site. Likewise, elevated concentrations of natural arsenic compounds were detected in the vicinity of the proposed mine site, which is common for gold-bearing areas. Concentrations of arsenic and mercury in surface and groundwater samples collected from both within and outside of the proposed mine site exceeded the applicable standard. Arsenic and mercury are also both present in sediment samples, especially downgradient of mineralized areas. The more harmful form of mercury, methlymercury, is present in existing sediment as well.

*Transportation Facilities* – The primary body of water affected by transportation facilities would be the Kuskokwim River downstream from Crooked Creek. Water in the river is generally considered fit for all purposes and several villages between Crooked Creek and Bethel draw drinking water directly from the Kuskokwim. However, there are points along the Kuskokwim, usually at confluences with tributaries that drain mineralized areas, where concentrations of mercury and other minerals are elevated. Data describing baseline groundwater quality within the transportation corridor comes from drinking water wells in Aniak, where iron has sometimes exceeded drinking water standard. Sediment sampling along the Kuskokwim River between Crooked Creek and Bethel showed elevated metal levels, including arsenic and mercury, at all sampling sites.

*Pipeline* – Detailed USGS groundwater quality data are not available for the west side of Cook Inlet, and groundwater quality data are not publically available for wells associated with the Chugach Electric Power Plant at Beluga. Baseline groundwater quality in the vicinity of the eastern terminus of the proposed pipeline corridor has been characterized by analyzing samples from wells located at Ladd Landing, located approximately 5 miles south of Beluga.

**Expected Effects:**

<u>Alternative 2: Donlin Gold's Proposed Action</u> –

*Mine Site* – Impacts to water quality at the mine site could result from geochemical alteration of mined rock and its interaction with air and water, as well as mercury deposition from stacks and fugitive dust. Surface and groundwater quality within the mine site footprint in American and Anaconda creek watersheds would be permanently affected by the creation of the WRF, TSF, and pit lake; however, due to perpetual water management and treatment, untreated water from these facilities would not leave the onsite watersheds. Effects from mine site waters on the environment outside the immediate mine area would be mostly of low intensity, as all contact water would be treated to meet water quality standards prior to discharge to Crooked Creek. Temperature effects to Crooked Creek below the mine are expected to be minor due to the small volume of warmer treated water compared to Crooked Creek flow. Contaminated water from the pit would drain outward into bedrock for several years as the pit initially fills; this effect would be temporary and localized, as the overall groundwater gradient would be towards the pit, maintaining hydraulic containment of affected groundwater. There is a low risk that high intensity impacts to Anaconda and Crooked creeks could result in the event of SRS pump failure and overflow in post-closure. There is also a possibility of contaminated groundwater migration from

the South Overburden Stockpile towards Crooked Creek. Mitigation measures are described that would help reduce this potential impact.

Impacts to surface water quality resulting from atmospheric deposition of mercury would be both low and high intensity. High intensity impacts would be likely to occur at some locations within the Crooked Creek and Donlin Creek watersheds, where the inputs of mercury deposition to water are expected to be the greatest. Water quality is likely to be within regulatory limits on average, but could exceed baseline conditions and EPA chronic criteria in some areas. Impacts to sediment quality in Crooked Creek, and increases in mercury and methylmercury concentrations in sediments, would be of low intensity, within the range of natural variation, and would be expected to decline in post-closure. Impacts to sediment quality from surface disturbances would be localized by containment from BMPs. Overall, the effects of the proposed action on water quality associated with the proposed mine site are considered minor to moderate.

*Transportation Facilities and Pipeline* – The transportation facilities and natural gas pipeline as proposed in Alternative 2 are expected to have minor effects on water quality. Surface water quality could be temporarily and locally affected during construction, but will be mitigated by BMPs. Construction of the pipeline would create localized surface water and sediment effects at stream crossings, mitigated by BMPs and horizontal directional drilling crossings of selected waterways, and winter trenching at other crossings. During operations, barging in shallow sections may have local effects on sediment and turbidity that would be temporary. Within these two components, negligible and no measurable groundwater effects are expected. Pipeline effects on sediment would arise primarily during construction, with construction timing and BMPs employed to keep effects to a minimum.

Other Alternatives: The effects of other alternatives on water quality would be similar to those of Alternative 2. Differences of note include:

- *Alternative 3A (LNG-Powered Haul Trucks)* would reduce fuel barging requirements, decreasing total barging on the Kuskokwim by 32 percent. Surface water effects such as increases in turbidity, arising from barging, could be reduced under Alternative 3A relative to Alternative 2.
- *Alternative 3B (Diesel Pipeline)* would eliminate fuel barging after the construction phase, reducing groundwater fuel spill risk along the Kuskokwim River. However, this alternative would expose groundwater and surface water along the proposed pipeline corridor to the risk of spills and leaks from the diesel pipeline.
- *Alternative 4 (Birch Tree Crossing Port)* would reduce the distance traveled by barge by 69 river miles, and requires a longer access road. Surface water quality impacts would be slightly increased due to stream crossings and runoff along the longer access road, while sediment impacts and spill risk exposure would be slightly decreased in the Kuskokwim River.
- *Alternative 5A (Dry Stack Tailings)* would exchange a dry stack and operating pond design for the wet tailings design of the Tailings Storage Facility under Alternative 2. The dry stack

would be unlined under Alternative 5A-Option 1, and would include a liner with pumped overdrain beneath the tailings under Option 2. Where the TSF under Alternative 2 would be lined beneath the facility, dry stack tailings would be covered with a geomembrane liner at closure, but would be expected to leach contact water into underdrains (whether or not a bottom liner is used) in quantities that eventually would be of similar magnitude as Alternative 2. This water would in turn be captured by a seepage recovery system (SRS) and pumped to the pit lake, where water would be treated before release. The main difference between the mine site alternatives and options with respect to surface water quality is the time it takes for the SRS water to clean up to the point that it can be decommissioned; that is, roughly 200 years under Option 1, and about 10 to 50 years under Option 2 and Alternative 2. Option 2 would provide the additional advantage of minimizing (but not preventing) the potential for water quality impacts to groundwater. Under either option, effects on downgradient water quality in Crooked Creek would be the same as Alternative 2, provided that the SRS water is contained and conveyed to the open pit. The pit lake would fill in 41 to 46 years following closure (depending on whether the dry stack is lined) instead of 52, and more water would need to be treated on an ongoing basis prior to release. The SRS would need to be monitored and maintained until it was demonstrated to be suitable for release to the environment, and a complete failure of the system could lead to release of untreated water in a matter of weeks. Fugitive dust from the dry stacks could enter surface water within and beyond the footprint of the proposed mine during operations. Overall magnitude of effects is considered minor to moderate.

- *Alternative 6A (Dalzell Gorge Route)* would change the alignment of the natural gas pipeline. The primary mechanisms of impact to groundwater quality and sediment quality resulting from construction of the natural gas pipeline would involve soil erosion associated with installation of the pipeline at river and stream crossings, and clearing of riparian habitat along the pipeline ROW. Specific locations of impacts would differ from Alternative 2 along the Dalzell Gorge segment; however, construction practices and stream crossing techniques would be the same.

## 3.7.1 APPLICABLE REGULATIONS

### 3.7.1.1 REGULATORY FRAMEWORK

The principal law governing surface water quality in the United States is the Federal Water Pollution Control Act, or Clean Water Act (CWA). The CWA establishes regulatory requirements that apply to industrial and municipal discharges, and includes a range of requirements for maintaining water quality. It provides EPA, the Corps, and the States with a variety of programs and tools to protect and restore the Nation's waters. These programs and tools generally rely either on water quality-based controls, such as water quality standards and

water quality-based permit limitations, or technology-based controls such as effluent guidelines and technology-based permit limitations. Newly constructed facilities (new sources) that discharge to surface waters either directly or indirectly are governed by New Source Performance Standards and pretreatment standards for new sources. In developing New Source Performance Standards, the CWA requires that EPA determine the "best available demonstrated control technology" for the particular industrial category. The provisions described at 40 CFR Part 440, Ore Mining and Dressing Point Source Category, Subpart J, Copper, Lead, Zinc, Gold, Silver, and Molybdenum Ores Subcategory, would apply to discharge of mine drainage and net precipitation associated with the Donlin Gold Project, as long as certain requirements are met.

The CWA establishes a framework for federal-state partnerships in which the federal government sets the agenda and standards for pollution abatement, while states are generally responsible for implementation and enforcement (Copeland 2010). In particular, the CWA requires that a state must have the necessary legal authority to administer the National Pollutant Discharge Elimination System (NPDES) Program before EPA will approve a state's NPDES Program application. On May 1, 2008, the State of Alaska submitted a final application to the EPA for authority to administer the NPDES Program for wastewater discharges in Alaska, and on October 31, 2008, EPA approved the application. The ADEC authority over mining APDES permits began on October 31, 2010. ADEC assumed full authority to administer the wastewater and discharge permitting and compliance program for Alaska on October 31, 2012. The resulting program is called the Alaska Pollutant Discharge Elimination System (APDES) Program, which regulates point source discharges under Section 402 of the CWA.

The CWA contains requirements that water quality standards (WQS) must be established, and that water quality must be monitored to determine compliance relative to the established standards. ADEC is responsible for setting and regulating WQS for the State of Alaska. The EPA ensures that all WQS set by states are at least as stringent as the federal standards. Standards modified by the state are not effective for CWA purposes unless they are approved by EPA, and there is often a lag time between when a standard is proposed by a state and when it can be used for CWA purposes. If there is a discrepancy, only EPA-approved standards apply for CWA purposes.

ADEC Division of Water, Wastewater Discharge Authorization Program (WDAP) is currently working on issuing General Permit AKG320000 – Statewide Pipelines (Statewide Pipeline GP), which will authorize discharges associated with the gas pipeline construction, operations, and maintenance. The following discharges are proposed to be included in the Statewide Pipeline GP: Domestic Wastewater, Gravel Pit Dewatering, Excavation Dewatering, Hydrostatic Test Water, Fire Test Water, Secondary Containment, Mobile Spill Response, Horizontal Directional Drilling, and Storm Water.

The Statewide Pipeline GP will preclude the need for multiple Alaska Pollution Discharge Elimination System permits which may include: AK002000 – Excavation Dewatering, AK003000 – Hydrostatic and Aquifer Pump Testing, AKR06000 – Multisector General Permit, AKR100000 – Construction General Permit, and AKG572000 – Secondary Treatment to Surface Water.

The Corps also has a role. Under Sections 301 and 502 of the CWA, any discharge of dredged or fill materials into waters of the U.S., including wetlands, is forbidden unless authorized by a permit issued by the Corps pursuant to Section 404. Essentially, all discharges of fill or dredged material affecting the bottom elevation of a jurisdictional water of the U.S. require a permit from Corps. These permits play an essential role in protecting streams and wetlands.

### 3.7.1.2 WATER QUALITY CRITERIA

#### 3.7.1.2.1 SURFACE WATER

On February 27, 2004, EPA partially approved revisions to Alaska Water Quality Standards (WQS), while taking no action on Alaska's proposed acute and chronic freshwater aquatic life criteria for mercury and selenium. Therefore, the new aquatic life criteria for mercury and selenium will not be in effect for CWA purposes until a decision is made by EPA about whether these criteria can be approved. In the interim, the previously approved aquatic life criteria for mercury (2.4 µg/l acute and 0.012 µg/l chronic, both as total recoverable) and selenium (20 µg/l acute and 5 µg/l chronic, both as total recoverable) will remain the applicable CWA standards (65 FR 24643).

In instances where the State of Alaska WQS have been approved by EPA, water quality in this section is described in relation to Alaska WQS, which include use classifications, numeric and narrative water quality criteria, and an anti-degradation policy. The usage classification system designates the beneficial uses that each water body within the State of Alaska is expected to support. In the State of Alaska, all water bodies are designated for all protected water use classes unless otherwise stated (18 AAC 70.050). The water quality data presented in this section are compared to the most stringent applicable State of Alaska water quality standards (for all designated water uses).

For most parameters, the most stringent criteria are the aquatic life criteria for fresh water. However, the most stringent criteria for antimony, arsenic, nitrate, and sulfate are for drinking water (ADEC 2008a; ADEC 2012d). The most stringent criterion for manganese is based on human health for consumption of drinking water and aquatic organisms (ADEC 2008a). The most stringent criteria for boron and cobalt are based on irrigation use (ADEC 2008a).

Criteria for some dissolved metals, including cadmium, chromium, copper, lead, nickel, silver, and zinc, are hardness-dependent, meaning that the acceptable concentrations of these metals depend on the hardness of the water. Hardness is a measure of the concentration of polyvalent cations, such as calcium ($Ca^{2+}$) and magnesium ($Mg^{2+}$), in the water. The polyvalent cations that contribute to water hardness reduce the bioavailability of certain trace metals by competing with the trace metal ions for binding sites within organisms. The extent of this effect varies according to which dissolved metals are present and their oxidation states. To account for the influence of water hardness on the bioavailability and potential toxicity of certain dissolved metals, the numeric water quality criteria for those metals are calculated so that the allowable concentrations of the metals increase in proportion to the hardness of the water (ADEC 2008a). The hardness-dependent water quality criteria applied in this section were calculated according to ADEC (2008a) protocols using the 15th percentile hardness measurement for the population of samples from each category of surface water sites sampled as part of the Donlin Gold Water Quality Characterization Program. The hardness-dependent numeric water quality criteria used as a basis for comparison to predicted concentrations of constituents in mine water treatment facilities, such as the TSF and pit lake, were calculated based on predicted hardness values for each mine water treatment facility. Thus the numeric water quality criteria for hardness-dependent parameters vary depending upon the measured (or predicted) hardness value for the matrix water. The ADEC numeric water quality standard for ammonia depends upon both the temperature and the pH of the matrix water, but not the hardness. Because the measured or predicted temperature and pH of the water may vary over a wide range of values depending on

time of year, sample location, and other factors, the most conservative possible numeric standard for ammonia in freshwater (0.179 mg/L; ADEC 2008a) is used as a basis for comparison for all of the waters considered in this section.

#### 3.7.1.2.2 GROUNDWATER

Groundwater is protected for a variety of uses, including drinking, culinary, and food processing; agriculture, including irrigation and stock watering; aquaculture; and industrial uses. ADEC regulates contaminated sites, underground storage tanks, and establishes water quality standards to serve to protect groundwater. But the department does not regulate groundwater directly. As specified at 18 AAC 70.050(a)(2): groundwater is protected for all uses in Class (1)(A), which include drinking, culinary, and food processing; agriculture, including irrigation and stock watering; aquaculture; and industrial uses.

Drinking water from groundwater sources is regulated by 18 AAC 80 (ADEC 2012c) and by EPA (2013k). EPA sets standards for approximately 90 contaminants in drinking water. These standards include National Primary Drinking Water Regulations, which are legally enforceable standards that apply to public water systems. Primary standards protect public health by limiting the levels of contaminants in drinking water. Secondary Drinking Water Standards are unenforceable federal guidelines regarding taste, odor, color and certain other effects of drinking water. It should be noted that the EPA Maximum Contaminant Level (MCLs) for Aluminum, Chloride, Copper, Fluoride, Iron, Manganese, pH, Silver, Sulfate, TDS, and Zinc are Secondary Drinking Water Regulations that set non-mandatory water quality standards. EPA does not enforce these "secondary maximum contaminant levels." EPA recommends them to the States as reasonable goals, but federal law does not require compliance with them. ADEC has established water quality standards to serve to protect groundwater, but the department does not regulate groundwater directly.

#### 3.7.1.2.3 SEDIMENT

There are no regulations established for chemical concentrations in sediment. Sediment Quality Guidelines (SQGs) recommended by ADEC (2013d), as well as other sediment quality criteria used for comparison purposes in project studies are discussed further below.

#### 3.7.1.2.4 IMPAIRED WATER BODIES

There are no water bodies listed as impaired under Section 303(d) of the CWA within the proposed mine area, river corridor, or proposed pipeline route. The Kuskokwim River is listed as a Category 5 water body about 30 miles upriver of Crooked Creek at the mouth of Red Devil Creek because abandoned mining facilities contribute antimony, arsenic, and mercury to the water. The designation extends from 100 feet upriver of the confluence of Red Devil Creek and the Kuskokwim River to 900 feet downriver from the confluence. Category 5 refers to pollutant-caused impairments requiring a Total Maximum Daily Load (TMDL) technical analysis that calculates the reduction in pollutants necessary for the impaired water body to again meet WQS.

Dutch Harbor, which is part of the transportation corridor for this project, is listed as a Category 4 impaired water body for petroleum hydrocarbon pollution resulting from industrial uses and urban runoff. Category 4 refers to impaired water bodies that have moved beyond the planning

phase of TMDL analysis towards the implementation phase of reducing point and non-point source pollutants.

Known contaminated sites within or near the proposed project footprint that could have a bearing on surface or groundwater quality are discussed in Section 3.2, Soils.

## 3.7.2 AFFECTED ENVIRONMENT

### 3.7.2.1 SURFACE WATER QUALITY

#### 3.7.2.1.1 MINE SITE

Background and Setting

The proposed mine site is located entirely within the Crooked Creek watershed. All proposed mine-related facilities are located in areas that drain to tributaries of Crooked Creek, including American, Anaconda, Lewis, and Queen creeks, and Omega and Snow gulches, all of which flow west into Crooked Creek (Figure 3.7-1) (BGC Engineering, Inc. [BGC] 2005). Several unnamed first-order gullies that drain directly into Crooked Creek are also located within the mine site area. Crooked Creek is the main drainage out of the area, and flows southward for approximately 12 miles before joining the west-flowing Kuskokwim River at the village of Crooked Creek. Collectively, these relatively short, low-flow streams with small catchment areas comprise the existing surface water resources within the proposed mine site.

Donlin Creek, located north of the proposed project area, and Crevice Creek, located immediately to the south of Anaconda Creek, are both tributaries of Crooked Creek. Although they are not located within the proposed mine site, water quality data collected from Donlin and Crevice Creeks provide background information about surface water quality in the areas immediately adjacent to the proposed project area. Additional water quality data have been collected on lower Crooked Creek several miles downstream of the proposed mine, and on two tributaries, Getmuna and Bell creeks, that join lower Crooked Creek in this area.

Baseline surface water conditions at the proposed mine site, which are presently influenced by both natural and anthropogenic factors, are described in the following subsections. The predominant factor influencing existing surface water quality conditions in and around the proposed mine site is the natural weathering of rocks associated with the mineralized area of interest. Spatial trends in existing surface water quality often correspond to the distribution of highly mineralized zones (Mueller et al. 2003; ARCADIS 2012b).

Surface waters within the Crooked Creek watershed are generally undisturbed and free from anthropogenic influences, with the exception of historic and current placer mining operations. Both upper Crooked Creek and Donlin Creek have been subject to placer mining activities in the past. Currently, an active placer operation mines gold from gravels in the upper reaches of Crooked Creek and its tributaries, including Donlin Creek, Snow Gulch, Queen Creek, and Lewis Creek. The placer mining area lies immediately to the north and upstream of the proposed facilities (SRK 2012b). The lower end of Snow Gulch has been extensively mined and sections of the stream have been rerouted, but the upper portions of Snow Gulch remain essentially undisturbed. The lower end of Queen Gulch has been mined and Queen Creek has been diverted into a ditch that discharges to Crooked Creek near American Creek. The principal

water quality impacts resulting from placer mining operations are generally associated with increased turbidity and stream sedimentation (Weber 1986). The duration of such impacts is usually limited to the time period of active placer mining, and the magnitude of the impacts generally decreases with distance downstream from mining input (Weber 1986). However, in some sulfide-rich areas, placer mining activities may result in acid drainage and increases in trace element concentrations in surface water (Madison 1981).

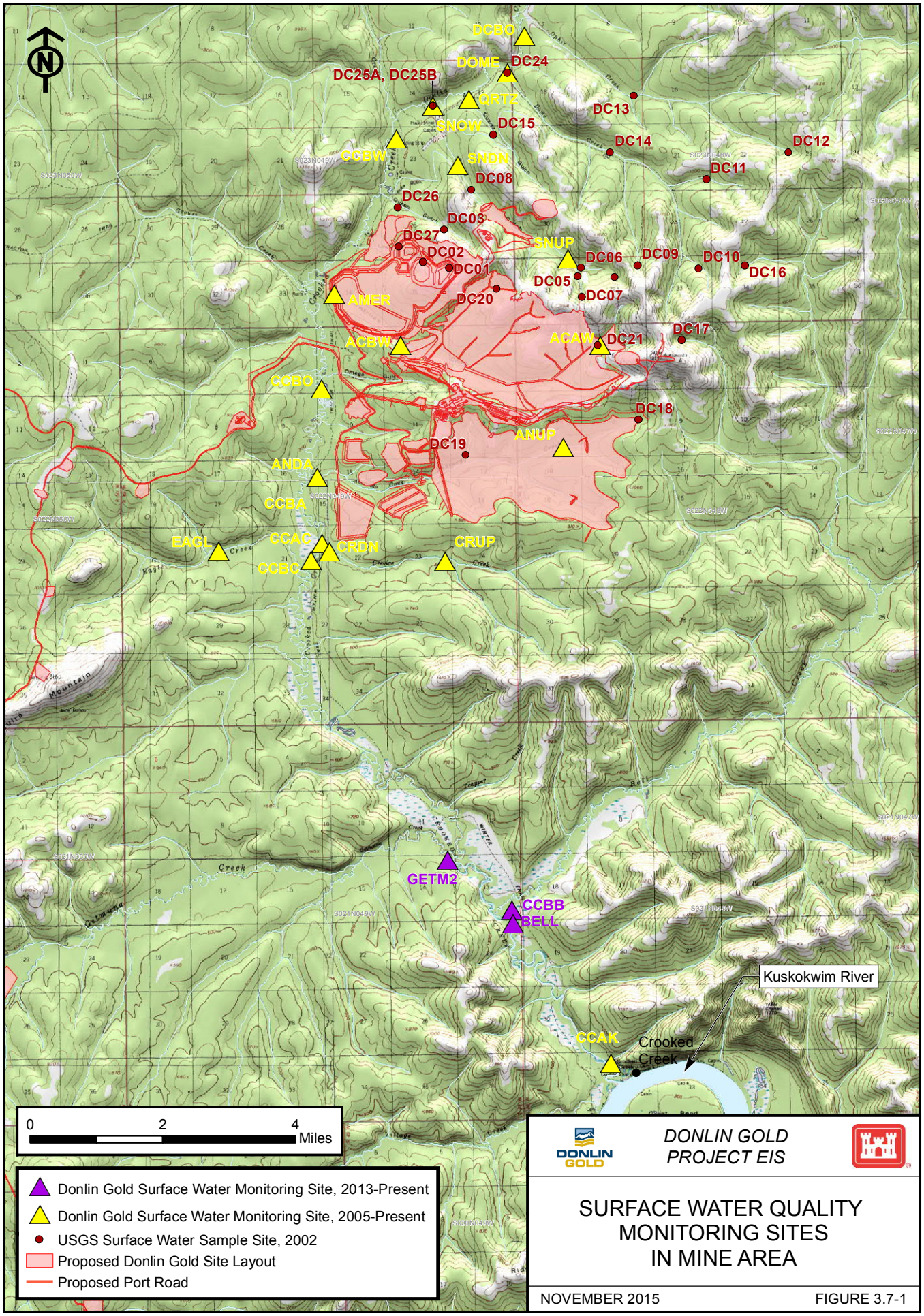
## Donlin Gold Water Quality Characterization

### *Sampling and Analytical Program*

Acquisition of baseline and background water quality data in the Crooked Creek watershed was initiated in 1996 in order to establish a reliable record of physical parameters and chemical constituents in surface water. Since that time, water quality parameters have been measured on an approximately quarterly basis at established stations in the Crooked Creek watershed, with the exception of 2001, when monitoring was curtailed for one year. Collectively, these data comprise the most extensive dataset describing baseline surface water quality within the proposed project area. The initial water quality data collection program included 14 water quality monitoring stations that were selected to characterize the upper portions of the mine site. As the water quality characterization program progressed, modifications were made to include additional analytes and monitoring stations (ARCADIS 2012b).

Although the Donlin Gold water quality characterization program data collected prior to 2005 provide some site-specific information, they were not collected according to the consistent procedures and data handling protocols specified in the quality management plan, which was implemented in 2005 and updated in 2012 (Barrick 2009; ARCADIS 2012b). As a result, the pre-2005 data include many outliers and systematic errors in recording (ARCADIS 2012b). Beginning in the first quarter of 2005, water quality sample collection and analysis has been conducted in accordance with a QAPP that incorporates Water Quality Monitoring, Sampling and Analysis Activity procedures. Groundwater sampling under the new QAPP began in the first quarter of 2005. Surface water sampling was not conducted during the first quarter of 2005, followed by a limited program in the second quarter, with the full surface water program beginning in the third quarter. For these reasons, the data collected after 2005 are the most appropriate for defining the background quality of surface waters at the proposed mine site and adjacent areas. In this section, surface water quality data are summarized for the period from the third quarter of 2005 through the second quarter of 2015.

Since 2005, the Donlin Gold water quality characterization program has involved collection and analysis of samples from most of the sites described in Table 3.7-1 and shown on Figure 3.7-1 in yellow. Three additional monitoring sites (CCBB, BELL, and GETM2) were added to the water quality characterization program in June 2013 (shown on Figure 3.7-1 in purple), in order to establish parameters for baseline water quality in lower Crooked Creek below all proposed facilities, and to characterize baseline inputs of constituents to Crooked Creek from Getmuna and Bell creeks. Both Getmuna and Bell creek stations are located outside of the anticipated area of influence of the proposed mine site, but Getmuna is located downstream of a proposed material borrow site along the potential route of the mine access road.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CCBC
CRUP
GETM2
CCBB
BELL
Kuskokwim River
CCAK
Crooked Creek
0
2
4
Miles
Donlin Gold Surface Water Monitoring Site, 2013-Present
Donlin Gold Surface Water Monitoring Site, 2005-Present
USGS Surface Water Sample Site, 2002
Proposed Donlin Gold Site Layout
Proposed Port Road
DONLIN GOLD
DONLIN GOLD PROJECT EIS
SURFACE WATER QUALITY MONITORING SITES IN MINE AREA
NOVEMBER 2015
FIGURE 3.7-1

Sample collection methods and details of analyses are described in the Donlin Creek Project Water Quality Monitoring and Data Management Procedures Manual (Barrick 2009). Because the primary factors that affect existing water quality around the proposed mine site are related to interactions of water with the mineralized area of interest, and to a lesser extent, the influences of current and historic placer mining activities, the surface water quality sampling sites were divided into three categories based on the location of each site relative to the mineralized area, and the potential for placer mining operations to affect water quality at each site. The three categories are described as follows:

Category 1: waters draining undisturbed areas and areas outside of the mineralized area of interest (background sites).

Category 2: waters draining areas of defined mineralized zones with no placer mining activities (background sites).

Category 3: waters draining areas of both placer mining and the mineralized zone of the proposed Donlin Gold Project (baseline sites).

**Table 3.7-1: Description of Surface Water Sampling Locations in Mine Area, Donlin Gold Baseline Water Quality Monitoring Program**

| Station Description | ID | Rationale and Purpose | Cat. | # of Sample Events | Easting[1] (meters) | Northing[1] (meters) |
|---|---|---|---|---|---|---|
| Donlin Creek below Ophir Creek | DCBO | Upstream of all proposed activity and above any disturbance from historic placer mining. Project Control. | 1 | 35 | 543948 | 6885105 |
| Snow Gulch Upstream of activity and mineralization trend | SNUP | Snow Gulch crosses both the mineralized trend and historic placer mining. This site is above both the mineralization trend and placer mining. | 1 | 18 | 545024 | 6879725 |
| Snow Gulch downstream of mineralization trend | SNDN | Snow Gulch below the mineralized trend and above historic placer tails. | 2 | 28 | 542329 | 6881964 |
| Snow Gulch above confluence with Crooked Creek | SNOW | Snow Gulch below mineralization and historic placer tails and above confluence with Crooked Creek. | 3 | 34 | 541729 | 6883397 |
| American Creek above waste rock | ACAW | American Creek upstream of proposed waste rock placement near upstream diversion of water. Also upstream of mineralization in American Creek. Placed to determine quality of diversion water that would be directed to Crooked Creek as non-mine water. | 1 | 24 | 545787 | 6877604 |
| American Creek below proposed waste rock storage | ACBW | American Creek Below waste rock and downstream of seepage collection pond. Designed as long-term monitoring station through reclamation and closure. | 2 | 30 | 540937 | 6877606 |

**Table 3.7-1: Description of Surface Water Sampling Locations in Mine Area, Donlin Gold Baseline Water Quality Monitoring Program**

| Station Description | ID | Rationale and Purpose | Cat. | # of Sample Events | Easting[1] (meters) | Northing[1] (meters) |
|---|---|---|---|---|---|---|
| American Creek above confluence with Crooked Creek | AMER | American Creek below all planned facilities and disturbance and above confluence with Crooked Creek. | 2 | 42 | 539333 | 6878839 |
| Crooked Creek Below Ophir | CCBO | Downstream of Ophir Creek, which drains from the camp area and airstrip | 3 | 34 | 539021 | 6876552 |
| Anaconda Creek up stream | ANUP | Anaconda Creek above any potential influence from diversions or other physical disturbance. | 1 | 21 | 544880 | 6875121 |
| Anaconda Creek above confluence with Crooked Creek | ANDA | Below all proposed facilities in Anaconda Creek and above Crooked Creek. | 1 | 34 | 539055 | 6874441 |
| Crooked Creek above Crevice Creek. | CCAC | Below all proposed facilities and potential impacts to Crooked Creek. This site replaces CCBA. | 3 | 33 | 538972 | 6872889 |
| Crooked Creek below Confluence with Crevice Creek | CCBC | Below all proposed facilities and potential impacts to Crevice Creek. | 3 | 30 | 538772 | 6872368 |
| Crooked Creek directly below Lyman Wash Plant | CCBW | Crooked Creek below influence of placer mining operation. | 3 | 33 | 540832 | 6882598 |
| Upper Crevice Creek | CRUP | Crevice Creek above any potential influence from Anaconda facilities. | 1 | 24 | 542022 | 6872357 |
| Lower Crevice Creek above confluence with Crooked Creek | CRDN | Crevice Creek below any potential influence from Anaconda facilities. | 3 | 30 | 539215 | 6872587 |
| Dome Creek upstream of Donlin Creek | DOME | Dome Creek downstream of potential exploration activities. | 1 | 10 | 543532 | 6884207 |
| Quartz Gulch upstream of Donlin Creek | QRTZ | Quartz Gulch downstream of potential exploration activities. | 1 | 6 | 542595 | 6883575 |
| Eagle Creek above confluence with Crooked Creek | EAGL | Eagle Creek downstream of potential domestic wastewater outfall facilities. | 3 | 9 | 563529 | 6872600 |
| Getmuna Creek above confluence with Crooked Creek | GETM2 | Getmuna Creek below any potential influence from Jungjuk Road material site, and upstream of any mine site influence on Crooked Creek. | 3 | 1 | 542076 | 6865101 |
| Bell Creek above confluence with Crooked Creek | BELL | Bell Creek upstream of potential mine influence on Crooked Creek. | 1 | 1 | 543636 | 6863886 |

**Table 3.7-1: Description of Surface Water Sampling Locations in Mine Area, Donlin Gold Baseline Water Quality Monitoring Program**

| Station Description | ID | Rationale and Purpose | Cat. | # of Sample Events | Easting[1] (meters) | Northing[1] (meters) |
|---|---|---|---|---|---|---|
| Crooked Creek downstream of confluence with Bell Creek | CCBB | Crooked Creek about 6 miles downstream of all proposed mine facilities and potential impacts to Crooked Creek. | 3 | 2 | 543667 | 6863547 |
| Crooked Creek upstream of confluence with Kuskokwim River | CCAK | Crooked Creek about 8 miles downstream of all proposed mine facilities and potential impacts to Crooked Creek, and upstream of historical mine influences on Kuskokwim River. | 3 | 15 | 546040 | 6860167 |

**Notes:**

1 Universal Transverse Mercator (UTM), Zone 4, NAD83 Datum

Source: ARCADIS 2012b, Enos 2013b.

*Study Results – General Patterns*

Table 3.7-2 through Table 3.7-4 summarize the cumulative results of water quality characterization program for the Category 1, 2, and 3 surface waters. The data in these tables are organized according to the following groups of water quality parameters:

- Major cations (aluminum, barium, calcium, iron, magnesium, manganese, potassium, and sodium), in mg/L;
- Major anions (ammonia, bicarbonate, carbonate, chloride, fluoride, nitrite and nitrate, and sulfate), in mg/L;
- Nutrients (nitrate, nitrite, and ammonia), in mg/L;
- Trace elements (antimony, arsenic, beryllium, boron, cadmium, chromium, cobalt, copper, lead, lithium, mercury, molybdenum, nickel, selenium, silver, thallium, vanadium, zinc) and compounds (total and weak-acid dissociable [WAD] cyanide), in µg/L (except for mercury, which is in ng/L);
- General water quality parameters (hardness, total alkalinity, total dissolved solids (TDS), and total suspended solids), in mg/L; and
- Field parameters (conductivity, dissolved oxygen, pH, turbidity, and water temperature), in various units.

*Averages*

Due to limitations of chemical analysis procedures, small concentrations cannot be precisely measured. These concentrations are said to be below the limit of detection (LOD). In statistical analyses, these values are often censored and substituted with a constant value, such as half the LOD. The arithmetic average values reported in Table 3.7-2 through Table 3.7-4 represent the

averages of measured concentrations for a given analysis. Results that are below the reporting limit for the analysis are replaced with a value equivalent to one-half of the reporting limit for the analysis for the purpose of calculating the average values reported in the tables.

**Table 3.7-2: Surface Water Quality Summary for Category 1 Locations – Background Sites Outside of Mineralized Areas**

| Analyte | Units | Frequency of Detection | | Range of Detection Limits (Reporting) | Range of Detection Limits (Method) | Range of Detected Concentrations[4] | Arithmetic Mean Concentration[3] | Maximum Sample Location | Most Stringent Applicable Water Quality Criterion | # Detects > Criterion |
|---|---|---|---|---|---|---|---|---|---|---|
| **Major Cations** | | | | | | | | | | |
| Calcium, Dissolved | mg/L | 182/182 | 100.0% | 0.1-2.00 | 0.031-0.62 | 10.4-88.9 | 27.2 | DCBO | - | - |
| Magnesium, Dissolved | mg/L | 182/182 | 100.0% | 0.03-2.00 | 0.015-0.62 | 2.87-43.5 | 9.06 | DCBO | - | - |
| Potassium, Dissolved | mg/L | 182/182 | 100.0% | 0.3-2.00 | 0.15-0.3 | 0.301-2.94 | 0.5 | ANUP | - | - |
| Sodium, Dissolved | mg/L | 182/182 | 100.0% | 0.3-2.00 | 0.15-0.3 | 1.42-20.3 | 4.47 | DCBO | - | - |
| **Major Anions** | | | | | | | | | | |
| Total Alkalinity (as $CaCO_3$) | mg/L | 182/182 | 100.0% | 0.02-40.0 | 2.00-12.4 | 35.0-410 | 96.7 | DCBO | 20 (min) [2b] | 0 |
| Bicarbonate | mg/L | 182/182 | 100.0% | 0.02-40.0 | 2.00-12.4 | 35.0-410 | 96.7 | DCBO | - | - |
| Fluoride | mg/L | 167/173 | 96.5% | 0.062-0.1 | 0.031-0.1 | 0.031-0.153 | 0.071 | DOME | 1[2e] | 0 |
| Sulfate | mg/L | 182/182 | 100.0% | 0.062-2.5 | 0.031-0.5 | 0.883-53.2 | 13.5 | SNUP | 250[1] | 0 |
| Chloride | mg/L | 182/182 | 100.0% | 0.062-0.5 | 0.031-0.5 | 0.163-7.63 | 0.67 | ACAW | 230[2b] | 0 |
| **Nutrients** | | | | | | | | | | |
| Nitrite + Nitrate(as N) | mg/L | 182/182 | 100.0% | 0.02-0.1 | 0.0062-0.031 | 0.0415-3.73 | 0.5 | ACAW | 10[2d] | 0 |
| Ammonia (as N) | mg/L | 59/181 | 32.6% | 0.062-0.1 | 0.031-0.031 | 0.031-0.388 | 0.059 | DCBO | 0.18[2h] | 3 |
| **Cyanide** | | | | | | | | | | |
| Total Cyanide | µg/L | 33/182 | 18.1% | 3.00-5.00 | 1.5-3.00 | 1.5-17.0 | 2.51 | ACAW | - | - |
| Wad Cyanide | µg/L | 41/182 | 22.5% | 3.00-5.00 | 1.5-3.00 | 1.5-17.0 | 2.52 | ACAW | 5.2[2g] | 2 |
| **Metals** | | | | | | | | | | |
| Mercury, Dissolved | ng/L | 14/14 | 100.0% | 1.00-1.00 | 0.5-0.5 | 0.551-3.64 | 1.6 | BELL | - | - |
| Mercury | ng/L | 179/187 | 95.7% | 1.00-10.0 | 0.5-5.00 | 0.625-170 | 7.57 | CRUP | 12[2b] | 22 |
| Aluminum, Dissolved | µg/L | 106/159 | 66.7% | 1.00-20.0 | 1.00-6.2 | 6.00-98.9 | 21.2 | ANDA | - | - |
| Aluminum, Total | µg/L | 179/182 | 98.4% | 1.00-500 | 1.00-155 | 7.05-25400 | 737 | DCBO | 87[2a] | 37 |
| Antimony, Dissolved | µg/L | 14/159 | 8.8% | 0.4-1.00 | 0.31-0.4 | 0.316-4.93 | 0.53 | SNUP | - | - |
| Antimony, Total | µg/L | 14/182 | 7.7% | 0.4-5.00 | 0.31-1.55 | 0.322-4.47 | 0.53 | SNUP | 6[2d] | 0 |
| Arsenic, Dissolved | µg/L | 9/159 | 5.7% | 0.5-5.00 | 0.5-2.5 | 1.65-12.8 | 2.68 | QRTZ | - | - |
| Arsenic, Total | µg/L | 29/182 | 15.9% | 0.5-25.0 | 0.5-12.5 | 0.9-194 | 3.87 | QRTZ | 10[2d] | 5 |
| Barium, Dissolved | µg/L | 159/159 | 100.0% | 0.5-3.00 | 0.5-0.94 | 19.2-226 | 76.4 | ANDA | - | - |
| Barium, Total | µg/L | 182/182 | 100.0% | 0.5-9.4 | 0.5-4.7 | 28.8-950 | 94.5 | DCBO | 2,000[2d] | 0 |
| Beryllium, Dissolved | µg/L | 0/159 | 0.0% | 0.1-0.4 | 0.1-0.13 | - | 0.2 | - | - | - |
| Beryllium, Total | µg/L | 15/182 | 8.2% | 0.1-2.00 | 0.1-0.65 | 0.13-1.62 | 0.22 | DCBO | 4[2d] | 0 |
| Boron, Dissolved | µg/L | 25/159 | 15.7% | 10.0-50.0 | 3.1-15.0 | 3.58-31.9 | 20.8 | DCBO | - | - |
| Boron, Total | µg/L | 48/182 | 26.4% | 10.0-250 | 3.1-75.0 | 3.55-72.8 | 20.2 | DCBO | 750[2e] | 0 |
| Cadmium, Dissolved | µg/L | 1/159 | 0.6% | 0.1-0.5 | 0.1-0.15 | 0.267-0.267 | 0.25 | DCBO | - | - |

**Table 3.7-2: Surface Water Quality Summary for Category 1 Locations – Background Sites Outside of Mineralized Areas**

| Analyte | Units | Frequency of Detection | | Range of Detection Limits (Reporting) | Range of Detection Limits (Method) | Range of Detected Concentrations[4] | Arithmetic Mean Concentration[3] | Maximum Sample Location | Most Stringent Applicable Water Quality Criterion | # Detects > Criterion |
|---|---|---|---|---|---|---|---|---|---|---|
| Cadmium, Total | µg/L | 11/182 | 6.0% | 0.1-1.5 | 0.1-0.75 | 0.15-3.00 | 0.28 | SNUP | 0.18[2ab] | 9 |
| Chromium, Dissolved | µg/L | 28/159 | 17.6% | 0.5-2.00 | 0.31-0.62 | 0.631-2.87 | 0.98 | ACAW | - | - |
| Chromium, Total | µg/L | 72/182 | 39.6% | 0.5-6.2 | 0.31-3.1 | 0.34-36.3 | 1.62 | DCBO | 100[2d] | 0 |
| Cobalt, Dissolved | µg/L | 19/159 | 11.9% | 0.05-4.00 | 0.05-1.2 | 0.16-11.7 | 2.29 | CRUP | - | - |
| Cobalt, Total | µg/L | 22/181 | 12.2% | 0.05-12.0 | 0.05-6.00 | 0.1-23.7 | 2.25 | DCBO | 50[2e] | 0 |
| Copper, Dissolved | µg/L | 134/159 | 84.3% | 0.5-1.00 | 0.31-0.5 | 0.311-3.75 | 0.69 | ANDA | - | - |
| Copper, Total | µg/L | 163/182 | 89.6% | 0.5-3.1 | 0.31-1.55 | 0.313-46.5 | 1.82 | QRTZ | 5.82[2ab] | 9 |
| Iron, Dissolved | µg/L | 112/159 | 70.4% | 20.0-250 | 6.2-78.0 | 10.0-924 | 190 | ANDA | - | - |
| Iron, Total | µg/L | 161/182 | 88.5% | 20.0-780 | 6.2-390 | 8.62-38,100 | 1246 | DCBO | 1,000[2b] | 34 |
| Lead, Dissolved | µg/L | 32/159 | 20.1% | 0.124-0.5 | 0.062-0.1 | 0.0639-0.329 | 0.11 | ACAW | - | - |
| Lead, Total | µg/L | 110/182 | 60.4% | 0.124-200 | 0.062-0.31 | 0.0667-19.7 | 0.56 | DCBO | 1.58[2ab] | 13 |
| Lithium, Dissolved | µg/L | 12/159 | 7.5% | 6.2-100 | 3.1-20.0 | 3.17-9.29 | 5.2 | DCBO | - | - |
| Lithium, Total | µg/L | 33/173 | 19.1% | 6.2-100 | 3.1-20.0 | 3.14-35.4 | 5.64 | DCBO | 2,500[2e] | 0 |
| Manganese, Dissolved | µg/L | 153/159 | 96.2% | 0.5-1.00 | 0.31-0.5 | 0.328-649 | 46.9 | ANUP | - | - |
| Manganese, Total | µg/L | 181/182 | 99.5% | 0.5-3.1 | 0.31-1.55 | 0.526-2,350 | 81.6 | DCBO | 50[2f] | 91 |
| Molybdenum, Dissolved | µg/L | 4/159 | 2.5% | 0.5-10.0 | 0.5-3.1 | 0.707-1.21 | 4.55 | DCBO | - | - |
| Molybdenum, Total | µg/L | 11/182 | 6.0% | 0.5-50.0 | 0.5-15.5 | 0.8-8.71 | 4.76 | DCBO | 10[2e] | 0 |
| Nickel, Dissolved | µg/L | 131/159 | 82.4% | 1.24-20.0 | 0.6-0.62 | 0.627-2.93 | 1.11 | CRUP | - | - |
| Nickel, Total | µg/L | 171/182 | 94.0% | 1.24-20.0 | 0.6-3.1 | 0.647-44.4 | 2.03 | DCBO | 32.7[2ab] | 1 |
| Selenium, Dissolved | µg/L | 7/159 | 4.4% | 0.3-5.00 | 0.1-1.5 | 0.1-3.46 | 2.47 | ACAW | - | - |
| Selenium, Total | µg/L | 12/182 | 6.6% | 0.3-25.0 | 0.1-7.5 | 0.1-3.98 | 2.55 | ACAW | 5[2b] | 0 |
| Silver, Dissolved | µg/L | 0/159 | 0.0% | 0.3-1.00 | 0.05-0.31 | - | 0.5 | - | - | - |
| Silver, Total | µg/L | 6/182 | 3.3% | 0.3-5.00 | 0.05-1.55 | 0.62-0.62 | 0.51 | ANDA | 1.46[2ac] | 0 |
| Thallium, Dissolved | µg/L | 0/159 | 0.0% | 0.5-1.00 | 0.1-0.31 | - | 0.5 | - | - | - |
| Thallium, Total | µg/L | 10/182 | 5.5% | 0.5-1000 | 0.1-1.55 | 0.338-0.696 | 0.51 | ANDA | 1.7[2f] | 0 |
| Vanadium, Dissolved | µg/L | 1/159 | 0.6% | 1.00-20.0 | 0.2-6.2 | 6.55-6.55 | 9.92 | ANDA | - | - |
| Vanadium, Total | µg/L | 20/182 | 11.0% | 1.00-100 | 0.2-31.0 | 6.45-65.3 | 10.7 | DCBO | 100[2e] | 0 |
| Zinc, Dissolved | µg/L | 63/159 | 39.6% | 5.00-5.00 | 2.00-2.5 | 2.61-15.6 | 3.68 | DCBO | - | - |
| Zinc, Total | µg/L | 103/182 | 56.6% | 5.00-25.0 | 1.5-12.5 | 1.65-159 | 7.05 | QRTZ | 75.1[2ab] | 2 |
| **General Water Quality Parameters** | | | | | | | | | | |
| Hardness (CaCO3) | mg/L | 180/180 | 100.0% | 1.00-5.00 | 1.00-5.00 | 19.8-401.12 | 102 | DCBO | - | - |
| Total Dissolved Solids | mg/L | 182/182 | 100.0% | 6.2-10.0 | 3.1-10.0 | 52.0-478 | 127 | DCBO | 500[1] | 0 |
| Total Suspended Solids | mg/L | 179/181 | 98.9% | 0.294-20.0 | 0.141-6.00 | 0.204-780 | 38.5 | CRUP | - | - |

**Table 3.7-2: Surface Water Quality Summary for Category 1 Locations – Background Sites Outside of Mineralized Areas**

| Analyte | Units | Frequency of Detection | | Range of Detection Limits (Reporting) | Range of Detection Limits (Method) | Range of Detected Concentrations[4] | Arithmetic Mean Concentration[3] | Maximum Sample Location | Most Stringent Applicable Water Quality Criterion | # Detects > Criterion |
|---|---|---|---|---|---|---|---|---|---|---|
| **Field Parameters** | | | | | | | | | | |
| Conductivity (Lab) | µS/cm | 182/182 | 100.0% | 0.954-1.00 | 0.477-1.00 | 89.4-809 | 217 | DCBO | - | - |
| Conductivity, Field | µS/cm | 184/184 | 100.0% | - | - | 46.0-755 | 131 | ACAW | - | - |
| Dissolved Oxygen, Field | mg/L | 187/187 | 100.0% | - | - | 3.46-125 | 15.8 | ANUP | - | - |
| Ox./Reduc. Pot.(ORP/eH), field | mV | 187/187 | 100.0% | - | - | -247.2-1,121 | 96.8 | ANDA | - | - |
| pH (lab) | pH units | 182/182 | 100.0% | 0.1-0.2 | 0.1-0.1 | 6.8-8.1 | 7.45 | CRUP | 6.5-8.5[1] | - |
| pH, field | pH units | 187/187 | 100.0% | - | - | 4.42-12.9 | 6.3 | ANDA | - | - |
| Water Temperature, Field | degrees C | 187/187 | 100.0% | - | - | -0.53-10.5 | 2.29 | BELL | - | - |
| Turbidity, Field | NTU | 157/157 | 100.0% | - | - | 0.00-215 | 11.5 | ANDA | 5[1] | 62 |

**Notes:**

Most Stringent Applicable Water Quality Criteria are provided for the parameters for which water quality standards have been established. Standards have not been established for all parameters. Cases where there are no applicable standards are indicated by a dash (-).

1 18 AAC 70. ADEC, Alaska Water Quality Standards. Amended as of April 8, 2012.
2 Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances. Amended through December 12, 2008. Most stringent criteria used. WQS for metals are expressed as 'total recoverable' concentrations.
2a Aquatic life for fresh water hardness-dependent criteria. Acute and chronic aquatic life numeric criteria for some metals (Cd, Cu, Pb, Ni, Zn) are hardness dependent. Values contained in this table were calculated using a hardness value of 57.58 mg/L as CaCO 3 For Al, if pH≥7.0 and hardness ≥50, then 750 ug/L.
2b Aquatic life for fresh water (chronic) criteria.
2c Aquatic life for fresh water (acute) criteria.
2d Drinking water criteria.
2e Irrigation water criteria.
2f Human health criteria for non-carcinogens (for consumption of water + aquatic organisms).
2g Aquatic life criteria (chronic)for free cyanide, measured as weak acid dissociable (WAD) cyanide.
2h Aquatic life for fresh water (chronic) criteria based on pH and temperature when early life stages of fish are present; The ADEC numeric water quality standard for ammonia depends upon both the temperature and the pH of the matrix water, but not the hardness. Because the measured or predicted temperature and pH of the water may vary over a wide range of values depending on time of year, sample location, and other factors, the most conservative possible numeric standard for ammonia in freshwater (0.179 mg/L; ADEC 2008a) is used as a basis for comparison for all of the waters considered in this section
3 Calculated for all observations using detected values and ½ of the reporting limit value when analyte not detected.
4 Determined for the minimum and maximum of all detected reportable values; negative values are included when no detections are observed.

**Table 3.7-3: Surface Water Quality Summary for Category 2 Locations - Background Sites in Mineralized Areas**

| Analyte | Units | Frequency of Detection | | Range of Detection Limits (Reporting) | Range of Detection Limits (Method) | Range of Detected Concentrations[4] | Arithmetic Average Concentration[3] | Maximum Sample Location | Most Stringent Applicable Water Quality Criterion | # Detects > Criterion |
|---|---|---|---|---|---|---|---|---|---|---|
| **Major Cations** | | | | | | | | | | |
| Calcium, Dissolved | mg/L | 96/96 | 100.0% | 0.1-1.00 | 0.031-0.2 | 17.8-55.5 | 29.3 | AMER | - | - |
| Magnesium, Dissolved | mg/L | 96/96 | 100.0% | 0.03-1.00 | 0.015-0.2 | 7.72-25.5 | 12.4 | SNDN | - | - |
| Potassium, Dissolved | mg/L | 96/96 | 100.0% | 0.3-2.00 | 0.15-0.3 | 0.327-1.34 | 0.5 | AMER | - | - |
| Sodium, Dissolved | mg/L | 96/96 | 100.0% | 0.3-2.00 | 0.15-0.3 | 1.45-13.9 | 3.5 | AMER | - | - |
| **Major Anions** | | | | | | | | | | |
| Total Alkalinity (as $CaCO_3$) | mg/L | 96/96 | 100.0% | 0.02-40.0 | 2.00-12.4 | 65.2-166 | 104 | SNDN | 20 (min) [2b] | 0 |
| Bicarbonate | mg/L | 96/96 | 100.0% | 0.02-40.0 | 2.00-12.4 | 65.2-166 | 104 | SNDN | - | - |
| Fluoride | mg/L | 86/87 | 98.9% | 0.062-0.5 | 0.031-0.1 | 0.038-0.116 | 0.073 | AMER | 1[2e] | 0 |
| Sulfate | mg/L | 96/96 | 100.0% | 0.062-3.00 | 0.031-0.5 | 9.47-51.3 | 21.5 | SNDN | 250[1] | 0 |
| Chloride | mg/L | 96/96 | 100.0% | 0.062-3.00 | 0.031-0.5 | 0.356-59.2 | 1.66 | AMER | 230[2b] | 0 |
| **Nutrients** | | | | | | | | | | |
| Nitrite + Nitrate(as N) | mg/L | 96/96 | 100.0% | 0.062-0.12 | 0.02-0.0372 | 0.101-3.24 | 0.52 | AMER | 10[2d] | 0 |
| Ammonia (as N) | mg/L | 32/94 | 34.0% | 0.062-0.1 | 0.031-0.031 | 0.032-0.239 | 0.062 | ACBW | 0.18[2h] | 3 |
| **Cyanide** | | | | | | | | | | |
| Total Cyanide | µg/L | 12/96 | 12.5% | 3.00-10.0 | 1.5-3.00 | 1.5-4.1 | 2.49 | SNDN | - | - |
| Wad Cyanide | µg/L | 16/96 | 16.7% | 3.00-10.0 | 1.5-3.00 | 1.5-3.4 | 2.45 | AMER | 5.2[2g] | 0 |
| **Metals** | | | | | | | | | | |
| Mercury, Dissolved | ng/L | 4/4 | 100.0% | 1.00-1.00 | 0.5-0.5 | 0.804-2.57 | 1.27 | AMER | - | - |
| Mercury | ng/L | 97/98 | 99.0% | 1.00-3.00 | 0.1-1.00 | 0.561-46.7 | 5.77 | SNDN | 12[2b] | 11 |
| Aluminum, Dissolved | µg/L | 52/78 | 66.7% | 5.00-20.0 | 1.00-6.2 | 6.3-889 | 27.7 | AMER | - | - |
| Aluminum | µg/L | 96/96 | 100.0% | 5.00-80.0 | 1.00-24.8 | 6.73-4240 | 288 | ACBW | 87[2a] | 11 |
| Antimony, Dissolved | µg/L | 21/78 | 26.9% | 0.62-2.00 | 0.31-0.4 | 0.311-1.05 | 0.5 | SNDN | - | - |
| Antimony | µg/L | 28/96 | 29.2% | 0.62-2.00 | 0.31-0.4 | 0.313-7.17 | 0.57 | AMER | 6[2d] | 1 |
| Arsenic, Dissolved | µg/L | 55/78 | 70.5% | 2.00-5.00 | 0.5-2.5 | 1.68-11.8 | 3.64 | SNDN | - | - |
| Arsenic | µg/L | 77/96 | 80.2% | 2.00-20.0 | 0.5-2.5 | 1.51-150 | 7.21 | SNDN | 10[2d] | 12 |
| Barium, Dissolved | µg/L | 78/78 | 100.0% | 1.88-3.00 | 0.5-0.94 | 37.3-151 | 54.9 | AMER | - | - |
| Barium | µg/L | 96/96 | 100.0% | 1.88-3.00 | 0.5-0.94 | 39.9-167 | 60.9 | AMER | 2,000[2d] | 0 |
| Beryllium, Dissolved | µg/L | 0/78 | 0.0% | 0.4-0.5 | 0.1-0.13 | - | 0.2 | - | - | - |
| Beryllium | µg/L | 5/96 | 5.2% | 0.4-0.5 | 0.1-0.13 | 0.143-0.26 | 0.2 | SNDN | 4[2d] | 0 |
| Boron, Dissolved | µg/L | 14/78 | 17.9% | 10.0-50.0 | 3.1-15.0 | 3.16-25.2 | 20.2 | SNDN | - | - |
| Boron | µg/L | 29/96 | 30.2% | 10.0-50.0 | 3.1-15.0 | 3.37-35.6 | 18.4 | SNDN | 750[2e] | 0 |

**Table 3.7-3: Surface Water Quality Summary for Category 2 Locations - Background Sites in Mineralized Areas**

| Analyte | Units | Frequency of Detection | | Range of Detection Limits (Reporting) | Range of Detection Limits (Method) | Range of Detected Concentrations[4] | Arithmetic Average Concentration[3] | Maximum Sample Location | Most Stringent Applicable Water Quality Criterion | # Detects > Criterion |
|---|---|---|---|---|---|---|---|---|---|---|
| Cadmium, Dissolved | µg/L | 1/78 | 1.3% | 0.5-0.5 | 0.1-0.15 | 0.168-0.168 | 0.25 | AMER | - | - |
| Cadmium | µg/L | 6/96 | 6.3% | 0.5-0.5 | 0.1-0.15 | 0.178-3.00 | 0.28 | SNDN | 0.25[2ab] | 2 |
| Chromium, Dissolved | µg/L | 9/78 | 11.5% | 1.00-2.00 | 0.31-0.62 | 0.657-3.18 | 1.00 | AMER | - | - |
| Chromium | µg/L | 32/96 | 33.3% | 1.00-2.00 | 0.31-0.62 | 0.485-7.14 | 1.13 | SNDN | 100[2d] | 0 |
| Cobalt, Dissolved | µg/L | 11/78 | 14.1% | 0.3-4.00 | 0.05-1.2 | 0.12-11.6 | 2.32 | SNDN | - | - |
| Cobalt | µg/L | 6/96 | 6.3% | 0.3-4.00 | 0.05-1.2 | 0.24-3.74 | 2.01 | SNDN | 50[2e] | 0 |
| Copper, Dissolved | µg/L | 67/78 | 85.9% | 0.62-3.00 | 0.31-0.5 | 0.312-1.63 | 0.59 | AMER | - | - |
| Copper | µg/L | 85/96 | 88.5% | 0.62-3.00 | 0.31-0.5 | 0.34-5.47 | 0.93 | SNDN | 8.54[2ab] | 0 |
| Iron, Dissolved | µg/L | 70/78 | 89.7% | 20.0-250 | 6.2-78.0 | 38.9-1190 | 188 | AMER | - | - |
| Iron | µg/L | 96/96 | 100.0% | 20.0-250 | 6.2-78.0 | 24.8-7930 | 662 | SNDN | 1,000[2b] | 14 |
| Lead, Dissolved | µg/L | 23/78 | 29.5% | 0.124-0.5 | 0.062-0.1 | 0.063-0.6 | 0.13 | AMER | - | - |
| Lead | µg/L | 57/96 | 59.4% | 0.124-0.5 | 0.062-0.1 | 0.066-3.18 | 0.28 | SNDN | 2.79[2ab] | 1 |
| Lithium, Dissolved | µg/L | 15/78 | 19.2% | 6.2-100 | 3.1-20.0 | 3.12-5.94 | 5.41 | AMER | - | - |
| Lithium | µg/L | 19/87 | 21.8% | 6.2-100 | 3.1-20.0 | 3.15-10.6 | 5.47 | SNDN | 2,500[2e] | 0 |
| Manganese, Dissolved | µg/L | 78/78 | 100.0% | 0.62-3.00 | 0.31-0.5 | 15.0-760 | 96.2 | AMER | - | - |
| Manganese | µg/L | 96/96 | 100.0% | 0.62-3.00 | 0.31-0.5 | 0.531-751 | 107 | AMER | 50[2f] | 71 |
| Molybdenum, Dissolved | µg/L | 0/78 | 0.0% | 2.00-10.0 | 0.5-3.1 | - | 4.7 | - | - | - |
| Molybdenum | µg/L | 6/96 | 6.3% | 2.00-10.0 | 0.5-3.1 | 0.895-6.2 | 4.76 | SNDN | 10[2e] | 0 |
| Nickel, Dissolved | µg/L | 71/78 | 91.0% | 1.24-3.00 | 0.6-0.62 | 0.663-2.58 | 1.13 | AMER | - | - |
| Nickel | µg/L | 94/96 | 97.9% | 1.24-3.00 | 0.6-0.62 | 0.665-8.16 | 1.44 | SNDN | 47.8[2ab] | 0 |
| Selenium, Dissolved | µg/L | 2/78 | 2.6% | 0.3-5.00 | 0.1-1.5 | 0.6-1.68 | 2.47 | SNDN | - | - |
| Selenium | µg/L | 4/96 | 4.2% | 0.3-5.00 | 0.1-1.5 | 0.5-3.00 | 2.48 | SNDN | 5[2b] | 0 |
| Silver, Dissolved | µg/L | 0/78 | 0.0% | 0.3-1.00 | 0.05-0.31 | - | 0.5 | - | - | - |
| Silver | µg/L | 2/96 | 2.1% | 0.3-1.00 | 0.05-0.31 | 0.62-0.62 | 0.5 | SNDN | 3.17[2ac] | 0 |
| Thallium, Dissolved | µg/L | 1/78 | 1.3% | 0.5-1.00 | 0.1-0.31 | 0.364-0.364 | 0.5 | ACBW | - | - |
| Thallium | µg/L | 7/96 | 7.3% | 0.5-1000 | 0.1-0.31 | 0.341-0.865 | 0.5 | AMER | 1.7[2f] | 0 |
| Vanadium, Dissolved | µg/L | 1/78 | 1.3% | 1.00-20.0 | 0.2-6.2 | 0.6-0.6 | 9.88 | AMER | - | - |
| Vanadium | µg/L | 6/96 | 6.3% | 1.00-20.0 | 0.2-6.2 | 0.8-14.2 | 9.97 | ACBW | 100[2e] | 0 |
| Zinc, Dissolved | µg/L | 27/78 | 34.6% | 1.00-5.00 | 2.00-2.5 | 2.58-12.4 | 3.22 | SNDN | - | - |
| Zinc | µg/L | 50/96 | 52.1% | 5.00-5.00 | 1.5-2.5 | 1.63-26.8 | 4.29 | SNDN | 109.8[2ab] | 0 |
| **General Water Quality Parameters** | | | | | | | | | | |
| Hardness ($CaCO_3$), Dissolved | mg/L | 95/95 | 100.0% | 5.00-7.00 | 1.00-5.00 | 22.4-206.4 | 121 | SNDN | - | - |

**Table 3.7-3: Surface Water Quality Summary for Category 2 Locations - Background Sites in Mineralized Areas**

| Analyte | Units | Frequency of Detection | | Range of Detection Limits (Reporting) | Range of Detection Limits (Method) | Range of Detected Concentrations[4] | Arithmetic Average Concentration[3] | Maximum Sample Location | Most Stringent Applicable Water Quality Criterion | # Detects > Criterion |
|---|---|---|---|---|---|---|---|---|---|---|
| Total Dissolved Solids | mg/L | 96/96 | 100.0% | 6.2-50.0 | 3.1-10.0 | 76.0-274 | 142 | AMER | 500[1] | 0 |
| Total Suspended Solids | mg/L | 94/95 | 98.9% | 0.298-5.00 | 0.143-1.5 | 0.2-141 | 15.1 | AMER | - | - |
| **Field Parameters** | | | | | | | | | | |
| Conductivity (Lab) | µS/cm | 96/96 | 100.0% | 0.954-10.0 | 0.477-1.00 | 165-470 | 245 | AMER | - | - |
| Conductivity, Field | µS/cm | 90/90 | 100.0% | - | - | 3.65-787 | 148 | SNDN | - | - |
| Dissolved Oxygen, Field | mg/L | 94/94 | 100.0% | - | - | 3.36-122.7 | 16.7 | ACBW | - | - |
| Ox./Reduc. Pot.(ORP/eH), Field | mV | 94/94 | 100.0% | - | - | -292.7-271 | 80.6 | ACBW | - | - |
| pH (Lab) | pH Units | 96/96 | 100.0% | 0.1-0.2 | 0.1-0.1 | 5.6-8.3 | 7.23 | AMER | 6.5-8.5[1] | - |
| pH, Field | pH Units | 94/94 | 100.0% | - | - | 5.54-8.94 | 7.04 | AMER | - | - |
| Water Temperature, Field | degrees C | 94/94 | 100.0% | - | - | -0.51-7.32 | 2.16 | AMER | - | - |
| Turbidity, Field | NTU | 72/72 | 100.0% | - | - | 0.81-97.2 | 8.83 | AMER | 5[1] | 33 |

**Notes:**

Most Stringent Applicable Water Quality Criteria are provided for the parameters for which water quality standards have been established. Standards have not been established for all parameters. Cases where there are no applicable standards are indicated by a dash (-).

1 18 AAC 70. ADEC, Alaska Water Quality Standards. Amended as of April 8, 2012.

2 Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances. Amended through December 12, 2008. Most stringent criteria used. WQS for metals are expressed as 'total recoverable' concentrations.

2a Aquatic life for fresh water hardness-dependent criteria. Acute and chronic aquatic life numeric criteria for some metals (Cd, Cu, Pb, Ni, Zn) are hardness dependent. Values contained in this table were calculated using a hardness value of 90.18 mg/L as CaCO 3 For Al, if pH≥7.0 and hardness ≥50, then 750 µg/L.

2b Aquatic life for fresh water (chronic) criteria.

2c Aquatic life for fresh water (acute) criteria.

2d Drinking water criteria.

2e Irrigation water criteria.

2f Human health criteria for non-carcinogens (for consumption of water + aquatic organisms).

2g Aquatic life criteria (chronic)for free cyanide, measured as weak acid dissociable (WAD) cyanide.

2h Aquatic life for fresh water (chronic) criteria based on pH and temperature when early life stages of fish are present. The ADEC numeric water quality standard for ammonia depends upon both the temperature and the pH of the matrix water, but not the hardness. Because the measured or predicted temperature and pH of the water may vary over a wide range of values depending on time of year, sample location, and other factors, the most conservative possible numeric standard for ammonia in freshwater (0.179 mg/L; ADEC 2008a) is used as a basis for comparison for all of the waters considered in this section.

3 Calculated for all observations using detected values and ½ of the reporting limit value when analyte not detected.

4 Determined for the minimum and maximum of all detected reportable values; negative values are included when no detections are observed.

**Table 3.7-4: Surface Water Quality Summary for Category 3 Locations – Baseline Sites Draining Proposed Mine and Placer Mining Areas**

| Analyte | Units | Frequency of Detection | | Range of Detection Limits (Reporting) | Range of Detection Limits (Method) | Range of Detected Concentrations[4] | Arithmetic Average Concentration[3] | Maximum Sample Location | Most Stringent Applicable Water Quality Criterion | # Detects > Criterion |
|---|---|---|---|---|---|---|---|---|---|---|
| **Major Cations** | | | | | | | | | | |
| Calcium, Dissolved | mg/L | 251/251 | 100.0% | 0.1-2.00 | 0.031-0.62 | 6.48-53.8 | 28 | SNOW | - | - |
| Magnesium, Dissolved | mg/L | 251/251 | 100.0% | 0.03-2.00 | 0.015-0.62 | 2.26-30.5 | 11.3 | SNOW | - | - |
| Potassium, Dissolved | mg/L | 251/251 | 100.0% | 0.3-2.00 | 0.15-0.3 | 0.312-4.17 | 0.55 | CRDN | - | - |
| Sodium, Dissolved | mg/L | 251/251 | 100.0% | 0.3-2.00 | 0.15-0.3 | 1.45-53.1 | 5.16 | CRDN | - | - |
| **Major Anions** | | | | | | | | | | |
| Total Alkalinity (as $CaCO_3$) | mg/L | 250/250 | 100.0% | 0.02-40.0 | 2.00-12.4 | 22.5-286 | 111 | CRDN | 20 (min) [2b] | 0 |
| Bicarbonate | mg/L | 250/250 | 100.0% | 0.02-40.0 | 2.00-12.4 | 22.5-279 | 111 | CRDN | - | - |
| Fluoride | mg/L | 233/234 | 99.6% | 0.062-0.1 | 0.031-0.1 | 0.033-0.93 | 0.08 | SNOW | 1[2e] | 0 |
| Sulfate | mg/L | 251/251 | 100.0% | 0.062-2.5 | 0.031-0.5 | 1.51-48.3 | 13.6 | SNOW | 250[1] | 0 |
| Chloride | mg/L | 251/251 | 100.0% | 0.062-0.5 | 0.031-0.5 | 0.183-2.91 | 0.63 | CRDN | 230[2b] | 0 |
| **Nutrients** | | | | | | | | | | |
| Nitrite + Nitrate(as N) | mg/L | 249/251 | 99.2% | 0.062-0.1 | 0.02-0.031 | 0.033-1.4 | 0.32 | CCAC | 10[2d] | 0 |
| Ammonia (as N) | mg/L | 77/250 | 30.8% | 0.062-0.1 | 0.031-0.031 | 0.0315-0.497 | 0.06 | CRDN | 0.18[2h] | 5 |
| **Cyanide** | | | | | | | | | | |
| Total Cyanide | µg/L | 48/251 | 19.1% | 3.00-5.00 | 1.5-3.00 | 1.5-5.6 | 2.46 | CCBB | - | - |
| Wad Cyanide | µg/L | 57/251 | 22.7% | 3.00-5.00 | 1.5-3.00 | 1.5-4.8 | 2.45 | CCBW | 5.2[2g] | 0 |
| **Metals** | | | | | | | | | | |
| Mercury, Dissolved | ng/L | 29/30 | 96.7% | 1.00-1.00 | 0.5-0.5 | 0.763-24.3 | 3.4 | CCAK | - | - |
| Mercury | ng/L | 253/260 | 97.3% | 1.00-10.0 | 0.1-5.00 | 0.54-260 | 8.93 | EAGL | 12[2b] | 38 |
| Aluminum, Dissolved | µg/L | 138/216 | 63.9% | 1.00-100 | 1.00-31.0 | 3.00-2380 | 35.7 | CRDN | - | - |
| Aluminum | µg/L | 242/251 | 96.4% | 1.00-200 | 1.00-62.0 | 6.32-18100 | 463 | EAGL | 87[2a] | 34 |
| Antimony, Dissolved | µg/L | 41/216 | 19.0% | 0.4-1.00 | 0.31-0.4 | 0.31-1.17 | 0.5 | CCBO | - | - |
| Antimony | µg/L | 28/251 | 11.2% | 0.4-1.00 | 0.31-0.4 | 0.316-2.41 | 0.5 | CCAC | 6[2d] | 0 |
| Arsenic, Dissolved | µg/L | 40/216 | 18.5% | 0.5-5.00 | 0.5-2.5 | 1.00-4.43 | 2.44 | SNOW | - | - |
| Arsenic | µg/L | 102/251 | 40.6% | 0.5-5.00 | 0.5-2.5 | 1.2-32.1 | 2.95 | CCBO | 10[2d] | 2 |
| Barium, Dissolved | µg/L | 216/216 | 100.0% | 0.5-3.00 | 0.5-0.94 | 22.3-216 | 78.9 | EAGL | - | - |
| Barium | µg/L | 251/251 | 100.0% | 0.5-3.00 | 0.5-0.94 | 27.8-488 | 89.8 | EAGL | 2,000[2d] | 0 |
| Beryllium, Dissolved | µg/L | 1/216 | 0.5% | 0.1-0.4 | 0.1-0.13 | 0.132-0.132 | 0.2 | CCBW | - | - |
| Beryllium | µg/L | 10/251 | 4.0% | 0.1-0.4 | 0.1-0.13 | 0.13-0.681 | 0.2 | EAGL | 4[2d] | 0 |
| Boron, Dissolved | µg/L | 37/216 | 17.1% | 10.0-50.0 | 3.1-15.0 | 3.31-25.8 | 21.0 | CRDN | - | - |
| Boron | µg/L | 75/251 | 29.9% | 10.0-50.0 | 3.1-15.0 | 3.25-88.3 | 19.8 | SNOW | 750[2e] | 0 |

**Table 3.7-4: Surface Water Quality Summary for Category 3 Locations – Baseline Sites Draining Proposed Mine and Placer Mining Areas**

| Analyte | Units | Frequency of Detection | | Range of Detection Limits (Reporting) | Range of Detection Limits (Method) | Range of Detected Concentrations[4] | Arithmetic Average Concentration[3] | Maximum Sample Location | Most Stringent Applicable Water Quality Criterion | # Detects > Criterion |
|---|---|---|---|---|---|---|---|---|---|---|
| Cadmium, Dissolved | µg/L | 1/216 | 0.5% | 0.1-0.5 | 0.1-0.15 | 0.266-0.266 | 0.25 | CCBC | - | - |
| Cadmium | µg/L | 13/251 | 5.2% | 0.1-0.5 | 0.1-0.15 | 0.15-0.419 | 0.25 | CCBC | 0.21[2ab] | 9 |
| Chromium, Dissolved | µg/L | 45/214 | 21.0% | 0.5-2.00 | 0.31-0.62 | 0.621-3.49 | 0.98 | CRDN | - | - |
| Chromium | µg/L | 91/249 | 36.5% | 0.5-2.00 | 0.31-0.62 | 0.5-25.7 | 1.32 | EAGL | 100[2d] | 0 |
| Cobalt, Dissolved | µg/L | 29/216 | 13.4% | 0.05-4.00 | 0.05-1.2 | 0.45-10.3 | 2.21 | EAGL | - | - |
| Cobalt | µg/L | 16/251 | 6.4% | 0.05-4.00 | 0.05-1.2 | 0.15-11.7 | 2.1 | EAGL | 50[2e] | 0 |
| Copper, Dissolved | µg/L | 200/214 | 93.5% | 0.5-1.00 | 0.31-0.5 | 0.329-4.02 | 0.74 | CRDN | - | - |
| Copper | µg/L | 236/250 | 94.4% | 0.5-10.0 | 0.31-0.5 | 0.366-25.0 | 1.53 | SNOW | 6.86[2ab] | 9 |
| Iron, Dissolved | µg/L | 196/216 | 90.7% | 20.0-250 | 6.2-78.0 | 9.06-3430 | 306 | CRDN | - | - |
| Iron | µg/L | 249/251 | 99.2% | 20.0-250 | 6.2-78.0 | 49.1-27100 | 1176 | EAGL | 1,000[2b] | 54 |
| Lead, Dissolved | µg/L | 48/216 | 22.2% | 0.124-0.5 | 0.062-0.1 | 0.062-1.31 | 0.12 | CRDN | - | - |
| Lead | µg/L | 151/251 | 60.2% | 0.124-200 | 0.062-0.1 | 0.0623-11.8 | 0.38 | EAGL | 2.01[2ab] | 7 |
| Lithium, Dissolved | µg/L | 33/216 | 15.3% | 6.2-100 | 3.1-20.0 | 3.1-6.59 | 5.04 | CRDN | - | - |
| Lithium | µg/L | 51/234 | 21.8% | 6.2-100 | 3.1-20.0 | 3.12-19.6 | 5.15 | EAGL | 2,500[2e] | 0 |
| Manganese, Dissolved | µg/L | 216/216 | 100.0% | 0.62-3.00 | 0.31-0.5 | 0.362-1170 | 82.7 | CCBW | - | - |
| Manganese | µg/L | 251/251 | 100.0% | 0.62-10.0 | 0.31-0.5 | 2.61-1460 | 108 | CCBO | 50[2f] | 194 |
| Molybdenum, Dissolved | µg/L | 7/216 | 3.2% | 2.00-10.0 | 0.5-3.1 | 0.674-4.23 | 4.3 | CCBW | - | - |
| Molybdenum | µg/L | 10/251 | 4.0% | 2.00-10.0 | 0.5-3.1 | 0.62-6.2 | 4.4 | CRDN | 10[2e] | 0 |
| Nickel, Dissolved | µg/L | 207/215 | 96.3% | 1.24-3.00 | 0.6-0.62 | 0.651-3.69 | 1.2 | CRDN | - | - |
| Nickel | µg/L | 247/250 | 98.8% | 1.24-3.00 | 0.6-0.62 | 0.659-26.2 | 1.84 | EAGL | 38.5[2ab] | 0 |
| Selenium, Dissolved | µg/L | 2/216 | 0.9% | 0.3-5.00 | 0.1-1.5 | 0.2-1.88 | 2.49 | CCBW | - | - |
| Selenium | µg/L | 8/251 | 3.2% | 0.3-5.00 | 0.1-1.5 | 0.2-3.00 | 2.49 | CRDN | 5[2b] | 0 |
| Silver, Dissolved | µg/L | 0/216 | 0.0% | 0.3-1.00 | 0.05-0.31 | - | 0.5 | - | - | - |
| Silver | µg/L | 4/251 | 1.6% | 0.3-1.00 | 0.05-0.31 | 0.62-0.62 | 0.5 | CRDN | 2.04[2ac] | 0 |
| Thallium, Dissolved | µg/L | 2/216 | 0.9% | 0.5-1.00 | 0.1-0.31 | 0.486-0.6 | 0.5 | SNOW | - | - |
| Thallium | µg/L | 6/251 | 2.4% | 0.5-1.00 | 0.1-0.31 | 0.31-0.62 | 0.5 | CRDN | 1.7[2f] | 0 |
| Vanadium, Dissolved | µg/L | 1/216 | 0.5% | 1.00-20.0 | 0.2-6.2 | 6.53-6.53 | 9.94 | CCBO | - | - |
| Vanadium | µg/L | 14/251 | 5.6% | 1.00-20.0 | 0.2-6.2 | 1.24-41.0 | 10.2 | EAGL | 100[2e] | 0 |
| Zinc, Dissolved | µg/L | 86/215 | 40.0% | 1.00-5.00 | 2.00-2.5 | 2.55-20.5 | 3.37 | SNOW | - | - |
| Zinc | µg/L | 131/250 | 52.4% | 5.00-5.00 | 1.5-2.5 | 1.5-75.3 | 4.88 | EAGL | 88.4[2ab] | 0 |
| **General Water Quality Parameters** | | | | | | | | | | |
| Hardness ($CaC0_3$), Dissolved | mg/L | 250/250 | 100.0% | 1.00-5.00 | 1.00-5.00 | 17.9-259.94 | 113 | SNOW | - | - |

**Table 3.7-4: Surface Water Quality Summary for Category 3 Locations – Baseline Sites Draining Proposed Mine and Placer Mining Areas**

| Analyte | Units | Frequency of Detection | | Range of Detection Limits (Reporting) | Range of Detection Limits (Method) | Range of Detected Concentrations[4] | Arithmetic Average Concentration[3] | Maximum Sample Location | Most Stringent Applicable Water Quality Criterion | # Detects > Criterion |
|---|---|---|---|---|---|---|---|---|---|---|
| Total Dissolved Solids | mg/L | 250/250 | 100.0% | 6.2-32.3 | 3.1-10.0 | 47.0-351 | 139 | CRDN | 500[1] | 0 |
| Total Suspended Solids | mg/L | 249/250 | 99.6% | 0.298-5.00 | 0.141-2.5 | 0.2-896 | 25.7 | EAGL | - | - |
| **Field Parameters** | | | | | | | | | | |
| Conductivity (Lab) | µS/cm | 250/250 | 100.0% | 0.954-1.00 | 0.477-1.00 | 58.5-559 | 238 | CRDN | - | - |
| Conductivity, Field | µS/cm | 242/242 | 100.0% | - | - | 26.0-518 | 138 | SNOW | - | - |
| Dissolved Oxygen, Field | mg/L | 251/251 | 100.0% | - | - | 1.00-127 | 15.5 | CCBW | - | - |
| OX./Reduc. Pot.(ORP/eH), Field | mV | 251/251 | 100.0% | - | - | -390-524.9 | 99.6 | EAGL | - | - |
| pH (Lab) | pH Units | 250/250 | 100.0% | 0.1-0.2 | 0.1-0.1 | 6.5-8.3 | 7.38 | CRDN | 6.5-8.5[1] | - |
| pH, Field | pH Units | 249/249 | 100.0% | - | - | 4.65-14.66 | 6.75 | CRDN | - | - |
| Water Temperature, Field | degrees C | 251/251 | 100.0% | - | - | -12.36-12.99 | 3.11 | CCAC | - | - |
| Turbidity, Field | NTU | 203/203 | 100.0% | - | - | 0.34-393 | 13.2 | EAGL | 5[1] | 94 |

**Notes:**

Most Stringent Applicable Water Quality Criterion are provided for the parameters for which water quality standards have been established. Standards have not been established for all parameters. Cases where there are no applicable standards are indicated by a dash (-).

1 18 AAC 70. ADEC, Alaska Water Quality Standards. Amended as of April 8, 2012.

2 Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances. Amended through December 12, 2008. Most stringent criteria used. WQS for metals are expressed as 'total recoverable' concentrations.

2a Aquatic life for fresh water hardness-dependent criteria. Acute and chronic aquatic life numeric criteria for some metals (Cd, Cu, Pb, Ni, Zn) are hardness dependent. Values contained in this table were calculated using a hardness value of 69.8 mg/L as CaCO3. For Al, if pH ≥7.0 and hardness ≥50, then 750 µg/L.

2b Aquatic life for fresh water (chronic) criteria.

2c Aquatic life for fresh water (acute) criteria.

2d Drinking water criteria.

2e Irrigation water criteria.

2f Human health criteria for non-carcinogens (for consumption of water + aquatic organisms).

2g Aquatic life criteria (chronic)for free cyanide, measured as weak acid dissociable (WAD) cyanide.

2h Aquatic life for fresh water (chronic) criteria based on pH and temperature when early life stages of fish are present. The ADEC numeric water quality standard for ammonia depends upon both the temperature and the pH of the matrix water, but not the hardness. Because the measured or predicted temperature and pH of the water may vary over a wide range of values depending on time of year, sample location, and other factors, the most conservative possible numeric standard for ammonia in freshwater (0.179 mg/L; ADEC 2008a) is used as a basis for comparison for all of the waters considered in this section.

3 Calculated for all observations using detected values and ½ of the reporting limit value when analyte not detected.

4 Determined for the minimum and maximum of all detected reportable values; negative values are included when no detections are observed.

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Table 3.7-2 through Table 3.7-4 show the minimum, maximum, and average values measured for each parameter within each category of sites. The range of detection-limit values is also given for analytes that were not present at concentrations above the analytical detection limits. The location of the maximum measured value for each parameter is shown, and the maximum measured values are compared to the State of Alaska WQS (most stringent standard for all designated water uses) (ADEC 2008a, 2012d). The selection of the appropriate standards is discussed in Section 3.7.1.2.1.

The following analytes had maximum concentrations that exceeded the relevant standards (ADEC 2008a, 2012a).

- Category 1 (background sites outside of mineralized areas):
  - Ammonia, WAD Cyanide, aluminum (total), arsenic (total), cadmium (total), copper (total), iron (total), lead (total), manganese (total), nickel (total), zinc (total), mercury (total), and turbidity were above the relevant standards.
- Category 2 (waters draining areas of defined mineralized zones with no placer mining activities):
  - Ammonia, aluminum (total), antimony (total), arsenic (total), cadmium (total), iron (total), manganese (total), mercury (total), and turbidity exceeded the relevant standards.
- Category 3 (sites draining proposed mine and placer mining areas):
  - Ammonia, aluminum (total), arsenic (total), cadmium (total), copper (total), iron (total), lead (total), manganese (total), mercury (total), and turbidity were above the relevant standards.

For all categories of surface water sampling locations, total concentrations of metals such as copper, aluminum, arsenic, iron, lead, and zinc were often substantially higher than dissolved concentrations, indicating that the majority of these metals are present as particulate matter rather than dissolved aqueous species (ARCADIS 2012b). Dissolved metals are generally more bioavailable than those present in the particulate phase; therefore particulate phase metals are less likely to contribute to effects on biological resources than dissolved aqueous phase metals.

The calculated averages for cadmium exceeded the ADEC standard for Category 1, Category 2, and Category 3 sites. However, this result is likely an artifact of the high reporting level detection limits (0.1 to 1.5 µg/L), which sometimes also exceeds the applicable water quality standard for cadmium. For all three stream categories, only about 6 percent of the samples had detectable levels of cadmium.

In order to generally check the correctness of the analytical data presented in Table 3.7-2 through Table 3.7-4, the anion-cation balances were determined for each individual sample for which sufficient data were available. As an aqueous solution is always electrically neutral, the sum (in milliequivalents/liter) of the anions and the cations should always balance. For Category 1 waters (Table 3.7-2) 180 out of 181 (99.4 percent) samples had a charge balance error of less than 15 percent. This was true for 95 out of 95 (100 percent) samples in Category 2 (Table 3.7-3), and 245 out of 249 (98.6 percent) samples in Category 3 (Table 3.7-4). The mean concentrations of selected analytes collected from each category of surface water locations (Categories 1, 2, and 3) were compared using the statistical program Pro-UCL version 4 (EPA

2009e). The surface water data were statistically compared to test the hypothesis that the mean concentrations of the key analytes in Category 1 waters (non-mineralized zones) were not statistically different (at a 95 percent confidence level) from the mean concentrations of the same analytes in Category 2 (mineralized areas, not impacted by historical placer mining) and Category 3 (mineralized areas impacted by historical placer mining, and encompassing the proposed project site) waters (ARCADIS 2012b). The comparison showed that at a 95 percent confidence level, there were no statistically significant differences between the categories, with the following exceptions:

- Barium- The mean concentration of barium was statistically higher in Category 2 waters versus Category 1 waters.
- Sulfate- The mean concentration of sulfate was statistically higher in Category 2 waters versus Category 1 waters.
- Manganese - The mean concentration of manganese was statistically higher in Category 3 waters versus Category 1 waters.

The statistically higher concentrations of barium and sulfate observed in Category 2 water and manganese in Category 3 water indicate that the mineralized locations, both mined and un-mined, have naturally elevated concentrations of these species relative to background, non-mineralized (Category 1) sample locations (ARCADIS 2012b).

The Donlin Gold Baseline Water Quality Monitoring Program includes three sites located within the Snow Gulch drainage; SNUP, above both the mineralization trend and placer mining (Category 1); SNDN, below the mineralized trend and above historic placer tails (Category 2); and SNOW, below mineralization and historic placer tails and above confluence with Crooked Creek (Category 3). Mean turbidity values at these three sites over the period from the third quarter of 2005 to through the second quarter of 2015 were 3.44 NTU at station SNUP, 5.50 NTU at station SNDN, and 3.13 NTU at station SNOW, all of which are below the mean turbidity values for each category of sites, suggesting that placer mining has not resulted in adverse water quality impacts in the Snow Gulch drainage.

### U.S. Geological Survey Study of Crooked Creek Watershed

#### *Sampling and Analytical Program*

In addition to the data generated by the Donlin Gold water quality characterization program, the U.S. Geological Survey (USGS) conducted a study involving the analysis of 20 stream samples, 6 samples from seeps, and 2 well water samples collected from the Crooked Creek watershed in July 2002 (Mueller et al. 2003). The sites sampled for the USGS study include the headwaters, mid-stream, and lower reaches of Bell Creek, Anaconda Creek, American Creek, Lewis Gulch, Queen Gulch, Snow Gulch, Quartz Gulch, Dome Creek, and Ophir Creek. The locations of several of these sites correspond to Donlin Gold's surface water sampling stations (Figure 3.7-1). Thus in some instances, the USGS water quality data are comparable to those collected as part of the Donlin Gold Baseline Water Quality Monitoring Program, however, it should be noted that temporal variations in the water quality parameters and differences in the numbers of samples analyzed for each location may be responsible for differences in the reported values and descriptive statistics for water quality parameters reported as part of the USGS study and the Donlin Gold Baseline Water Quality Monitoring Program.

Samples were collected using trace-clean techniques and all analyses were performed at the Denver laboratories of the USGS, with the exception of the total organic carbon analyses, which were performed at the Applied Science and Engineering Technology laboratory, University of Alaska-Anchorage (UAA). Analyses for dissolved constituents were performed subsequent to filtration through 0.45 µm filters; unfiltered samples were also analyzed to determine concentrations of total recoverable constituents (Mueller et al. 2003).

*Study Results – General Patterns*

The USGS study generally characterizes stream and seep waters in the Crooked Creek watershed as neutral to slightly alkaline pH (6.9-7.9), with major element and anion abundances in the following order, from highest concentration to lowest: calcium, magnesium, sodium, potassium; and, bicarbonate, sulfate, nitrate, chlorine, fluorine (Mueller et al. 2003). The dissolved oxygen (DO) concentrations range from 6.9 to 12 mg/L, and specific conductance values range from 89 to 531 µS/cm (Mueller et al. 2003). A statistical summary of the analyses performed on surface water samples is provided as Table 3.7-5.

One of the goals of the USGS study was to examine spatial relationships between water chemistry and mineralized areas within the Crooked Creek watershed, around and within the mine site. Analyses of the total recoverable fractions of constituents (as opposed to the dissolved fraction) were used to characterize spatial patterns in the distributions of certain constituents in the water. Two general spatial patterns were identified (Mueller et al. 2003):

- First, the locations of elevated concentrations of arsenic and antimony in samples collected from Lewis Gulch, Queen Gulch, and Quartz Gulch correspond to the orientation of the known mineralized zone (Section 3.1.1.2 Geology, Figure 3.1-3). Weathering of arsenopyrite and stibnite associated with the mineralized zone was identified as the most likely factor responsible for the anomalous concentrations. In addition, concentrations of aluminum, iron, and to a lesser extent manganese, were elevated at sites associated with the known mineralized zone, as well as at DC10 located in the upper reaches of the Dome Creek drainage approximately 2 miles east of the known mineralized zone (Figure 3.7-1). The elevated concentrations of aluminum, iron, and manganese may be related to weathering of minerals in the igneous rocks that are spatially associated with the gold deposit.
- The second spatial pattern involves elevated concentrations of calcium, magnesium, sulfate, and antimony relative to other surface water sites in the study area. This occurs at DC17 located in the upper part of the Bell Creek drainage east of the known mineralized zone, and at DC07, a bedrock seep on the south side of Snow Gulch. Mueller et al. (2003) suggest that the elevated concentrations[1] may be attributable to changes in lithology associated with local interbedding of limestone.

1 These include calcium (55 mg/L), magnesium (23 mg/L), and sulfate (130 mg/L).

**Table 3.7-5: Summary of USGS Surface Water Quality Data from Proposed Mine Area**

| Parameter | Surface Water Samples | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Filtered-acidified | | | | | Unfiltered-acidified | | | | |
| | MAX | MIN | MEDIAN | MEAN | n | MAX | MIN | MEDIAN | MEAN | n |
| Temperature (ºC) | 7.6 | 2 | 3.5 | 3.9 | 25 | 7.6 | 2 | 3.5 | 3.9 | 25 |
| pH | 8 | 7 | 7.5 | 7.5 | 25 | 8 | 7 | 7.5 | 7.50 | 25 |
| Conductivity (µS/cm) | 535 | 90 | 289 | 304 | 25 | 535 | 90 | 289 | 304 | 25 |
| Dissolved Oxygen (mg/L) | 13 | 7 | 12 | 11 | 25 | 13 | 7 | 12 | 11.00 | 25 |
| Alkalinity (mg/L) | 140 | 35 | 100 | 104 | 25 | 140 | 35 | 100 | 104 | 25 |
| Total Alkalinity (mg/L) | 170 | 43 | 122 | 126 | 25 | 170 | 43 | 122 | 126 | 25 |
| Chlorine (mg/L) | 0.7 | 0.4 | 0.5 | 0.6 | 26 | 0.7 | 0.4 | 0.5 | 0.6 | 26 |
| Fluorine (mg/L) | 0.10 | 0.08 | 0.10 | 0.09 | 24 | 0.1 | 0.08 | 0.10 | 0.09 | 24 |
| Nitrate (mg/L) | 4.4 | 0.7 | 2.5 | 2.5 | 26 | 4.4 | 0.7 | 2.45 | 2.51 | 26 |
| Sulfate (mg/L) | 130 | 3 | 19 | 26 | 26 | 130 | 3 | 19 | 26 | 26 |
| Calcium (mg/L) | 64 | 11 | 31 | 32.0 | 26 | 61 | 11 | 34 | 34 | 26 |
| Magnesium (mg/L) | 25 | 1.8 | 12 | 13.0 | 26 | 23 | 1.8 | 11 | 12.0 | 26 |
| Sodium (mg/L) | 5 | 0.7 | 1.6 | 1.8 | 26 | 5.1 | 0.78 | 1.5 | 1.7 | 26 |
| Potassium (mg/L) | 0.66 | 0.26 | 0.4 | 0.4 | 26 | 1 | 0.18 | 0.38 | 0.40 | 26 |
| Silver (µg/L) | <3 | N.A. | N.A. | N.A. | N.A. | <3 | N.A. | N.A. | N.A. | N.A. |
| Aluminum (µg/L) | 19 | 0.95 | 7.6 | 8.1 | 26 | 15300 | 17 | 132 | 1056 | 26 |
| Arsenic (µg/L) | 7.7 | 1 | 3.7 | 4.0 | 14 | 274 | 1 | 4 | 25 | 15 |
| Boron (µg/L) | 7.4 | 6.3 | 6.3 | 6.7 | 3 | 5.5 | 5.3 | 5.4 | 5.4 | 2 |
| Barium (µg/L) | 101 | 18 | 56 | 53 | 26 | 218 | 18 | 54 | 64 | 26 |
| Beryllium (µg/L) | <0.05 | N.A. | N.A. | N.A. | N.A. | 0.5 | 0.07 | 0.14 | 0.21 | 4 |
| Bismuth (µg/L) | 0.08 | 0.005 | 0.03 | 0.038 | 12 | 0.11 | 0.007 | 0.02 | 0.030 | 8 |
| Cadmium (µg/L) | <0.02 | N.A. | N.A. | N.A. | N.A. | 0.22 | 0.02 | 0.06 | 0.07 | 7 |
| Cobalt (µg/L) | 0.10 | 0.02 | 0.04 | 0.04 | 26 | 9.3 | 0.04 | 0.12 | 0.82 | 26 |
| Chromium (µg/L) | 6.4 | 1 | 5.1 | 4.8 | 26 | 16 | 1.7 | 3.5 | 4.1 | 26 |
| Copper (µg/L) | 1.2 | 0.5 | 0.7 | 0.8 | 7 | 16 | 0.5 | 0.8 | 2.7 | 14 |
| Iron (µg/L) | 74 | 2 | 16 | 20 | 23 | 18,000 | 20 | 180 | 1,600 | 25 |
| Lithium (µg/L) | 3.4 | 1.1 | 2.0 | 2.1 | 23 | 18 | 1.1 | 1.9 | 3.0 | 20 |
| Manganese (µg/L) | 35 | 0.04 | 2.0 | 6.8 | 26 | 790 | 0.4 | 12 | 62 | 26 |
| Molybdenum (µg/L) | 2.1 | 0.20 | 0.39 | 0.66 | 17 | 2.4 | 0.22 | 0.46 | 0.76 | 21 |
| Nickel(µg/L) | 0.7 | 0.3 | 0.4 | 0.5 | 26 | 21 | 0.6 | 1 | 2.6 | 26 |
| Phosphorus (µg/L) | 0.1 | 0.01 | 0.02 | 0.03 | 21 | 0.5 | 0.01 | 0.02 | 0.07 | 13 |

**Table 3.7-5: Summary of USGS Surface Water Quality Data from Proposed Mine Area**

| Parameter | Surface Water Samples | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Filtered-acidified | | | | | Unfiltered-acidified | | | | |
| | MAX | MIN | MEDIAN | MEAN | n | MAX | MIN | MEDIAN | MEAN | n |
| Lead (µg/L) | 0.05 | 0.05 | 0.05 | 0.05 | 1 | 12 | 0.05 | 0.2 | 1.3 | 17 |
| Rubidium (µg/L) | 0.53 | 0.05 | 0.25 | 0.25 | 26 | 7.9 | 0.19 | 0.33 | 0.78 | 26 |
| Antimony (µg/L) | 4.1 | 0.1 | 0.5 | 1.0 | 16 | 4.5 | 0.1 | 0.33 | 0.91 | 20 |
| Selenium (µg/L) | 4.2 | 1 | 1.5 | 2.0 | 6 | 4.4 | 1 | 1.4 | 1.7 | 16 |
| Silicon (µg/L) | 4.1 | 1.7 | 3 | 3 | 26 | 14 | 1.8 | 3.1 | 3.9 | 26 |
| Strontium (µg/L) | 383 | 36 | 130 | 134 | 26 | 366 | 34 | 125 | 126 | 26 |
| Titanium (µg/L) | 1 | 0.3 | 0.6 | 0.6 | 26 | 191 | 0.4 | 3.4 | 17 | 24 |
| Uranium (µg/L) | 1.3 | 0.01 | 0.25 | 0.27 | 26 | 1.3 | 0.03 | 0.25 | 0.34 | 24 |
| Vanadium (µg/L) | 1.9 | 0.5 | 1.5 | 1.4 | 26 | 28 | 0.6 | 1.35 | 3.3 | 26 |
| Tungsten (µg/L) | 3.8 | 0.1 | 0.3 | 0.6 | 26 | 13 | 0.03 | 0.2 | 0.39 | 24 |
| Zinc (µg/L) | 5.6 | 0.5 | 0.7 | 1.4 | 11 | 59 | 0.6 | 0.95 | 6.0 | 22 |
| Zirconium (µg/L) | 0.1 | 0.06 | 0.06 | 0.07 | 11 | 1.8 | 0.05 | 0.1 | 0.24 | 15 |

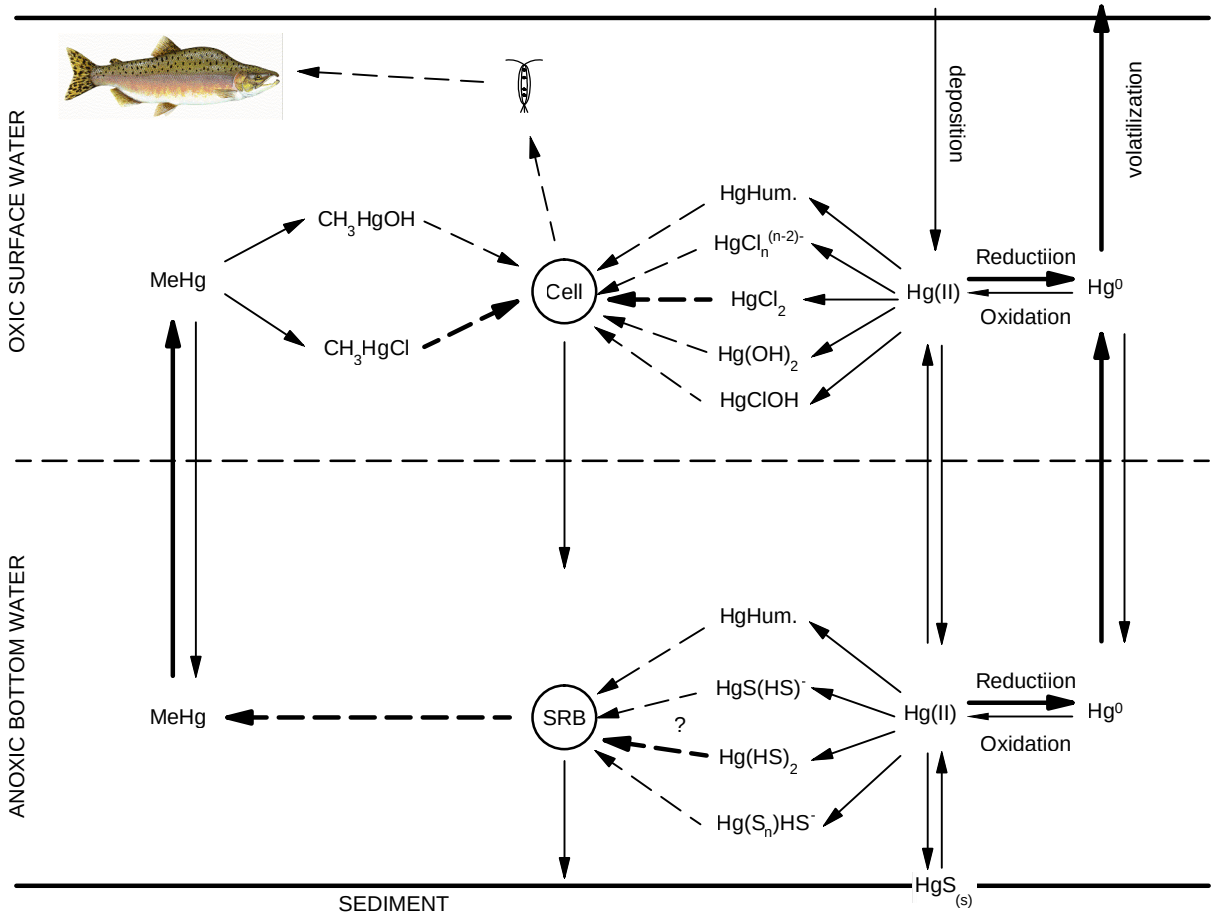
Source: Mueller et al. 2003

Note: Cells marked "N.A." indicate parameters for which the maximum measured values did not exceed the lower limit of quantification for the analysis.

## Discussion of Individual Constituents

### *Mercury and Methylmercury*

Because mercury is potentially toxic and accumulates in organisms, including plants and fish, the distribution and speciation of mercury in the water are important water quality considerations for the proposed project. Besides elemental mercury, which is relatively insoluble in water, the major forms of mercury in water are ionic mercury, which forms complexes with chloride, sulfide, or organic acids; and organic mercury, which is mainly methylmercury (Morel et al. 1998). In aquatic environments, the ionic forms of mercury are often associated with particulate material or dissolved organic matter (e.g., humic acids and other forms of dissolved organic carbon). The processes that transform mercury between its elemental, ionic, and organic forms are described in detail by Morel et al. (1998), and are summarized in Figure 3.7-2.




Data Sources: Morel, et al. (1998)

1. Processes that transform mercury between elemental, ionic, and organic forms in oxic and anoxic waters. Sulfate-reducing bacteria (SRB) and iron-reducing bacteria in anoxic waters and sediments are responsible for converting the ionic mercury into methylmercury (MeHg).

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THE AQUATIC CYCLE OF MERCURY

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FIGURE 3.7-2

Oxidation of elemental mercury to ionic mercury occurs both in the atmosphere via photochemically initiated processes, and in the water as a result of both photo-oxidation and enzyme-catalyzed reactions (Morel et al. 1998; Lalonde et al. 2001; Siciliano et al. 2002). Aqueous ionic mercury in oxic waters interacts with chloride and hydroxide ions and organic acids to form complexes that are bioavailable, but do not bioaccumulate because they are readily excreted by organisms. In anoxic waters, however, ionic mercury exhibits an extremely high affinity for sulfide, such that the speciation of dissolved ionic mercury in anoxic waters is completely dominated by sulfide and bisulfide complexes [2], even when total sulfide concentrations are very low (Morel et al. 1998). Some neutrally charged mercury-sulfide complexes and mercury-organic ligand complexes are available for uptake by the sulfate-reducing and iron-reducing bacteria that are responsible for the conversion of ionic mercury to methylmercury in anoxic waters and sediments (Morel et al. 1998; Benoit et al. 1999; Schaefer et al. 2011; Hsu-Kim et al. 2013). Methylation occurs primarily in anoxic, low pH (acidic) environments with high concentrations of organic matter. Because methylmercury is more readily retained by higher trophic-level organisms than other mercury species, it is the primary form of mercury that biomagnifies in the food chain. The accumulation of methylmercury in higher organisms results mainly from the ingestion of methylmercury-containing food rather than direct uptake of methylmercury from the water (Morel et al. 1998).

As part of the Donlin Gold water quality characterization program, concentrations of total mercury in surface water samples collected from the mine area have been analyzed using EPA Method 1631 (EPA 2002a). Concentrations of total mercury detected in 529 water samples collected between June 2005 and June 2015 ranged from 0.54 to 260 nanograms per liter (ng/L) (Enos 2013b; Weglinski 2015g). The applicable numeric criteria for mercury for CWA purposes are the EPA-approved aquatic life criteria: 2,400 ng/L acute and 12 ng/L chronic, both as total recoverable Hg (EPA 2013k). Total mercury concentrations did not exceed the acute criterion in any of the samples; 71 samples had total mercury concentrations in excess of the chronic criterion. Samples with total mercury concentrations greater than 12 ng/L were distributed among all of the three categories of sites defined by the Donlin Gold water quality characterization program, with 22 of the samples collected from Category 1 sites, 11 from Category 2 sites, and 38 from Category 3 sites, suggesting that naturally elevated concentrations of mercury are found sporadically in surface water in the vicinity of the proposed mine site.

Seasonal trend analysis of total mercury concentrations measured as part of the Donlin Gold water quality characterization program was performed using Seasonal Kendall and Mann-Kendall statistical tests (ARCADIS 2012b). No statistically significant temporal trends in the mercury concentrations were detected when data were analyzed on a quarter-by-quarter basis (ARCADIS 2012b). Correlation analysis to indicate the proportion of the variance in the analyte concentration that can be attributed to the variation in stream flow using least squares regression showed moderately strong relationships between mercury concentrations and stream flow at stations CCAC ($r^2$=0.575; $p$=0.026; $n$=15) and CCAK ($r^2$=0.659; $p$=0.107; $n$=7) (Tetra Tech 2013). In addition, analysis of the mercury concentrations measured during base flow, spring flow, and storm flow conditions indicate that the mercury concentrations are generally higher during spring flow and storm flow conditions relative to base flow (Tetra Tech

[2] Sulfide and bisulfide complexes include $Hg(HS)_2$, $HgS(HS)^-$, and $HgS_2^{2-}$.

2013). Due to higher concentrations of mercury and higher flow rates, the mercury load in Crooked Creek increases during spring flow and storm flow conditions relative to base flow (Tetra Tech 2013). Higher stream discharge is usually associated with higher flow velocity, which entrains particulate material from the substrate (Tetra Tech 2013). Thus the data suggest that a substantial fraction of the total mercury load in the Crooked Creek watershed (measured as total mercury in the water) is associated with particles entrained from the substrate during high flow events. This particulate mercury is generally less bioavailable than mercury found in the dissolved phase.

During a USGS investigation of the spatial distribution of chemical constituents in the Kuskokwim River (Wang 1999), total mercury was detected at a concentration of 10.5 ng/L in a 1997 sample collected from Crooked Creek near its confluence with the Kuskokwim River. The USGS result is consistent with those from Donlin Gold station CCAK, where total mercury concentrations ranging from 1.59 to 96.9 ng/L (arithmetic mean = 10.8 ng/L; n=20) were measured in water samples collected between June 2005 and 2015.

Concentration of methylmercury in water is a key factor that determines concentrations and accumulation of this organic mercury constituent in biota (Morel et al. 1998). Methylmercury concentrations in water are often lower and more temporally variable than concentrations in sediment. In 2007, measurements of methylmercury were added to the Donlin Gold sediment monitoring program (Section 3.7.2.3.2), and in 2013 and 2014, methylmercury and dissolved mercury, respectively, were added to the surface water quality characterization program. Monitoring of these constituents in water will be repeated on a quarterly basis in order to establish baseline concentrations in the vicinity of the mine site and provide a record of mercury flux and variability in the water column. Analysis of methylmercury in mine area water samples was conducted on unfiltered samples using EPA method 1630 (EPA 1998a). Preliminary results from the June 2013 sampling event (Table 3.7-6) indicate that methylmercury concentrations range from below the detection limit (0.020 ng/L) to 0.058 ng/L. Several samples with results close to the detection limit had laboratory qualifiers indicating that methylmercury was also found in a blank. All three of the samples with clear methylmercury detections were from Category 3 waters, and two of these three were located in lower Crooked Creek, several miles below the proposed mine site.

**Table 3.7-6: Preliminary Methylmercury Results in Proposed Mine Area Surface Water Samples, June 2013**

| Station ID | Category[a] | Result[b] (ng/L) |
|---|---|---|
| AMER | 2 | 0.038[B] |
| ANDA | 1 | 0.034[B] |
| CCAK | (3) | 0.058 |
| CCBB | (3) | 0.056 |
| CCBC | 3 | ND (<0.020) |
| CCBO | 3 | 0.054 |
| CCBW | 3 | 0.025[B] |
| CRDN | 3 | ND (<0.020) |

**Table 3.7-6: Preliminary Methylmercury Results in Proposed Mine Area Surface Water Samples, June 2013**

| Station ID | Category[a] | Result[b] (ng/L) |
|---|---|---|
| DCBO | 1 | 0.031[B] |

**Notes:**

a Categories:
1 = Background sites outside of mineralized areas
2 = Background sites in mineralized areas
3 = Baseline sites draining proposed mine and placer mining areas
(3) = Baseline sites draining proposed mine and placer mining areas, located 6-8 miles downstream
b Analyses performed on unfiltered samples.
B = Analyte found in blank associated with sample.
ND = not detected above method detection limit (MDL) shown in parentheses.

Source: Enos 2013b.

Other data describing the concentration of methylmercury in surface water from the Crooked Creek watershed were collected in 1997 as part of the USGS investigation of the spatial distribution of chemical constituents in the Kuskokwim River (Wang 1999). The concentration of methylmercury was 0.49 ng/L in an unfiltered water sample collected from Crooked Creek near its confluence with the Kuskokwim River (Wang 1999). The Donlin Gold results are about one order of magnitude below this value.

The recommended CWA Section 304(a) numeric water quality criterion for methylmercury is expressed as a fish and shellfish tissue concentration, not as a water column concentration (EPA 2010a). This criterion, 0.3 mg methylmercury per kg fish tissue (wet weight), describes the concentration of methylmercury in freshwater and estuarine fish and shellfish tissue that should not be exceeded to protect consumers of fish and shellfish among the general population. The 0.3 mg/kg criterion is based on a fish consumption rate of 17.5 g/day. It is important to note that the 0.3 mg/kg criterion is for fish that humans would consume. Because methylmercury bioaccumulates in biota, lower trophic level organisms will have generally lower methylmercury levels than higher trophic level organisms (the ones that humans are more likely to consume). It is possible for concentrations to increase by an order of magnitude between prey and higher level predatory fish. States and authorized tribes remain free to adjust EPA's recommended criterion, provided that their new or revised water quality criterion for methylmercury protect the designated uses and are based on scientifically defensible methodology. Concentrations of total mercury in fish tissue from the Crooked Creek drainage (Section 3.13.2.1.5, Fish and Aquatic Resources) range from 0.013 to 0.045 mg/kg wet weight (OtterTail 2012f). These values, which include both methylmercury and other forms of mercury, are well below the EPA criterion for methylmercury alone.

*Arsenic*

Arsenic is naturally occurring within the mineralization in the Donlin gold deposit. It exists primarily in the form of sulfide minerals including arsenopyrite, orpiment, and realgar. Because of its widespread occurrence at the project site, it is an important parameter for characterizing baseline water quality in the proposed project area. The most stringent Alaska Water Quality Standard numeric criterion for total arsenic is 10 µg/L (for drinking water) (ADEC 2008a). The

numeric criteria for protection of aquatic life are less stringent than the criterion for drinking water; the acute criterion for protection of aquatic life is 340 µg/L (one hour average), and the chronic criterion for the protection of aquatic life is 150 µg/L (4 day average). Unlike the applicable criterion for drinking water, the criteria for the protection of aquatic life refer to the concentrations of dissolved arsenic in the water. None of the applicable criteria distinguish between different oxidation states of arsenic, and no data are known to be available concerning whether the toxicities of the different redox species of arsenic to aquatic organisms are additive (ADEC 2008a).

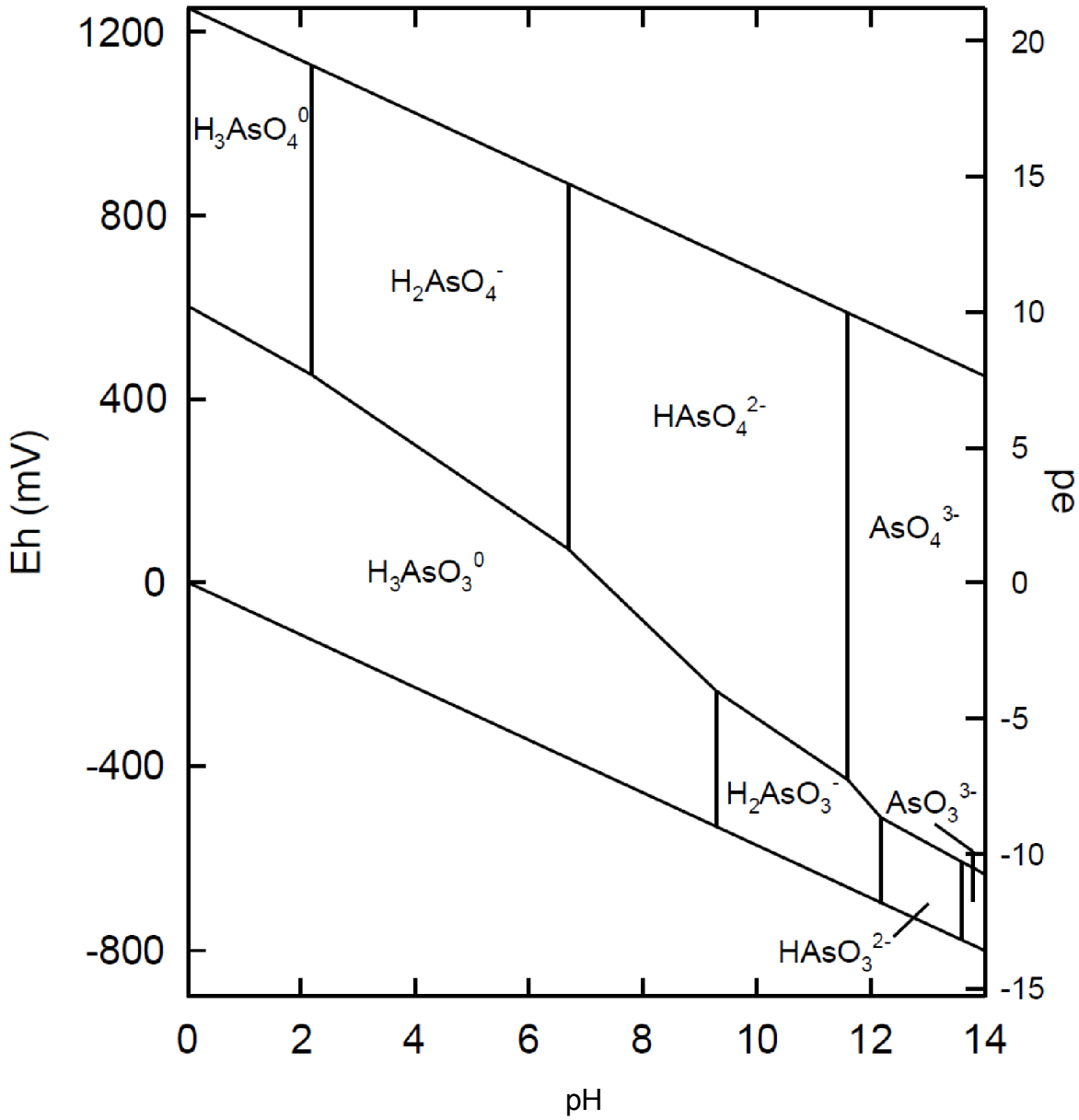
Samples collected as part of the Donlin Gold water quality characterization program contain total arsenic concentrations greater than the most stringent applicable criterion (10 µg/L for protection of drinking water) in all three categories of site: the highest concentration in Category 1 waters was 194 µg/L at sample location QRTZ; in Category 2 waters, was 150 µg/L at sample location SNDN; and in Category 3 waters, was 32.1 µg/L at sample location CCBO (Enos 2013b; Weglinski 2015g). With regard to arsenic concentrations, creeks draining the known mineralized area (Quartz, Snow, Queen, Lewis, and American) have characteristics that set them apart from other waters (SRK 2012b). Because gold is associated with arsenopyrite, arsenic concentrations are generally greatest in the creeks draining the mineralized area of interest (Mueller et al. 2003; SRK 2012b).

Arsenic can occur in the environment in several oxidation states (-3, 0, +3 and +5), but in natural waters is mostly found in inorganic form as oxyanions of trivalent arsenite or pentavalent arsenate (Smedley and Kinniburgh 2002). Arsenic speciation (distribution between different oxidation states) is driven primarily by the pH and oxidation-reduction potential of the aquatic environment. Under oxidizing conditions and at higher pH, the less mobile arsenate (pentavalent) form is favored; whereas more mobile trivalent arsenite ions dominate the speciation under reducing conditions and at lower pH (Smedley and Kinniburgh 2002). The Eh-pH diagram for arsenic in oxygenated water is shown on Figure 3.7-3. The only available measurements of arsenic speciation in the vicinity of the proposed mine site suggest that the predominant arsenic species in the surface water are the oxidized, less mobile pentavalent species (Mueller et al. 2003).

### *Antimony*

Like arsenic, antimony is a potentially toxic redox active-metalloid that occurs primarily as compounds of trivalent antimonite and pentavalent antimonate in natural environments. Stibnite is the most common form of antimony in sulfide deposits. Stibnite may dissolve gradually in stream waters with circumneutral pH, with the antimony mobilized into solution and subsequently precipitated into hydrated iron oxides, clays, organic material, and sulfide compounds. In the fluvial environment, antimony from stibnite deposits can be mobilized and cycled through aquatic ecosystems and riparian vegetation (Ashley et al. 2005).

Of 529 surface water samples analyzed for total antimony as part of the Donlin Gold water quality characterization program between June 2005 and June 2015, 70 had concentrations of antimony above the detection limits (Enos 2013b; Weglinski 2015g). The sample with the highest concentration of antimony (7.17 µg/L) was collected from location AMER on American




Notes:

1. Shown for the system As–$O_2$–$H_2O$ at 25ºC and 1 bar pressure, with total [As] = $1*10^{-5}$ mol/L.
2. Predominant[DN1] forms in mine site surface water are oxidized, less mobile As(V) species (Mueller et al. 2003).

Data Sources: Smedley and Kinniburgh 2002

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Eh-pH DIAGRAM[1] OF AQUEOUS ARSENIC SPECIES[2] IN OXYGENATED WATER

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FIGURE 3.7-3

Creek, below all proposed facilities and disturbance and above its confluence with Crooked Creek. The most stringent applicable numeric water quality criterion for antimony in surface water is the State of Alaska criterion for drinking water, which specifies a maximum concentration of 6 μg/L total antimony. Only one of the surface water samples (from AMER in 2012) had a reportable antimony concentration in excess of this criterion.

*Cyanide*

Cyanide is a chemical group consisting of one atom of carbon connected to one atom of nitrogen by a triple molecular bond. Cyanides are compounds (substances formed by the joining of two or more atoms) that contain a cyanide group. Cyanides can occur naturally as products of anabolism in some plants, bacteria, and fungi, or they can be manmade (CDC 2013). Unlike elemental constituents of surface waters (such as arsenic and mercury), cyanides can be destroyed by oxidation reactions, which predominantly yield less-toxic cyanate as a reaction product that can be subsequently hydrolyzed, ultimately yielding ammonium and bicarbonate ions. Such reactions may occur both naturally and as a result of anthropogenic processes. Because many cyanide compounds are potentially toxic, and because cyanide would be used in the gold extraction process at the proposed mine, the baseline concentrations of cyanides in surface waters are an important water quality consideration.

Since 2005, concentrations of weak acid dissociable (WAD) cyanide have been measured in 529 surface water samples as part of the Donlin Gold water quality characterization program. The WAD method provides an indication of the cyanide forms that could be potentially toxic to humans and animals. Frequency of detection in these samples ranged from 17 percent in Category 2 waters, to 23 percent in both Category 1 and Category 3 waters (Table 3.7-2 through Table 3.7-4. Only two of the samples had concentrations in excess of the most stringent Alaska Water Quality Standard numeric criterion (5.2 µg/L, measured as WAD cyanide or equivalent) (Enos 2013b). Both of these samples were collected from Category 1 background locations outside of mineralized areas (17 µg/L at ACAW and 5.9 µg/L at ANDA), and may represent naturally occurring forms of cyanide described above. None of the samples collected from Category 2 and 3 sites had WAD cyanide concentrations greater than the most stringent criterion.

## Crooked Creek Watershed Loading Study

The term "loading" is defined as the mass of a chemical constituent or element that is discharged per unit time. It is calculated by multiplying the concentration of the chemical in the water by the measured volumetric discharge rate of water in a stream or river, or through a discharge structure (Tetra Tech 2013). As part of the baseline characterization of surface water quality in the Crooked Creek watershed, loading of several metals and other chemical constituents was analyzed based on concurrent water quality and flow measurements made between 2005 and 2010. The *Baseline Water Quality Loading Analysis* (Tetra Tech 2013) provides a characterization of the mass loading for selected chemical constituents at established sites within the Crooked Creek watershed. Key findings from the report are summarized below.

At the Donlin Gold project site, stream flow changes throughout the year, occurring as one of three main flow regimes: base flow, storm-generated flow, and spring breakup and runoff. Consistently high flows can be expected during spring breakup and runoff. Hydrographs from area gages indicate that relatively high stream flows can occur from late April through June,

depending on the year. Lower base flows occur in the summer and fall after spring runoff subsides, and in the winter under the snow pack. Storm events can occur anytime during the summer and fall months; however, they are generally more prominent in August and September (Tetra Tech 2013).

Both the concentrations of chemical constituents in the water, and the total mass loading at particular stations, are affected by seasonal changes in stream flow. Concentrations of some metals and other analytes often increase concomitant with stream flow, especially when the analyte of interest is present primarily in the particulate phase, associated with sediments or naturally occurring minerals. Higher stream discharge is usually associated with higher flow velocity, which entrains sediments from the substrate, increasing the total concentration of the analyte in the water (Tetra Tech 2013). Positive correlations between flow rate and the concentrations of total aluminum, iron, and manganese have been noted in area streams (ARCADIS 2012b; Tetra Tech 2013). In contrast, concentrations of other analytes, for example sulfates, may decrease with increasing stream flow as a result of dilution. Tetra Tech (2013) considered the correlations between stream flow and both total and dissolved phase concentrations of cadmium, copper, nickel, and zinc. Overall, the positive correlations between stream flow and total concentrations of these elements were consistent with what would be expected for analytes entrained from sediment and other solid material by high stream flow.

Loading records were calculated for all events where both stream flow and water quality data were concurrently measured (Table 3.7-1). The following general observations were made based on the individual event data (Tetra Tech 2013):

- In Snow Gulch, a Category 2 drainage, loads increase for most analytes as the drainage travels through mineralized zones, with up to an order of magnitude increase in load often observed between stations SNUP and SNDN. This trend is more prominent during spring runoff and storm-generated flow than during base flow. In contrast, loading increases only slightly near the mouth of the drainage (between stations SNDN and SNOW). For example, the average load of total iron during storm events increases substantially from 0.91 kg/day at Station SNUP to 7.0 kg/day at station SNDN, and increases only slightly more between there and station SNOW near the mouth (to 7.5 kg/day).
- Loads of most analytes are similar between Station DCBO on Donlin Creek, and Station CCBW just downstream of its confluence with Crooked Creek. This observation is generally true during all three flow regimes: base flow, storm flow, and spring breakup. Loading from Snow Gulch appears to have little influence on the load at Station CCBW, probably because of the relatively lower stream flow in Snow Gulch compared to Crooked Creek.
- American Creek was the smallest drainage evaluated. The data indicate that the range of flow values at Station AMER was small in relation to the other stations. Total daily loads of arsenic at AMER ranged from 0.11 to 0.32 kg/day, which represents approximately 17 percent of the total daily arsenic load in Crooked Creek at Station CCBO, located downstream of the confluence with American Creek.
- Similar to Snow Gulch, the loads for most analytes in American Creek increase as the creek flows through the mineralized zones. This trend is evident for all three flow regimes (base flow, storm flow, and spring breakup), but is most apparent during spring

runoff and storm flow events. Mean total iron loads increase substantially between Stations CCBW and CCBO, located on either side of the American Creek confluence, for all three flow regimes.

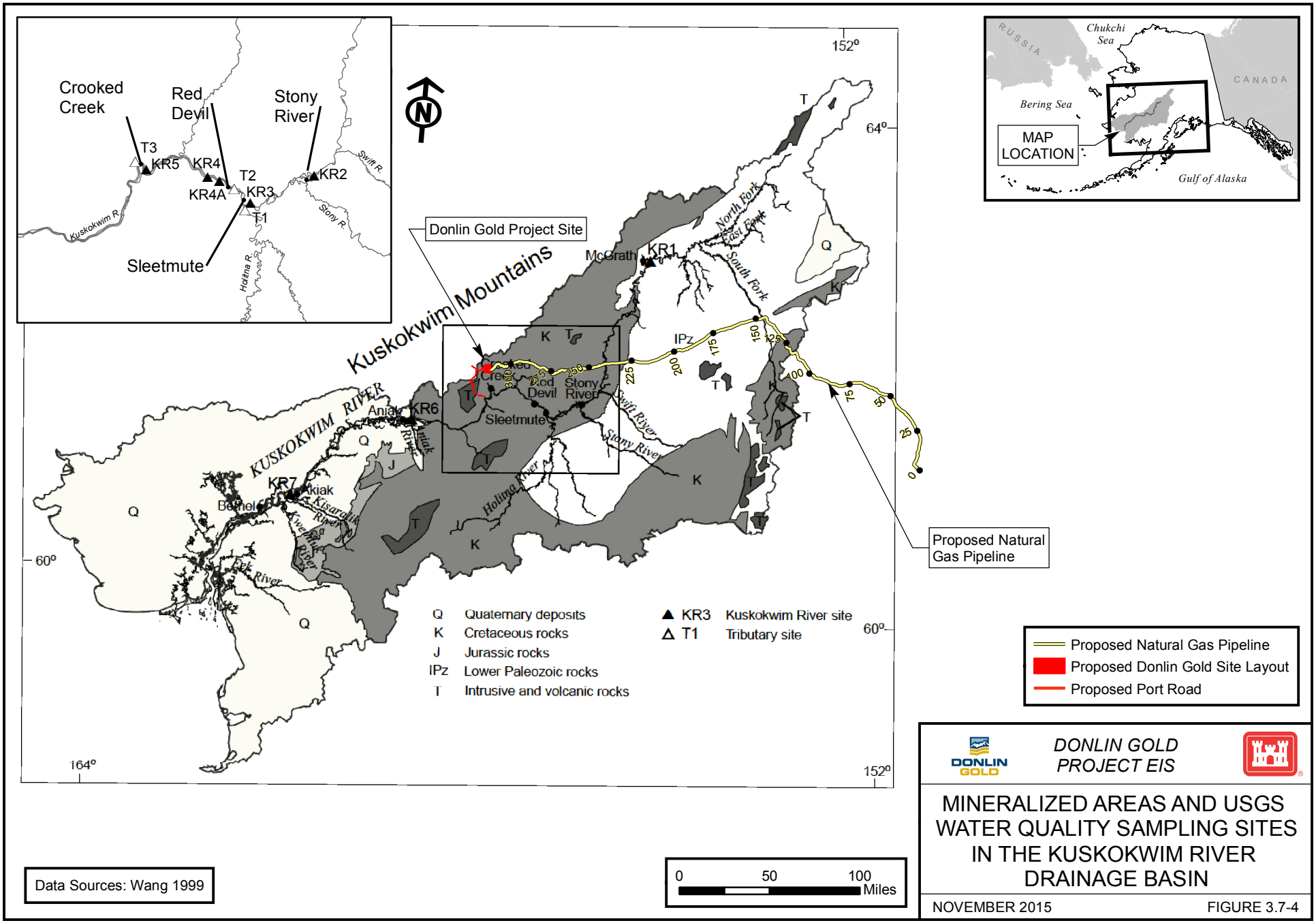
- Loads of analytes generally increase in Anaconda Creek from the upper part of the drainage to the mouth of the drainage across all three flow regimes. The increase in average load can be up to an order of magnitude for total aluminum, iron, and mercury. This trend is most prominent during spring runoff and storm events. For example, the average load of total iron during spring runoff increases from 16 kg/day at station ANUP to 103 kg/day at Station ANDA.
- Similar to Anaconda Creek, loads of most analytes in Crevice Creek generally increase from the upper part of the drainage to the mouth, and the trend is most noticable during spring runoff and storm events.
- The loads of most analytes increase approximately two to four times on Crooked Creek between Station CCBC below the proposed mine area and Station CCAK near the mouth of Crooked Creek. Evaluation of the observed analyte concentrations and flow data indicate that such increases are caused in part by large increases in flow between the two stations.

#### 3.7.2.1.2 TRANSPORTATION FACILITIES

Kuskokwim River

The primary body of water potentially affected by proposed transportation facilities is the Kuskokwim River, which drains a basin of over 50,000 square miles along its 700-mile course from Interior Alaska to the Bering Sea (Wang 1999). Water quality in the Kuskokwim River downstream from its confluence with Crooked Creek (the area considered within the transportation corridor for this analysis) is generally protected for all uses under the Alaska Water Quality Standards. Several villages between Crooked Creek and Bethel get their drinking water directly from the river (Section 3.5, Surface Water Hydrology).

The middle section of the Kuskokwim River runs through a highly mineralized region of Alaska that contains mercury, antimony, gold, silver, and polymetallic deposits (Szumigala and Weakland 2012). Although the Kuskokwim River basin is largely undeveloped, mining for placer gold and mercury have occurred in the basin. Remnant waste rock and ore from historic mining activities are still present at some sites and influence the distribution of chemical constituents in the Kuskokwim River (Wang 1999; BLM 2012e). Mineralized areas are primarily associated with Cretaceous-age sedimentary rock and Tertiary-age intrusives as shown on Figure 3.7-4. The Kuskokwim River is not industrially polluted, but it does have anomalous mercury content near naturally mineralized sources and historic mine sites (Nelson et al. 1977; BLM 2012e). The highest individual mercury anomalies occur near the largest mineralized sources of tributary streams, and the mercury content is rapidly diluted downstream (Nelson et al. 1977; Wang 1999). It is likely that some mercury from allochthonous sources (e.g., Asian coal) is present in the Kuskokwim River as a result of atmospheric transport and deposition; however, the spatial distributions of mercury concentrations in Kuskokwim River watersheds strongly suggest that local minerals are the predominant source of the mercury in the water.

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MINERALIZED AREAS AND USGS WATER QUALITY SAMPLING SITES IN THE KUSKOKWIM RIVER DRAINAGE BASIN

NOVEMBER 2015 FIGURE 3.7-4

Background water quality in the Kuskokwim River is described in the USGS Water-Resources Investigations Report 99-4177: *Spatial Distribution of Chemical Constituents in the Kuskokwim River* (Wang 1999), incorporated here by reference. The USGS has collected water quality data from the Kuskokwim River at the Crooked Creek confluence since 1951. Historical water quality data for the Kuskokwim River at Crooked Creek are summarized below and in Table 3.7-7:

In general, Kuskokwim River water, like Crooked Creek water, is classified as calcium to calcium-magnesium-bicarbonate water. Calcium and magnesium concentrations decrease down the main stem of the Kuskokwim, as do the bicarbonate and sulfate concentrations. However, the total loads of calcium, magnesium, bicarbonate, and sulfate generally increase at downstream locations as a result of increased volumetric flow rates.

Dissolved-iron concentrations increase downstream from McGrath and peak at Crooked Creek. Dissolved-iron concentrations in Crooked Creek are about four times greater than those in the Kuskokwim River, however the contribution of Crooked Creek to the dissolved-iron load in the Kuskokwim River is relatively minor, due to the much greater discharge of the Kuskokwim River (about 40,000 cubic feet per second [cfs]) relative to Crooked Creek (about 200 cfs).

Dissolved manganese concentrations are relatively uniform throughout the main stem of the Kuskokwim River, and are higher in Crooked Creek than in the main stem of the Kuskokwim River.

The highest concentrations of dissolved strontium and barium in Kuskokwim River water were measured upstream of the confluence with Crooked Creek, and concentrations of both dissolved strontium and barium decrease with distance downriver.

Total mercury concentrations in water samples from the main stem of the Kuskokwim River range from 1.9 to 9.7 ng/L, which are comparable to average total mercury concentrations in each of the three location categories in the Crooked Creek watershed (5.77 to 8.93 ng/L) measured as part of the Donlin Gold water quality characterization program (Table 3.7-2 through Table 3.7-4). Elevated concentrations of total mercury have been measured in Red Devil Creek; a tributary to the Kuskokwim River located about 30 miles upstream of Crooked Creek and not considered part of the proposed project area. In Red Devil Creek, total mercury exceeds the concentration at which the EPA indicates that aquatic life is affected; however, the elevated concentrations of total mercury in Red Devil Creek water do not substantially affect total mercury concentrations in the main stem of the Kuskokwim River because Red Devil Creek is small (discharge about 1 cfs) relative to the Kuskokwim River (about 40,000 cfs) (Wang 1999, BLM 2012e). A description of mercury transport at a regional scale by Nelson et al. (1977) suggests that mercury is concentrated in hotspots near lode sources, the influences of which decrease over short spatial scales due to the effects of dilution and mixing driven by water and sediment discharge in the main stem of the Kuskokwim River.

Nutrient concentrations are generally low throughout the lower Kuskokwim River system, and virtually all of the nitrogen present is in the form of nitrate (Wang 1999). The historical median suspended sediment concentration at the Kuskokwim River confluence with Crooked Creek during open water is 134 mg/L, with an inner quartile range from 87 to 223 mg/L (Table 3.7-7) (Wang 1999). The historical mean suspended sediment concentration at the Kuskokwim River confluence with Crooked Creek is 188 mg/L (Table 3.7-7) (Wang 1999). As a basis for comparison, the mean concentration of total suspended solids measured at Category 3 sites as part of the Donlin Gold Baseline Water Sampling Program was 25.7 mg/L. Thus, the mean

concentration of suspended sediment in the Kuskokwim River at its confluence with Crooked Creek is more than six times greater than the mean value recorded for the Category 3 sites, suggesting that concentrations of suspended sediment in the Kuskokwim River are generally much higher than those measured in Crooked Creek and other tributaries located downstream from the proposed mine location.

**Table 3.7-7: Historical Water Quality Data from Kuskokwim River at Crooked Creek**

| Property or constituent | Unit | Period of record | Mean | Median | Q1a | Q3b | Reporting Limit | Most Stringent Applicable Water Quality Criterion |
|---|---|---|---|---|---|---|---|---|
| Suspended sediment | mg/L | 1967-97 | 188 | 134 | 87 | 223 | 1.0 | 200[1] |
| Specific conductance | S/cm | 1951-98 | 171 | 176 | 152 | 193 | 1.0 | - |
| pH | pH units | 1951-98 | 7.6 | 7.6 | 7.3 | 7.8 | 0.1 | 6.5-8.5 |
| Dissolved oxygen | mg/L | 1975-97 | 10.6 | 10.3 | 9.9 | 11.25 | 0.1 | 7 (min) |
| Alkalinity | mg/L as $CaCO_3$ | 1951-97 | 70 | 73 | 64 | 80 | 1.0 | 20 (min) |
| Calcium | mg/L as Ca | 1951-96 | 24.6 | 25 | 21 | 28 | 0.1 | - |
| Magnesium | mg/L as Mg | 1951-96 | 5.6 | 5.5 | 4.6 | 6.4 | 0.1 | - |
| Sulfate | mg/L as $SO_4$ | 1951-96 | 16.7 | 17 | 13 | 20 | 0.1 | 250 |
| Silica | mg/L as $SiO_2$ | 1951-96 | 8.3 | 8 | 7.1 | 9.45 | 0.1 | - |
| Arsenic, total | µg/L as As | 1975-82 | 4.4 | 4 | 3 | 5 | 1 | 10 |
| Barium, dissolved | µg/L as Ba | 1980-96 | 35.9 | 35 | 30 | 41 | 1 | 2,000[2] |
| Iron, total | µg/L as Fe | 1975-82 | 5,440 | 4,500 | 3,700 | 7,300 | 10 | 1,000 |
| Iron, dissolved | µg/L as Fe | 1975-96 | 227 | 225 | 140 | 300 | 10 | - |
| Manganese, total | µg/L as Mn | 1975-82 | 130 | 130 | 80 | 170 | 10 | 50 |
| Manganese, dissolved | µg/L as Mn | 1975-96 | 12.2 | 6.5 | 5 | 9 | 4 | - |
| Strontium, dissolved | µg/L as Sr | 1975-96 | 130 | 140 | 99 | 160 | 10 | - |

**Notes:**

Samples collected during the open water period, mid-May to mid-October.

a 25th percentile

b 75th percentile

1 ADEC (2012d) specifies no measurable increase in concentration of settleable solids above natural conditions; for irrigation or water spreading, may not exceed 200 mg/l for an extended period of time. In addition, the water quality standard requires no measureable increase in concentration of settleable solids above natural conditions, as measured by the volumetric Imhoff cone method.

2 ADEC (2008a) WQS for barium expressed as total concentration.

Source: Wang 1999.

In addition to the USGS data describing the spatial distribution of chemical constituents in the Kuskokwim River, the Georgetown Tribal Council has conducted baseline water quality monitoring and analyses describing surface water quality at a site located in the main stem of the Kuskokwim River adjacent to Georgetown, Alaska, beginning in 2008 (Schaberg 2014). The Georgetown Tribal Council baseline water quality sampling project was initiated due to impending development in the area, including the Donlin Gold Project. The primary goal of water quality monitoring was to document existing conditions in Georgetown prior to development in the area (Schaberg 2014). The water quality analyses conducted by the Georgetown Tribal Council from 2008 through 2013 indicate that pH values at the Kuskokwim River site were within acceptable pH range, according to ADEC standards. The average pH at the Kuskokwim River site was 7.7 ± 0.5 (Schaberg 2014). Likewise, measured levels of dissolved oxygen were within the range specified by the most stringent applicable water quality standards. The average dissolved oxygen concentration at the Kuskokwim River site was 12.7 mg/L ± 2.8 and concentrations of dissolved oxygen do not appear to be trending upward or downward in any way (Schaberg 2014). Arsenic, barium, chromium, lead, and vanadium measured at the Kuskokwim River site were present at very low levels; well below the thresholds specified by the applicable water quality criteria (Schaberg 2014). Cadmium was never detected at the Kuskokwim River site used for the Georgetown Tribal Council Water Quality Monitoring Program (Schaberg 2014). During a single sampling event in September 2013, the analysis for semi-volatile organic compounds (SVOCs) detected bis-2-ethylhexyl phthalate, also known as DEHP, in a sample of the Kuskokwim River water at a concentration of 0.010 mg/L (Schaberg 2014). The EPA has established an MCL of 0.006 mg/L for this contaminant. Although the concentration of DEHP measured in the Kuskokwim River water in September 2013 exceeds the MCL, it is possible that sample contamination was responsible for the elevated concentration of DEHP and ongoing testing conducted by the Georgetown Tribal Council will continue to monitor levels of SVOCs and other potential contaminants of concern in the Kuskokwim River at Georgetown (Schaberg 2014).

### Angyaruaq (Jungjuk) and Birch Tree Crossing Roads

Most of the proposed mine access road to the potential Jungjuk Port, and the initial section of the proposed BTC Road (Alternative 4), would be located in the Crooked Creek drainage basin. The southern portion of the proposed mine access road would be located in the Jungjuk Creek drainage, a separate tributary to Kuskokwim River. The proposed airstrip, some material sites, a short northern section of the mine access road, and the central portion of the proposed BTC Road would be located in the headwaters of the Iditarod River, which flows northwest into the Yukon River. Additional tributaries to the Kuskokwim River, such as the Owhat River, would be crossed by the western portion of the BTC Road (see Section 3.5, Surface Water Hydrology).

Surface water quality in the Crooked Creek watershed is described in detail in Section 3.7.2.1.1. Sampling location GETM2 provides baseline water quality data for the Getmuna Creek, a major tributary to Crooked Creek that would be crossed by the mine access road. Factors affecting water quality in Crooked Creek, such as trends correlated to mineralized areas, may be similar for Jungjuk Creek, and the Iditarod and Owhat rivers. While the specific prospect targeted by the proposed mine does not extend south of American Creek, bedrock types and mineralization similar to those that host the Donlin Gold prospect extend throughout the proposed mine access road and about half of the potential BTC Road (Figure 3.7-4) (e.g., Bundtzen and Laird 1991).

Jungjuk Creek has clear water, a moderate gradient, and a gravel/cobble-dominated substrate. Beaver activity is present in much of the drainage basin (OtterTail Environmental Inc. 2012f, Recon 2011b). Likewise, Owhat River has a gravel and cobble streambed. The Iditarod River and a number of smaller drainages crossed by the western part of the BTC route contain mucky stream bottoms in permafrost thermokarst terrain (RECON 2007c).

Dutch Harbor Fuel Storage Facility

As described in Section 3.2, Soils, a number of ADEC contaminated sites have been documented in Dutch Harbor near potential locations of the proposed fuel storage facility expansion. These are related to numerous historical spills in and near the harbor from decades of fuel shipping and handling in the area.

#### 3.7.2.1.3 PIPELINE

The proposed pipeline would be located in a sparsely populated portion of Alaska and as such, limited water quality data are available to characterize surface water quality in the vicinity of the potential pipeline corridor. The proposed corridor crosses more than 400 individual streams ranging in size from small, intermittent channels to large glacially fed river systems (CH2MHill 2011c). Multiple data sources were queried for surface water quality information to provide a generalized characterization for the area, including the USGS National Water Information System (NWIS).

Nine NWIS surface water monitoring stations occur within watersheds crossed by the proposed pipeline route. These stations are located in the following watersheds (Section 3.5, Surface Water Hydrology, Figure 3.5-16):

- Susitna River–Frontal Cook Inlet
- Lower Skwentna River
- George River
- Crooked Creek

The NWIS data span from 1959 to 2007, and are a compilation of many discrete water quality analyses. Therefore, not all of the same water quality data are available for all of the sampling locations. Similarly, not all areas were sampled during the same time periods. In addition, most of the NWIS sampling locations were not located adjacent to the proposed pipeline corridor; and the data are not necessarily representative of surface water quality along the potential pipeline route. For these reasons, the NWIS water quality data are not considered further as a source of information about baseline water quality along the proposed pipeline route.

Water quality field measurements (including pH, temperature, conductivity, color, and turbidity) were collected during the Donlin Gold aquatic resources surveys at about half of the stream crossings along the proposed pipeline route in 2010. The results are summarized in (Table 3.7-8) and described below (OtterTail 2012c):

Values of pH ranged widely from 3.6 to 9.6 for the 394 measurements. The arithmetic average was 7.55, and the pH value equivalent to the $-\log_{10}$ arithmetic average of hydrogen ion concentrations was 6.05. A review of the individual pH data indicate that the highest and lowest values are likely data outliers, as 95 percent of the measured pH values are between 6.0

and 9.0. The most stringent ADEC WQS (fresh water supply – aquaculture) for pH are 6.5-8.5 or not more than 0.5 pH unit from natural conditions; 74 percent of the measured values are within the range of 6.5-8.5.

The average of 434 temperature measurements was 45.7°F (7.6°C). ADEC WQS (fresh water supply – aquaculture) for temperature range from a maximum of 13°C for spawning and incubation areas, to no more than 20°C at any time. Of the total number of temperature measurements collected, 32 (or 7.4 percent) exceeded the most stringent WQS of 13°C, and none exceeded 20°C.

Baseline turbidity measurements along the proposed pipeline route ranged from 0.06 to 500 Nephelometric Turbidity Units (NTU). The most stringent ADEC WQS for fresh water streams (water supply for drinking and contact recreation) specifies that turbidity may not exceed 5 NTU above natural conditions when the natural turbidity is 50 NTU or less, and may not have more than 10 percent increase in turbidity when the natural turbidity is more than 50 NTU, not to exceed a maximum increase of 25 NTU.

Some of the highest turbidity values were measured in the Middle Fork Kuskokwim River and in two of its tributaries (Figure 3.7-5) with baseline turbidity values ranging from 58.4 to 165 NTU, values which are probably related to naturally high levels of glacial silt or fine-grained soils in the area. Surficial deposits and soil/bank erosion conditions that provide an indication of possible sources of naturally high turbidity levels are described in Sections 3.1, Geology and 3.2, Soils, respectively.

There are no WQS for conductivity. Color was recorded at some stream crossings based on qualitative descriptors that are not comparable to WQS color units.

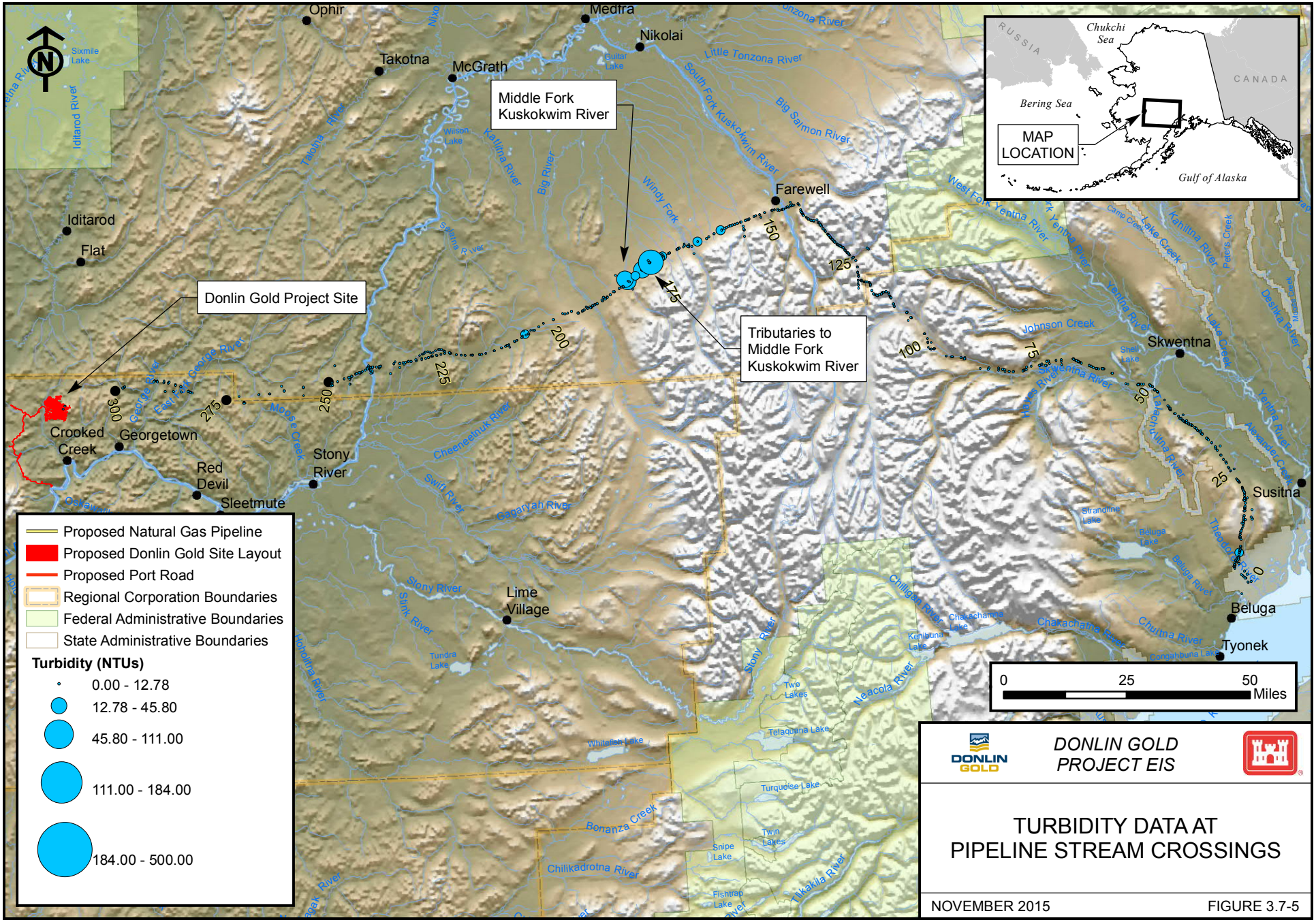
**Table 3.7-8: Summary of Surface Water Quality Field Measurements along Proposed Pipeline Route**

| Parameter | Units | Number of Measurements (n) | Range of Measured Values | Arithmetic Average |
|---|---|---|---|---|
| pH | pH units | 394 | 3.6 – 9.6 | 7.55[a] |
| Turbidity | NTU | 182 | 0.06 - 500 | 12.2 |
| Conductivity | µS/cm | 447 | 1 - 2000 | 244 |
| Water Temperature | Degrees C | 434 | 1.17 – 16.6 | 7.62 |

**Notes:**

a average – $\log_{10}[H^+] = 6.05$

Source: OtterTail 2012c.


Middle Fork Kuskokwim River
Donlin Gold Project Site
Tributaries to Middle Fork Kuskokwim River
Ophir
Medfra
Nikolai
Takotna
McGrath
Farewell
Iditarod
Flat
Crooked Creek
Georgetown
Red Devil
Sleetmute
Stony River
Lime Village
Skwentna
Susitna
Beluga
Tyonek
Little Tonzona River
South Fork Kuskokwim River
Big Salmon River
Windy Fork
Kahiltna River
Big River
Takotna River
Iditarod River
Sixmile Lake
Wilson Lake
Guitar Lake
Selma River
Cheenneetnuk River
Swift River
Gagaryah River
Stony River
Stink River
Kuholina River
Tundra Lake
Bonanza Creek
Chilikadrotna River
Tikkakila River
Fishtrap Lake
Snipe Lake
Twin Lakes
Turquoise Lake
Telaquana Lake
Whitefish Lake
Two Lakes
Neacola River
Chilligan River
Chakachatna River
Chuitna River
Beluga River
Beluga Lake
Strandline Lake
Theodore River
Johnson Creek
Yentna River
West Fork Yentna River
Skwentna River
Lake Creek
Peters Creek
Deshka River
Alexander Creek
Meeks Creek
East Fork George River
George River
Chakachamna Lake
Kenibuna Lake
Congahbuna Lake
Shell Lake
Camp Creek
Proposed Natural Gas Pipeline
Proposed Donlin Gold Site Layout
Proposed Port Road
Regional Corporation Boundaries
Federal Administrative Boundaries
State Administrative Boundaries
Turbidity (NTUs)
0.00 - 12.78
12.78 - 45.80
45.80 - 111.00
111.00 - 184.00
184.00 - 500.00
0
25
50
Miles
RUSSIA
Chukchi Sea
CANADA
Bering Sea
MAP LOCATION
Gulf of Alaska
DONLIN GOLD
DONLIN GOLD PROJECT EIS
TURBIDITY DATA AT PIPELINE STREAM CROSSINGS
NOVEMBER 2015
FIGURE 3.7-5

### 3.7.2.2 GROUNDWATER QUALITY

#### 3.7.2.2.1 MINE SITE

Background

Groundwater in the vicinity of the proposed mine site occurs in three main hydrogeologic environments: an alluvium unit, a colluvial layer, and an underlying bedrock unit (ARCADIS 2012b). The alluvium unit is primarily associated with Crooked Creek (BGC 2007a). The relatively thin colluvial layer is present along gently sloping valley walls and valley bottoms, and the bedrock unit consists primarily of siltstones, shales, graywacke, and intrusives (ARCADIS 2012b). A complete description of geology and groundwater occurrence at the mine site, including discussion of geologic ages and aquifer properties of the alluvium, colluvium, and bedrock units, is provided in Section 3.1, Geology and Section 3.6, Groundwater Hydrology.

The main sources of recharge to the groundwater system are rainfall and snowmelt, and to a lesser extent, infiltration from stream beds. Groundwater discharge occurs through creeks, streams, and gulches, and also through evapotranspiration. In general, the level of the water table mimics the surface topography, with the greatest depths to groundwater occurring in upland areas and shallowest depths to groundwater in the valley bottoms and low-lying areas (BGC 2007a).

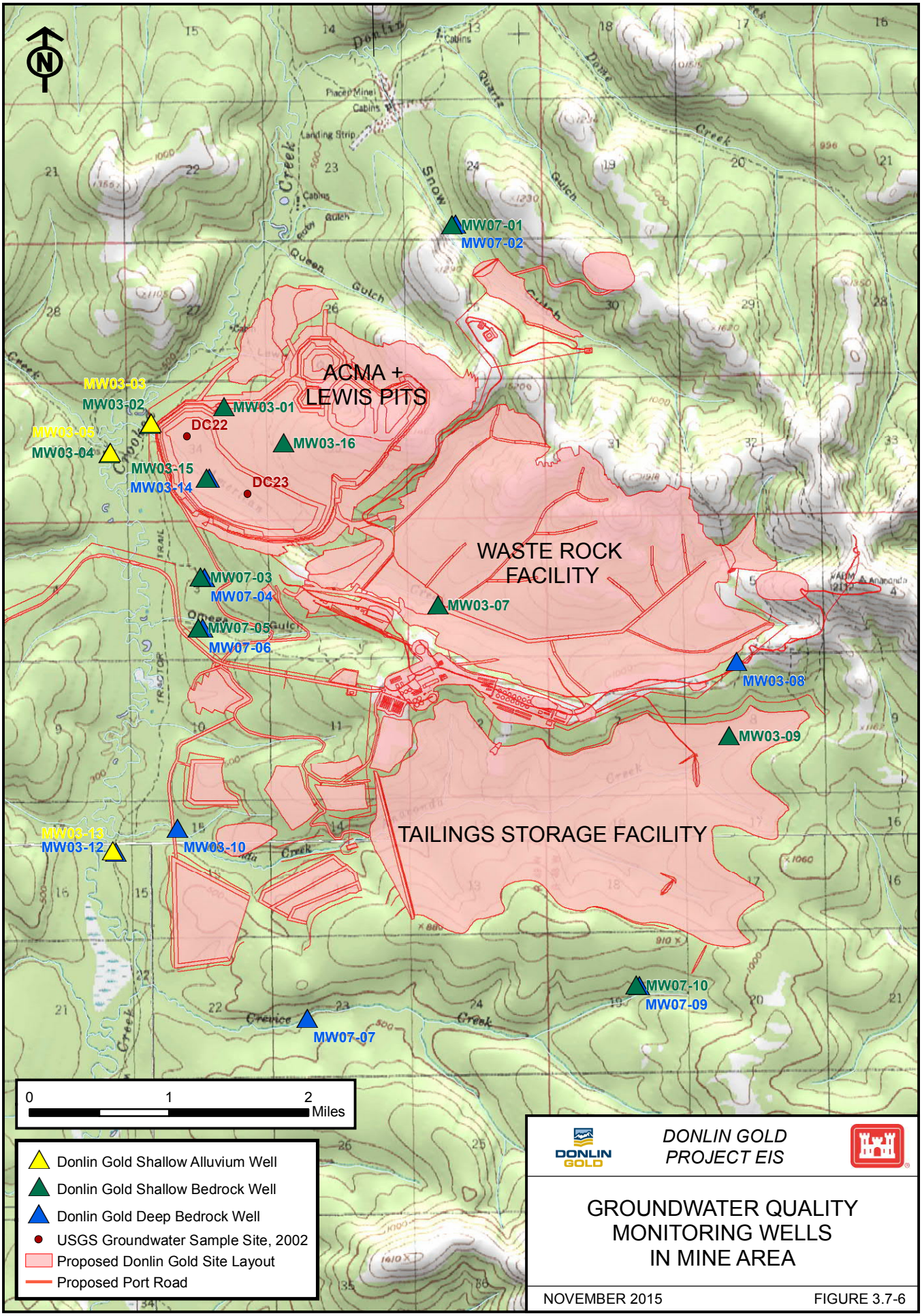
Donlin Gold Groundwater Quality Characterization Program

*Sampling and Analytical Program*

A total of 23 wells comprise the groundwater monitoring network at the Donlin Gold proposed project site. Monitoring locations were established to characterize the groundwater system both upgradient and downgradient of each major proposed mine facility. Sixteen monitoring wells (MW03 series) were installed in late 2003, and 14 of these were initially sampled during the first quarter of 2004 and quarterly thereafter. Ten additional wells (MW07 series) were installed in late 2007, and one well was not sampled due to an ice plug. These MW07 series wells have been sampled quarterly beginning in 2008 (ARCADIS 2012b). Additional wells, designated as MW05 and MW13 series, were completed as observation points for pumping tests and sampled during the tests (e.g., BCG 2014f).

For the purposes of this analysis, wells with quarterly monitoring data were grouped into shallow and deep categories. The shallow category includes wells less than about 75 feet deep; these range in depth from roughly 15 to 30 feet for the alluvial wells, and 20 to 75 feet for the shallow bedrock wells. The deep category includes wells greater than 75 feet deep; these range in depth from 75 to more than 500 feet (BGC 2007a, 2011d).

Table 3.7-9 summarizes the well locations, related mine facilities, and sampling information for the monitoring wells that are part of Donlin Gold's groundwater quality sampling program, and Figure 3.7-6 shows the well locations.

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GROUNDWATER QUALITY MONITORING WELLS IN MINE AREA

NOVEMBER 2015

FIGURE 3.7-6

*Study Results*

A summary of groundwater quality data collected during Donlin Gold's groundwater quality sampling program is provided in Table 3.7-10 and Table 3.7-11. Data are divided between shallow and deep categories as specified in Table 3.7-9.

The following analytes occurred at concentrations above the ADEC (2008a) WQS in at least one water sample from the shallow wells:

- Ammonia (as N), aluminum (total), antimony (total), arsenic (total), barium (total), cobalt (total), copper (total), iron (total), lead (total), manganese (total), nickel (total), and total dissolved solids exceeded the ADEC water quality standard (ADEC 2008a).
- Measured pH values (field) ranged from 4.35 to 13.84; with some measured pH values outside of the range specified by the ADEC water quality standard (ADEC 2008a).

The following analytes were measured at concentrations above the ADEC (2008) WQS in at least one water sample from the deep wells:

- Ammonia (as N), aluminum (total), antimony (total), arsenic (total), barium (total), iron (total), manganese (total), molybdenum (total), nickel (total), selenium (total), thallium (total), total dissolved solids, and fluoride exceeded the ADEC (2008a) standards.
- Measured pH values (field) ranged from 6.02 to 9.98; with some measured pH values outside of the range specified by the ADEC water quality standard (ADEC 2008a).

It should be noted that the EPA MCLs for Aluminum, Chloride, Copper, Fluoride, Iron, Manganese, pH, Silver, Sulfate, TDS, and Zinc are Secondary Drinking Water Regulations that set non-mandatory water quality standards. EPA does not enforce these secondary maximum contaminant levels, which are primarily for taste and aesthetics, not health benefits. EPA recommends them to States as reasonable goals, but federal law does not require compliance with them. ADEC has, however, adopted their own enforceable regulations governing the concentrations of these constituents in drinking water systems.

BGC (2007a) noted that there appeared to be slight differences in groundwater composition between bedrock wells in the vicinity of the ore body compared to bedrock wells outside this zone (BGC 2007a). For example, ranges of TDS, arsenic, and iron were slightly higher in the vicinity of the proposed pit than outside the mineralized area. In addition, within the vicinity of the ore body, there appeared to be some variation of water quality with depth. These observations generally hold true with the current dataset. For example, arsenic is notably higher in the shallow wells (mean $[As]_{total}$ = 0.204 mg/L) than the deep wells (mean $[As]_{total}$ = 0.053 mg/L).

*Averages*

Due to limitations of chemical analysis procedures, small concentrations cannot be precisely measured. These concentrations are said to be below the limit of detection (LOD). In statistical analyses, these values are often censored and substituted with a constant value, such as half the LOD. The arithmetic average values reported in Table 3.7-10 and Table 3.7-11 represent the averages of measured concentrations that are greater than the reporting limit for a given analysis. Results that are below the reporting limit for the analysis are replaced with a value equivalent to one-half of the reporting limit for the analysis for the purpose of calculating the average values reported in the tables.

**Table 3.7-9: Groundwater Quality Monitoring Well Locations**

| Well ID | UTM Zone 4, NAD83 | | Category | Target |
|---|---|---|---|---|
| | Easting | Northing | | |
| MW03-01 | 539999 | 6879366 | Shallow | Shallow Downgradient from mineralized zone |
| MW03-02 | 539144 | 6879164 | Shallow | Shallow Bedrock downgradient from pit / upstream from American Creek |
| MW03-03 | 539163 | 6879178 | Shallow | Alluvium downgradient from pit / upstream from American Creek |
| MW03-04 | 538680 | 6878830 | Shallow | Shallow Bedrock downgradient from pit / downstream from American Creek |
| MW03-05 | 538685 | 6878841 | Shallow | Alluvium downgradient from pit / downstream from American Creek |
| MW03-07 | 542470 | 6877084 | Shallow | Shallow Bedrock Downgradient from the proposed waste rock facilities |
| MW03-08 | 545875 | 6876430 | Deep | Deep Bedrock Upgradient from the proposed waste rock facilities |
| MW03-09 | 545829 | 6875574 | Shallow | Shallow Bedrock Upgradient from the proposed tailings facility |
| MW03-10 | 539423 | 6874503 | Deep | Deep bedrock groundwater downgradient from proposed tailings facility |
| MW03-12 | 538714 | 6874223 | Deep | Deep Bedrock downgradient from proposed tailings / downstream from Anaconda Creek |
| MW03-13 | 538719 | 6874245 | Shallow | Alluvium downgradient from proposed tailings / downstream from Anaconda Creek |
| MW03-14 | 539782 | 6878537 | Deep | Existing deep bedrock groundwater quality in the mineralized zone |
| MW03-15 | 539797 | 6878539 | Shallow | Existing shallow bedrock groundwater quality in the mineralized zone |
| MW03-16 | 540692 | 6878952 | Shallow | Shallow bedrock groundwater upgradient from the proposed pit |
| MW07-01 | 542627 | 6881469 | Shallow | Shallow bedrock groundwater - Snow Gulch |
| MW07-02 | 542627 | 6881477 | Deep | Deep bedrock groundwater - Snow Gulch |
| MW07-03 | 539729 | 6877401 | Shallow | Shallow bedrock groundwater - downgradient from process facility – Omega North |
| MW07-04 | 539734 | 6877400 | Deep | Deep bedrock groundwater - downgradient from process facility – Omega North |
| MW07-05 | 539703 | 6876817 | Shallow | Shallow bedrock groundwater - downgradient from process facility – Omega Gulch |
| MW07-06 | 539714 | 6876812 | Deep | Deep bedrock groundwater - downgradient from process facility – Omega Gulch |
| MW07-07 | 540910 | 6872313 | Deep | Deep bedrock groundwater - downgradient of potential water diversion from Anaconda to Crevice Creek |
| MW07-09 | 544752 | 6872692 | Deep | Deep bedrock groundwater - upgradient of potential water diversion from Anaconda to Crevice Creek |
| MW07-10 | 544752 | 6872692 | Shallow | Shallow bedrock groundwater - upgradient of potential water diversion from Anaconda to Crevice Creek |

Source: ARCADIS 2012b; BGC 2007a.

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**Table 3.7-10: Groundwater Quality Summary for Shallow Mine Site Wells**

| Analyte | Units | Frequency of Detection | | Range of Detection Limits (Reporting) | Range of Detection Limits (Method) | Range of Detected Concentrations[4] | Arithmetic Average Concentration[3] | Maximum Sample Location | Alaska Most Stringent Applicable Water Quality Criterion | Max Detects Exceeds Alaska Criterion |
|---|---|---|---|---|---|---|---|---|---|---|
| **Major Cations** | | | | | | | | | | |
| Calcium, Dissolved | mg/L | 448/448 | 100.0% | 0.1-2.00 | 0.031-0.75 | 6.2-72.3 | 30.9 | MW03-16 | - | - |
| Magnesium, Dissolved | mg/L | 449/449 | 100.0% | 0.03-2.00 | 0.015-0.62 | 0.986-30.3 | 9.35 | MW03-16 | - | - |
| Potassium, Dissolved | mg/L | 437/444 | 98.4% | 0.3-4.00 | 0.15-1.2 | 0.237-2.31 | 0.85 | MW03-02 | - | - |
| Sodium, Dissolved | mg/L | 441/443 | 99.5% | 0.005-20.0 | 0.0015-6.00 | 1.13-124 | 17.6 | MW03-02 | - | - |
| **Major Anions** | | | | | | | | | | |
| Total Alkalinity (as $CaCO_3$) | mg/L | 448/448 | 100.0% | 0.02-40.0 | 2.00-12.4 | 21.2-1.300 | 143 | MW03-01 | - | - |
| Bicarbonate | mg/L | 407/407 | 100.0% | 0.02-40.0 | 2.00-12.4 | 21.2-1,300 | 142 | MW03-01 | - | - |
| Fluoride | mg/L | 389/399 | 97.5% | 0.062-2.5 | 0.031-2.00 | 0.038-0.753 | 0.12 | MW03-13 | 1[2e] | No |
| Sulfate | mg/L | 447/448 | 99.8% | 0.062-50.0 | 0.031-10.0 | 0.659-117 | 14.8 | MW03-16 | 250[1] | No |
| Chloride | mg/L | 446/448 | 99.6% | 0.062-12.5 | 0.031-10.0 | 0.223-20.1 | 0.77 | MW03-16 | - | - |
| **Nutrients** | | | | | | | | | | |
| Nitrite + Nitrate(as N) | mg/L | 302/448 | 67.4% | 0.062-1.00 | 0.02-0.31 | 0.031-5.96 | 0.25 | MW03-01 | 10[2d] | No |
| Ammonia (as N) | mg/L | 357/441 | 81.0% | 0.02-0.2 | 0.031-0.1 | 0.0333-2.09 | 0.36 | MW03-03 | 0.18[2h] | Yes |
| **Cyanide** | | | | | | | | | | |
| Total Cyanide | µg/L | 93/445 | 20.9% | 3.00-10.0 | 1.5-3.00 | 1.5-9.2 | 2.64 | MW03-15 | - | - |
| Wad Cyanide | µg/L | 92/444 | 20.7% | 3.00-10.0 | 1.5-3.00 | 1.5-7.00 | 2.6 | MW03-13 | 200[2d] | No |
| **Metals** | | | | | | | | | | |
| Mercury | ng/L | 329/444 | 74.1% | 0.5-10.0 | 0.1-5.00 | 0.515-265 | 5.49 | MW07-01 | 2,000[2d] | No |
| Aluminum, Dissolved | µg/L | 148/369 | 40.1% | 1.00-62.0 | 1.00-31.0 | 5.00-3,810 | 36.1 | MW03-13 | - | - |
| Aluminum | µg/L | 347/447 | 77.6% | 1.00-400 | 1.00-62.0 | 6.2-9,180 | 410 | MW03-13 | 5,000[2e] | Yes |
| Antimony, Dissolved | µg/L | 61/369 | 16.5% | 0.4-10.0 | 0.31-10.0 | 0.313-508 | 4.37 | MW03-16 | - | - |
| Antimony | µg/L | 68/448 | 15.2% | 0.4-5.00 | 0.31-1.55 | 0.317-613 | 4.05 | MW03-16 | 6[2d] | Yes |
| Arsenic, Dissolved | µg/L | 274/369 | 74.3% | 0.5-25.0 | 0.2-12.5 | 1.64-2,250 | 145 | MW03-16 | - | - |
| Arsenic | µg/L | 350/448 | 78.1% | 0.5-25.0 | 0.2-12.5 | 1.1-2,340 | 165 | MW03-16 | 10[2d] | Yes |
| Barium, Dissolved | µg/L | 366/368 | 99.5% | 0.5-30.0 | 0.5-10.0 | 5.11-1,750 | 445 | MW03-13 | - | - |
| Barium | µg/L | 446/448 | 99.6% | 0.5-30.0 | 0.5-5.00 | 5.49-2,040 | 480 | MW03-02 | 2,000[2d] | Yes |
| Beryllium, Dissolved | µg/L | 10/369 | 2.7% | 0.1-3.00 | 0.1-3.00 | 0.147-0.57 | 0.21 | MW03-02 | - | - |
| Beryllium | µg/L | 47/448 | 10.5% | 0.1-400 | 0.1-0.65 | 0.131-1.76 | 0.22 | MW03-16 | 4[2d] | No |
| Boron, Dissolved | µg/L | 193/325 | 59.4% | 10.0-250 | 3.1-75.0 | 3.2-158 | 33.0 | MW03-02 | - | - |
| Boron | µg/L | 269/405 | 66.4% | 10.0-250 | 3.1-75.0 | 3.23-138 | 32.9 | MW03-02 | 750[2e] | No |
| Cadmium, Dissolved | µg/L | 4/369 | 1.1% | 0.1-3.00 | 0.05-3.00 | 0.053-0.253 | 0.24 | MW03-07 | - | - |

**Table 3.7-10: Groundwater Quality Summary for Shallow Mine Site Wells**

| Analyte | Units | Frequency of Detection | | Range of Detection Limits (Reporting) | Range of Detection Limits (Method) | Range of Detected Concentrations[4] | Arithmetic Average Concentration[3] | Maximum Sample Location | Alaska Most Stringent Applicable Water Quality Criterion | Max Detects Exceeds Alaska Criterion |
|---|---|---|---|---|---|---|---|---|---|---|
| Cadmium | µg/L | 23/448 | 5.1% | 0.1-2.5 | 0.05-0.75 | 0.059-1.72 | 0.25 | MW03-16 | 5[2d] | No |
| Chromium, Dissolved | µg/L | 87/369 | 23.6% | 0.5-10.0 | 0.31-10.0 | 0.378-6.88 | 1.09 | MW03-13 | - | - |
| Chromium | µg/L | 187/448 | 41.7% | 0.5-10.0 | 0.31-3.1 | 0.328-12.0 | 1.44 | MW03-16 | 100[2d] | No |
| Cobalt, Dissolved | µg/L | 63/369 | 17.1% | 0.05-20.0 | 0.05-6.00 | 0.13-3,670 | 20.7 | MW03-16 | - | - |
| Cobalt | µg/L | 51/448 | 11.4% | 0.05-20.0 | 0.05-6.00 | 0.07-2,910 | 8.52 | MW03-07 | 50[2e] | Yes |
| Copper, Dissolved | µg/L | 150/369 | 40.7% | 0.5-10.0 | 0.31-10.0 | 0.312-448 | 1.87 | MW03-16 | - | - |
| Copper | µg/L | 300/448 | 67.0% | 0.5-3.1 | 0.31-1.55 | 0.315-904 | 4.46 | MW03-16 | 200[2e] | Yes |
| Iron, Dissolved | µg/L | 297/368 | 80.7% | 20.0-780 | 6.2-390 | 7.04-52,600 | 6900 | MW03-03 | - | - |
| Iron | µg/L | 437/448 | 97.5% | 20.0-1,000 | 6.2-390 | 36.1-53,100 | 8011 | MW03-03 | 5,000[2e] | Yes |
| Lead, Dissolved | µg/L | 86/369 | 23.3% | 0.124-10.0 | 0.062-3.00 | 0.062-6.07 | 0.18 | MW03-13 | - | - |
| Lead | µg/L | 324/448 | 72.3% | 0.124-200 | 0.062-0.31 | 0.0621-174 | 1.06 | MW03-07 | 50[2e] | Yes |
| Lithium, Dissolved | µg/L | 239/328 | 72.9% | 6.2-100 | 3.1-20.0 | 3.3-78.0 | 16.3 | MW03-02 | - | - |
| Lithium | µg/L | 263/357 | 73.7% | 6.2-100 | 3.1-20.0 | 3.13-80.0 | 16.5 | MW03-02 | 2,500[2e] | No |
| Manganese, Dissolved | µg/L | 367/369 | 99.5% | 0.62-30.0 | 0.31-10.0 | 0.31-1,530 | 520 | MW03-05 | - | - |
| Manganese | µg/L | 447/448 | 99.8% | 0.5-30.0 | 0.31-5.00 | 0.55-2,650 | 551 | MW07-03 | 200[2e] | Yes |
| Molybdenum, Dissolved | µg/L | 3/369 | 0.8% | 0.5-60.0 | 0.5-15.5 | 0.7-0.7 | 5.08 | MW03-05 | - | - |
| Molybdenum | µg/L | 9/448 | 2.0% | 0.5-50.0 | 0.5-15.5 | 0.6-5.00 | 4.99 | MW03-07 | 10[2e] | No |
| Nickel, Dissolved | µg/L | 287/369 | 77.8% | 1.24-80.0 | 0.6-20.0 | 0.628-859 | 4.15 | MW03-07 | - | - |
| Nickel | µg/L | 383/448 | 85.5% | 1.24-6.2 | 0.6-3.1 | 0.628-1,060 | 4.43 | MW03-07 | 200[2e] | Yes |
| Selenium, Dissolved | µg/L | 8/368 | 2.2% | 0.3-25.0 | 0.1-7.5 | 1.54-9.01 | 2.53 | MW03-13 | - | - |
| Selenium | µg/L | 8/448 | 1.8% | 0.3-25.0 | 0.1-7.5 | 0.1-3.63 | 2.49 | MW03-05 | 10[2e] | No |
| Silver, Dissolved | µg/L | 0/368 | 0.0% | 0.3-6.00 | 0.05-1.55 | - | 0.51 | - | - | - |
| Silver | µg/L | 2/448 | 0.4% | 0.3-5.00 | 0.05-1.55 | 0.1-0.332 | 0.5 | MW03-03 | - | |
| Thallium, Dissolved | µg/L | 1/368 | 0.3% | 0.5-10.0 | 0.1-3.00 | 0.365-0.365 | 0.51 | MW07-05 | - | - |
| Thallium | µg/L | 12/448 | 2.7% | 0.5-5.00 | 0.1-1.55 | 0.31-0.794 | 0.5 | MW03-16 | 2[2f] | No |
| Vanadium, Dissolved | µg/L | 2/368 | 0.5% | 1.00-100 | 0.2-31.0 | 0.2-0.4 | 10.0 | MW03-03 | - | - |
| Vanadium | µg/L | 15/448 | 3.3% | 1.00-100 | 0.2-31.0 | 0.5-21.7 | 9.98 | MW03-13 | 100[2e] | No |
| Zinc, Dissolved | µg/L | 192/368 | 52.2% | 2.00-100 | 1.5-50.0 | 1.74-4770 | 20.8 | MW03-16 | - | - |
| Zinc | µg/L | 306/448 | 68.3% | 2.00-25.0 | 1.5-12.5 | 1.66-253 | 12.6 | MW03-13 | 2,000[2e] | No |
| **General Water Quality Parameters** | | | | | | | | | | |
| Hardness ($CaCO_3$), Dissolved | mg/L | 448/448 | 100.0% | 1.00-7.00 | 1.00-5.00 | 12.2-302 | 115 | MW03-16 | - | - |
| Total Dissolved Solids | mg/L | 448/448 | 100.0% | 6.2-50.0 | 3.1-10.0 | 35.0-780 | 173 | MW03-02 | 500[1] | Yes |

**Table 3.7-10: Groundwater Quality Summary for Shallow Mine Site Wells**

| Analyte | Units | Frequency of Detection | | Range of Detection Limits (Reporting) | Range of Detection Limits (Method) | Range of Detected Concentrations[4] | Arithmetic Average Concentration[3] | Maximum Sample Location | Alaska Most Stringent Applicable Water Quality Criterion | Max Detects Exceeds Alaska Criterion |
|---|---|---|---|---|---|---|---|---|---|---|
| Total Suspended Solids | mg/L | 441/443 | 99.5% | 0.294-15.0 | 0.142-10.0 | 0.198-580 | 31.3 | MW03-13 | - | - |
| **Field Parameters** | | | | | | | | | | |
| Conductivity (Lab) | µS/cm | 446/446 | 100.0% | 0.954-10.0 | 0.477-1.00 | 105-6,000 | 304 | MW03-02 | - | - |
| Conductivity, Field | µS/cm | 429/429 | 100.0% | - | - | 56.0-5,660 | 216 | MW03-13 | - | - |
| Dissolved Oxygen, Field | mg/L | 409/409 | 100.0% | - | - | 0.37-80.04 | 5.44 | MW03-02 | - | - |
| Ox./Reduc. Pot.(ORP/eH), Field | mV | 447/447 | 100.0% | - | - | -612.3-317.6 | 8.21 | MW07-10 | - | - |
| pH (Lab) | pH Units | 448/448 | 100.0% | 0.1-0.2 | 0.1-0.1 | 5.91-8.5 | 6.91 | MW03-02 | 6.5-8.5 | - |
| pH, Field | pH Units | 440/440 | 100.0% | - | - | 4.35-13.84 | 6.55 | MW03-15 | - | - |
| Water Temperature, Field | degrees C | 450/450 | 100.0% | - | - | -0.27-7.33 | 1.93 | MW03-16 | - | - |

**Notes:**

Most Stringent Applicable Water Quality Criteria are provided for the parameters for which water quality standards have been established. Standards have not been established for all parameters. Cases where there are no applicable standards are indicated by a dash (-).

1 18 AAC 70. ADEC, Alaska Water Quality Standards. Amended as of April 8, 2012, maximum drinking water levels.

2 Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances. Amended through December 12, 2008.

2a Aquatic life for fresh water hardness-dependent criteria. For Al, if pH≥7.0 and hardness ≥50, then 750 µg/L.

2b Aquatic life for fresh water (chronic) criteria.

2c Aquatic life for fresh water (acute) criteria.

2d Drinking water criteria.2e Irrigation water criteria.

2f Human health criteria for non-carcinogens (for consumption of water + aquatic organisms).

2g Aquatic life criteria (chronic)for free cyanide, measured as weak acid dissociable (WAD) cyanide.

2h Aquatic life for fresh water (chronic) criteria based on pH and temperature when early life stages of fish are present. The ADEC numeric water quality standard for ammonia depends upon both the temperature and the pH of the matrix water, but not the hardness. Because the measured or predicted temperature and pH of the water may vary over a wide range of values depending on time of year, sample location, and other factors, the most conservative possible numeric standard for ammonia in freshwater (0.179 mg/L; ADEC 2008a) is used as a basis for comparison for all of the waters considered in this section.

3 Calculated for all observations using detected values and ½ of the reporting limit value when analyte not detected.

4 Determined for the minimum and maximum of all detected reportable values; negative values are included when no detections are observed.

**Table 3.7-11: Groundwater Quality Summary for Deep Mine Site Wells**

| Analyte | Units | Frequency of Detection | | Range of Detection Limits (Reporting) | Range of Detection Limits (Method) | Range of Detected Concentrations[4] | Arithmetic Average Concentration[3] | Maximum Sample Location | Alaska Most Stringent Water Quality Criterion | Max Detects Exceeds Alaska Criterion |
|---|---|---|---|---|---|---|---|---|---|---|
| **Major Cations** | | | | | | | | | | |
| Calcium, Dissolved | mg/L | 250/250 | 100.0% | 0.1-2.00 | 0.031-0.62 | 1.83-91.5 | 31.7 | MW03-12 | - | - |
| Magnesium, Dissolved | mg/L | 250/250 | 100.0% | 0.03-1.00 | 0.015-0.2 | 0.801-30.1 | 8.02 | MW07-04 | - | - |
| Potassium, Dissolved | mg/L | 248/249 | 99.6% | 0.3-4.00 | 0.15-1.2 | 0.375-3.41 | 1.17 | MW03-14 | - | - |
| Sodium, Dissolved | mg/L | 248/249 | 99.6% | 0.3-100 | 0.15-30.0 | 1.32-248 | 41.5 | MW03-14 | - | - |
| **Major Anions** | | | | | | | | | | |
| Total Alkalinity (As $CaCO_3$) | mg/L | 250/250 | 100.0% | 6.2-50.0 | 2.00-15.5 | 20.5-466 | 193 | MW03-14 | - | - |
| Bicarbonate | mg/L | 235/235 | 100.0% | 6.2-50.0 | 2.00-15.5 | 20.5-446 | 188 | MW03-14 | - | - |
| Fluoride | mg/L | 227/232 | 97.8% | 0.062-0.5 | 0.031-0.1 | 0.034-2.48 | 0.24 | MW03-14 | 1[2e] | Yes |
| Sulfate | mg/L | 250/250 | 100.0% | 0.062-3.00 | 0.031-0.5 | 0.11-85.4 | 8.78 | MW03-14 | 250[1] | No |
| Chloride | mg/L | 250/250 | 100.0% | 0.062-3.00 | 0.031-0.5 | 0.259-10.6 | 0.97 | MW03-14 | - | - |
| **Nutrients** | | | | | | | | | | |
| Nitrite + Nitrate(as N) | mg/L | 145/249 | 58.2% | 0.062-1.00 | 0.02-0.31 | 0.032-2.00 | 0.16 | MW03-12 | 10[2d] | No |
| Ammonia (as N) | mg/L | 171/247 | 69.2% | 0.062-0.101 | 0.031-0.1 | 0.032-6.57 | 0.4 | MW07-04 | 0.18[2h] | Yes |
| **Cyanide** | | | | | | | | | | |
| Total Cyanide | µg/L | 40/248 | 16.1% | 3.00-10.0 | 1.5-3.00 | 1.5-6.6 | 2.58 | MW07-04 | - | - |
| Wad Cyanide | µg/L | 54/246 | 22.0% | 3.00-10.0 | 1.5-3.00 | 1.5-13.4 | 2.54 | MW03-14 | 200[2d] | No |
| **Metals** | | | | | | | | | | |
| Mercury | ng/L | 167/249 | 67.1% | 0.5-5.00 | 0.1-0.5 | 0.504-65.3 | 2.31 | MW03-14 | 2,000[2d] | No |
| Aluminum, Dissolved | µg/L | 45/220 | 20.5% | 5.00-20.0 | 1.00-20.0 | 6.49-530 | 17.5 | MW03-14 | - | - |
| Aluminum | µg/L | 213/249 | 85.5% | 5.00-100 | 1.00-31.0 | 6.24-14,200 | 263 | MW03-14 | 5,000[2e] | Yes |
| Antimony, Dissolved | µg/L | 50/220 | 22.7% | 0.62-2.00 | 0.31-1.00 | 0.321-67.2 | 4.48 | MW07-02 | - | - |
| Antimony | µg/L | 59/249 | 23.7% | 0.62-50.0 | 0.31-1.00 | 0.316-84.1 | 3.92 | MW07-02 | 6[2d] | Yes |
| Arsenic, Dissolved | µg/L | 132/220 | 60.0% | 2.00-5.00 | 0.5-5.00 | 1.63-1,980 | 45.7 | MW03-14 | - | - |
| Arsenic | µg/L | 146/249 | 58.6% | 2.00-5.00 | 0.5-5.00 | 1.69-2,050 | 47.5 | MW03-14 | 10[2d] | Yes |
| Barium, Dissolved | µg/L | 219/220 | 99.5% | 1.88-150 | 0.94-47.0 | 27.4-6,780 | 1515 | MW03-12 | - | - |
| Barium | µg/L | 248/248 | 100.0% | 1.88-37.6 | 0.94-18.8 | 30.8-7,060 | 1602 | MW03-12 | 2,000[2d] | Yes |
| Beryllium, Dissolved | µg/L | 1/220 | 0.5% | 0.4-0.5 | 0.1-0.4 | 0.531-0.531 | 0.2 | MW07-04 | - | - |
| Beryllium | µg/L | 12/249 | 4.8% | 0.4-400 | 0.1-0.4 | 0.141-1.1 | 0.25 | MW03-14 | 4[2d] | No |
| Boron, Dissolved | µg/L | 136/205 | 66.3% | 10.0-500 | 3.1-150 | 3.9-215 | 43.9 | MW03-14 | - | - |
| Boron | µg/L | 162/234 | 69.2% | 10.0-50.0 | 3.1-15.0 | 3.95-218 | 44.8 | MW03-14 | 750[2e] | No |
| Cadmium, Dissolved | µg/L | 2/220 | 0.9% | 0.1-0.5 | 0.05-0.5 | 0.09-0.602 | 0.24 | MW07-04 | - | - |

**Table 3.7-11: Groundwater Quality Summary for Deep Mine Site Wells**

| Analyte | Units | Frequency of Detection | | Range of Detection Limits (Reporting) | Range of Detection Limits (Method) | Range of Detected Concentrations[4] | Arithmetic Average Concentration[3] | Maximum Sample Location | Alaska Most Stringent Water Quality Criterion | Max Detects Exceeds Alaska Criterion |
|---|---|---|---|---|---|---|---|---|---|---|
| Cadmium | µg/L | 11/249 | 4.4% | 0.1-25.0 | 0.05-0.5 | 0.121-0.766 | 0.3 | MW03-10 | 5[2d] | No |
| Chromium, Dissolved | µg/L | 28/220 | 12.7% | 1.00-2.00 | 0.31-1.00 | 0.326-9.02 | 1.09 | MW03-14 | - | - |
| Chromium | µg/L | 76/249 | 30.5% | 1.00-50.0 | 0.31-1.00 | 0.411-19.0 | 1.39 | MW03-14 | 100[2d] | No |
| Cobalt, Dissolved | µg/L | 12/220 | 5.5% | 0.3-4.00 | 0.05-4.00 | 0.23-13.3 | 2.11 | MW03-14 | - | - |
| Cobalt | µg/L | 16/249 | 6.4% | 0.3-200 | 0.05-4.00 | 0.37-8.89 | 2.45 | MW07-02 | 50[2e] | No |
| Copper, Dissolved | µg/L | 115/220 | 52.3% | 0.62-3.00 | 0.31-1.00 | 0.311-35.7 | 0.78 | MW03-14 | - | - |
| Copper | µg/L | 181/249 | 72.7% | 0.62-50.0 | 0.31-1.00 | 0.315-60.3 | 1.95 | MW07-04 | 200[2e] | No |
| Iron, Dissolved | µg/L | 121/220 | 55.0% | 20.0-250 | 6.2-78.0 | 7.02-6210 | 835 | MW07-02 | - | - |
| Iron | µg/L | 184/249 | 73.9% | 20.0-250 | 6.2-78.0 | 6.46-9,620 | 926 | MW07-04 | 5000[2e] | Yes |
| Lead, Dissolved | µg/L | 39/220 | 17.7% | 0.124-0.5 | 0.062-0.2 | 0.0711-324 | 1.69 | MW03-14 | - | - |
| Lead | µg/L | 128/249 | 51.4% | 0.124-200 | 0.062-0.2 | 0.0625-24.3 | 0.42 | MW03-14 | 50[2e] | No |
| Lithium, Dissolved | µg/L | 164/205 | 80.0% | 6.2-100 | 3.1-20.0 | 3.1-196 | 24.0 | MW03-14 | - | - |
| Lithium | µg/L | 179/216 | 82.9% | 6.2-100 | 3.1-20.0 | 3.16-194 | 24.9 | MW03-14 | 2,500[2e] | No |
| Manganese, Dissolved | µg/L | 213/220 | 96.8% | 0.62-3.00 | 0.31-1.00 | 0.34-685 | 104 | MW03-12 | - | - |
| Manganese | µg/L | 249/249 | 100.0% | 0.62-3.00 | 0.31-1.00 | 0.436-658 | 115 | MW03-12 | 200[2e] | Yes |
| Molybdenum, Dissolved | µg/L | 9/220 | 4.1% | 3.00-10.0 | 0.5-10.0 | 0.6-40.0 | 5.28 | MW03-14 | - | - |
| Molybdenum | µg/L | 13/248 | 5.2% | 3.00-500 | 0.5-10.0 | 0.7-30.0 | 6.15 | MW03-14 | 10[2e] | Yes |
| Nickel, Dissolved | µg/L | 160/219 | 73.1% | 1.24-3.00 | 0.6-2.00 | 0.628-10.5 | 1.48 | MW03-14 | - | - |
| Nickel | µg/L | 192/249 | 77.1% | 1.24-100 | 0.6-2.00 | 0.631-898 | 5.68 | MW03-10 | 200[2e] | Yes |
| Selenium, Dissolved | µg/L | 5/219 | 2.3% | 0.3-5.00 | 0.1-5.00 | 2.1-24.3 | 2.65 | MW03-10 | - | - |
| Selenium | µg/L | 9/249 | 3.6% | 0.3-250 | 0.1-5.00 | 1.77-18.4 | 3.1 | MW03-10 | 10[2e] | Yes |
| Silver, Dissolved | µg/L | 1/219 | 0.5% | 0.3-1.00 | 0.05-1.00 | 0.608-0.608 | 0.5 | MW07-04 | - | - |
| Silver | µg/L | 3/248 | 1.2% | 0.3-50.0 | 0.05-1.00 | 0.609-1.3 | 0.6 | MW07-09 | - | - |
| Thallium, Dissolved | µg/L | 1/219 | 0.5% | 0.5-1.00 | 0.1-1.00 | 0.475-0.475 | 0.5 | MW03-10 | - | - |
| Thallium | µg/L | 8/249 | 3.2% | 0.5-50.0 | 0.1-1.00 | 0.312-3.11 | 0.6 | MW03-12 | 2[2f] | Yes |
| Vanadium, Dissolved | µg/L | 1/219 | 0.5% | 1.00-20.0 | 0.2-20.0 | 0.2-0.2 | 9.96 | MW07-04 | - | - |
| Vanadium | µg/L | 9/249 | 3.6% | 1.00-1,000 | 0.2-20.0 | 0.7-42.5 | 12.0 | MW03-14 | 100[2e] | No |
| Zinc, Dissolved | µg/L | 106/218 | 48.6% | 1.00-5.00 | 1.5-5.00 | 2.38-214 | 12.4 | MW03-12 | - | - |
| Zinc | µg/L | 141/248 | 56.9% | 2.00-250 | 1.5-5.00 | 2.01-502 | 19.3 | MW07-04 | 2,000[2e] | No |
| **General Water Quality Parameters** | | | | | | | | | | |
| Hardness ($CaCO_3$), Dissolved | mg/L | 249/249 | 100.0% | 5.00-7.00 | 1.00-5.00 | 7.87-292.72 | 112 | MW03-12 | - | - |
| Total Dissolved Solids | mg/L | 250/250 | 100.0% | 6.2-50.0 | 3.1-10.0 | 38.0-1,210 | 226 | MW03-14 | 500[1] | Yes |

**Table 3.7-11: Groundwater Quality Summary for Deep Mine Site Wells**

| Analyte | Units | Frequency of Detection | | Range of Detection Limits (Reporting) | Range of Detection Limits (Method) | Range of Detected Concentrations[4] | Arithmetic Average Concentration[3] | Maximum Sample Location | Alaska Most Stringent Water Quality Criterion | Max Detects Exceeds Alaska Criterion |
|---|---|---|---|---|---|---|---|---|---|---|
| Total Suspended Solids | mg/L | 205/248 | 82.7% | 0.294-5.00 | 0.115-1.5 | 0.196-197 | 4.94 | MW07-04 | - | - |
| **Field Parameters** | | | | | | | | | | |
| Conductivity (Lab) | µS/cm | 249/249 | 100.0% | 0.954-10.0 | 0.477-1.00 | 140-1,000 | 377 | MW03-14 | - | - |
| Conductivity, Field | µS/cm | 232/232 | 100.0% | - | - | 7.00-2,410 | 241 | MW03-08 | - | - |
| Dissolved Oxygen, Field | mg/L | 227/227 | 100.0% | - | - | 0.62-41.3 | 4.49 | MW03-08 | - | - |
| Ox./Reduc. Pot.(ORP/eH), Field | mV | 237/237 | 100.0% | - | - | -268.4-325.7 | 33.8 | MW03-10 | - | - |
| pH (Lab) | pH Units | 250/250 | 100.0% | 0.1-0.2 | 0.1-0.1 | 6.5-8.9 | 7.41 | MW03-14 | 6.5-8.5 | - |
| pH, Field | pH Units | 237/237 | 100.0% | - | - | 6.02-9.98 | 7.23 | MW07-07 | - | - |
| Water Temperature, Field | degrees C | 245/245 | 100.0% | - | - | 0.05-8.9 | 1.88 | MW03-14 | - | - |

**Notes:**

Most Stringent Applicable Water Quality Criteria are provided for the parameters for which water quality standards have been established. Standards have not been established for all parameters. Cases where there are no applicable standards are indicated by a dash (-).

1 18 AAC 70. ADEC, Alaska Water Quality Standards. Amended as of April 8, 2012, maximum drinking water levels.

2 Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances. Amended through December 12, 2008. Most stringent criteria used.

2a Aquatic life for fresh water hardness-dependent criteria. For Al, if pH≥7.0 and hardness ≥50, then 750 µg/L.

2b Aquatic life for fresh water (chronic) criteria.

2c Aquatic life for fresh water (acute) criteria.

2d Drinking water criteria.

2e Irrigation water criteria.

2f Human health criteria for non-carcinogens (for consumption of water + aquatic organisms).

2g Aquatic life criteria (chronic)for free cyanide, measured as weak acid dissociable (WAD) cyanide.

2h Aquatic life for fresh water (chronic) criteria based on pH and temperature when early life stages of fish are present. The ADEC numeric water quality standard for ammonia depends upon both the temperature and the pH of the matrix water, but not the hardness. Because the measured or predicted temperature and pH of the water may vary over a wide range of values depending on time of year, sample location, and other factors, the most conservative possible numeric standard for ammonia in freshwater (0.179 mg/L; ADEC 2008a) is used as a basis for comparison for all of the waters considered in this section.

3 Calculated for all observations using detected values and ½ of the reporting limit value when analyte not detected.

4 Determined for the minimum and maximum of all detected reportable values; negative values are included when no detections are observed.

U.S. Geological Survey Study of Crooked Creek Watershed

Two groundwater samples, DC22 and DC23, were analyzed during the USGS investigation in 2002 (Mueller et al. 2003). The samples were collected from wells on the lower southwestern slope of the ridge that separates Lewis Gulch from American Creek (Figure 3.7-6). The two samples are notably different from the USGS surface and seep waters in that they have higher pH (7.6-8.4), lower dissolved oxygen (0.02 to 0.49 mg/L), and higher specific conductance (384 to 770 μS/cm) relative to samples collected from surface waters and seeps.

#### 3.7.2.2.2 TRANSPORTATION FACILITIES

Kuskokwim River

Groundwater along the Kuskokwim River exists in alluvial deposits that may be hundreds of feet thick. Surface water drainage is into the Kuskokwim River, which flows southwest, and on a regional scale, the ground water system tends to mimic the drainage patterns observed for surface water (Dorava 1994). The groundwater generally flows in the direction of topographic gradients to the valley bottoms, where it emerges in streams (Dorava 1994). Adjacent to the Kuskokwim River, shallow groundwater flows into and out of the riverbanks as the elevation of water in the river rises and falls (Dorava 1994). This flow of water into and out of the aquifer in response to changing stage of the river is termed "bank storage effects" (Figure 3.7-7). Such interactions between the groundwater and surface water have the potential to influence groundwater quality, such that the quality of the groundwater in areas adjacent to the Kuskokwim River is linked to water quality in the main stem of the river.

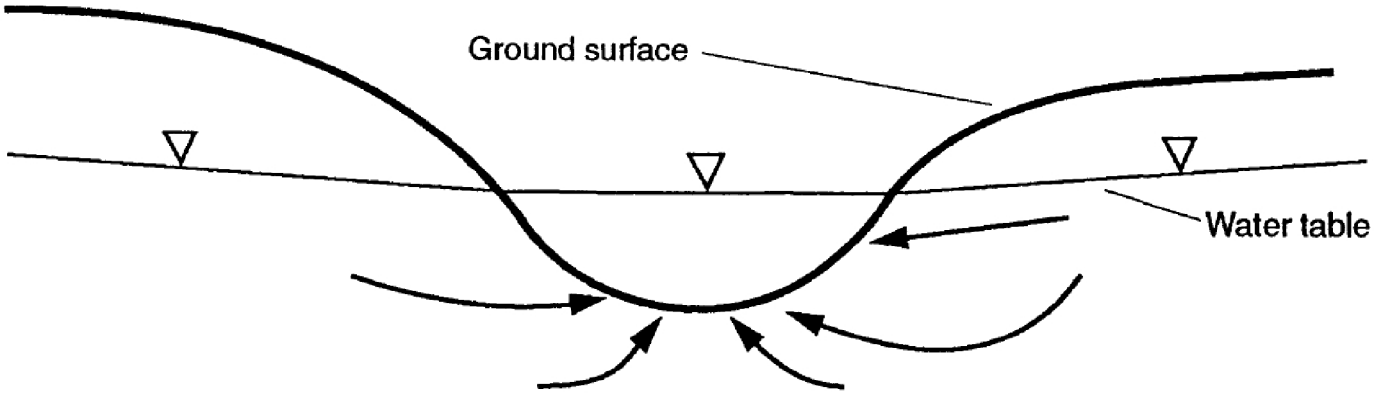
The use of groundwater resources for community water supply in villages along the Kuskokwim River is described in Section 3.6, Groundwater Hydrology. Water quality data for community wells in Aniak provide some regional context for these resources. Analyses of samples from more than 30 wells drilled in Aniak in 1980 indicated an iron content averaging 0.30 mg/L, a silica content ranging from 7 to 20 mg/L, and alkalinity as $CaCO_3$ ranging from 100 to 200 mg/L (Dorava 1994). The iron content in Aniak groundwater is often higher than the 0.3 mg/L secondary maximum contaminant level (MCL) specified by EPA for drinking water (EPA 2013j).

Angyaruaq (Jungjuk) and Birch Tree Crossing Roads

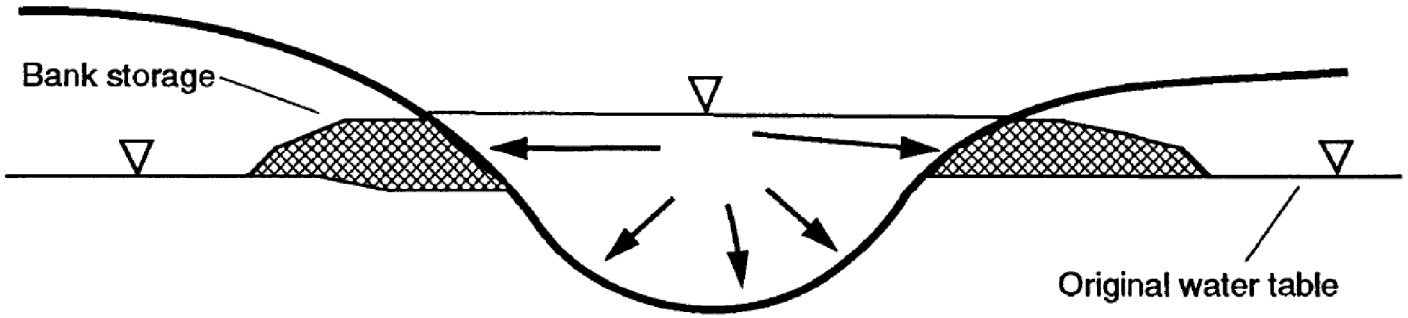
The location of the proposed Angyaruaq (Jungjuk) and BTC roads relative to drainage basins in the areas is described in Section 3.5, Surface Water Hydrology. In general, baseline groundwater quality throughout the area of the Angyaruaq (Jungjuk) Road and most of the BTC Road is expected to be very similar to groundwater quality in the Crooked Creek drainage basin due to similar settings and bedrock types, which is described in Section 3.7.2.2.1.

Dutch Harbor Fuel Storage Facility

As described in Section 3.2, Soils, a number of ADEC contaminated sites have been documented in Dutch Harbor related to historical spills from existing tank farms and fuel handling in the area. Additional information on the location and footprint of the proposed facility would be needed to further assess site-specific groundwater quality conditions.




**LOW-FLOW CONDITIONS---FLOW IS INTO STREAM**




**HIGH-WATER CONDITIONS---FLOW IS OUT OF STREAM**

Data Sources: Dorava (1994)

1.Shallow groundwater flowing into and out of aquifer and riverbanks as water elevation in river rises and falls.

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GROUNDWATER/SURFACE WATER INTERACTIONS DUE TO BANK STORAGE EFFECTS[1] ALONG KUSKOKWIM RIVER

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FIGURE 3.7-7

#### 3.7.2.2.3 PIPELINE

The installation and operation of the proposed natural gas pipeline is not anticipated to affect groundwater quality outside the immediate vicinity of the trench; therefore, project-specific groundwater quality data were not collected in the proposed pipeline corridor.

Known and potential uses of groundwater resources along the proposed pipeline are summarized in Section 3.6, Groundwater Hydrology. Groundwater wells for commercial, community, and private water supply are located near the proposed diesel pipeline route (Alternative 3B) in the Beluga to Tyonek area. Detailed USGS groundwater quality data are not available for the west side of Cook Inlet, and groundwater quality data are not publically available for wells associated with the Chugach Electric Association Power Plant at Beluga. Baseline groundwater quality in the vicinity of the eastern terminus of the proposed pipeline corridor has been characterized by analyzing samples from wells located at Ladd Landing, located approximately 5 miles south of Beluga (Riverside 2010). Groundwater quality from the glacial drift hydrostratigraphic unit in the Ladd Landing area is characterized by circumneutral pH values (average = 6.8), low hardness values (average = 20 mg/L as $CaCO_3$), and relatively low concentrations of total dissolved solids (average = 71 mg/L) (Riverside 2010). Selected groundwater samples from wells in the Ladd Landing area often exceeded the most stringent water quality criteria for total aluminum (average = 119µg/L), total iron (average = 1,000µg/L), and total manganese (average = 90 µg/L) (Riverside 2010). These exceedences did not correspond to elevated turbidity or TSS concentrations, though most exceedences were associated with dissolved aluminum below the detection limits of the analyses, indicating that aluminum in the samples was particulate (Riverside 2010).

### 3.7.2.3 SEDIMENT

There are no regulations established for chemical concentrations in sediment. Sediment Quality Guidelines (SQGs) recommended by ADEC (2013b) for use at contaminated sites include Threshold Effects Levels (TELs) and Probable Effects Levels (PELs) published in NOAA Screening Quick Reference Tables for both fresh and marine water sediment (Buchman 2008). TELs are concentrations below which adverse effects of benthic organisms are expected to occur rarely, and PELs represent concentrations above which effects are expected to be frequent.

Other sediment quality criteria used for comparison purposes in project studies (e.g., RWJ Consulting Inc. 2010a) include Canadian Interim Sediment Quality Guidelines (ISQG) for protection of freshwater aquatic life (Canadian Council of Ministers of the Environment [CCME] 2014), Washington State (2013) marine sediment quality criteria, and ADEC (2000, 2012a) cleanup levels for soils.

#### 3.7.2.3.1 MINE SITE

The Donlin Gold environmental studies program has conducted several studies to characterize sediment quality in the vicinity of the proposed mine site. In 1999 and 2006 through 2008, sediment samples were collected and analyzed to establish baseline concentrations of metals in sediment from the Crooked Creek watershed. Stream sediment grab samples were collected at nine sampling stations within the Crooked Creek watershed, several of which correspond to sample locations used for the collection of surface water samples. The sediment sample

locations are shown in Figure 3.7-8, and reasons for the selection of each location are provided below:

DCBO is located on Donlin Creek above all historic placer mining, and past, current, and proposed activities in the Crooked Creek drainage, and serves as a background control site.

FLAT is located on Flat Creek above the confluence with Crooked Creek. FLAT is outside the known mineralized area and serves as a background control site.

CCBW, located on Crooked Creek, is downstream of current placer mining activities, but upstream of the proposed mine site.

GRSE is located on Grouse Creek upstream of the confluence with Crooked Creek. GRSE is outside the known mineralized area and serves as a background control site.

AMER, located on American Creek, drains the known mineralized area.

CCBO is below the known mineralized area on Crooked Creek upstream of the proposed tailing impoundment.

ANDA, located on Anaconda Creek, drains the proposed tailing impoundment area.

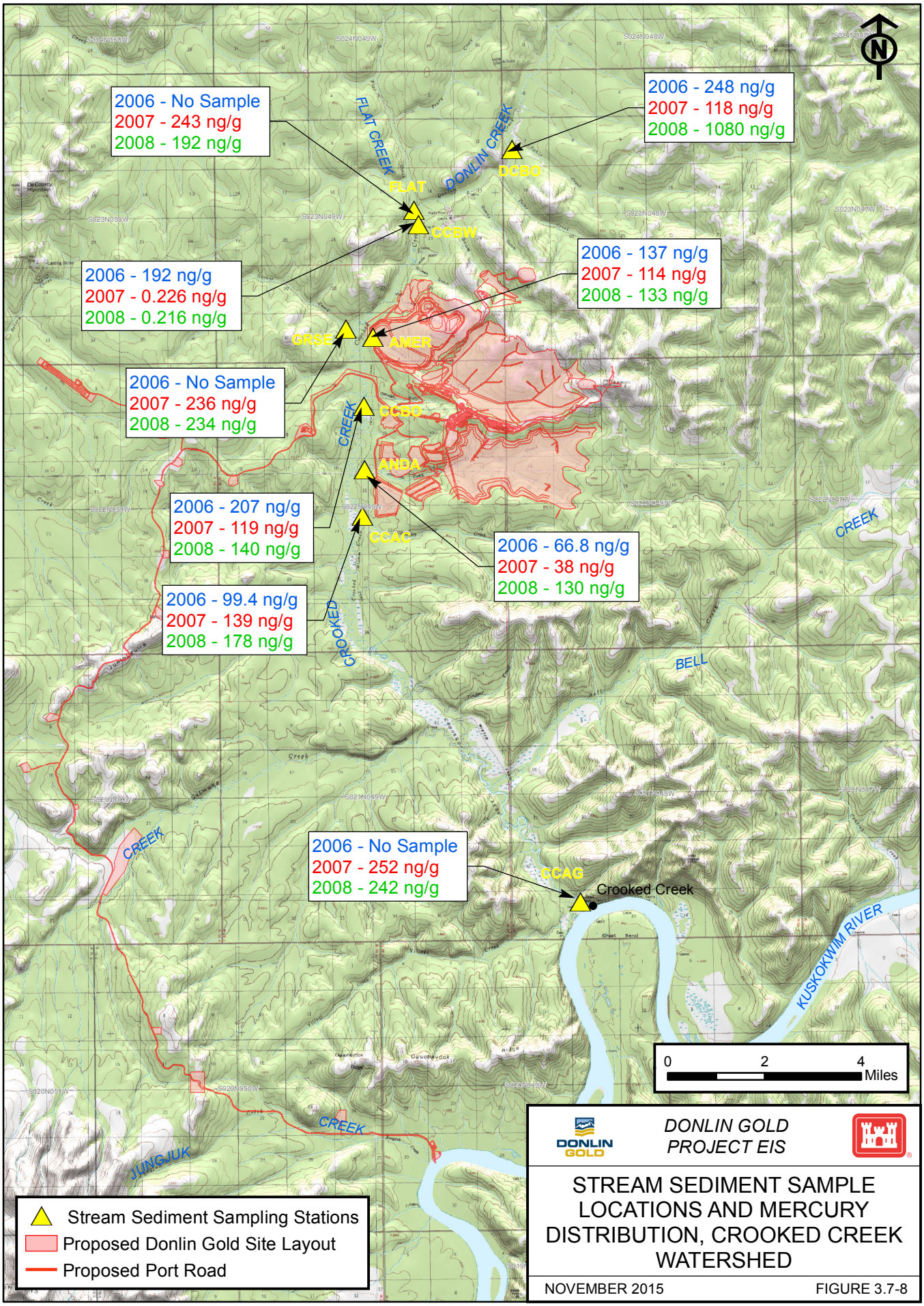
CCAC is located on Crooked Creek, downstream of all past, current, and proposed mining activity and known mineralization.

CCAG located on Crooked Creek just upstream of the USGS gauging station at the Village of Crooked Creek.

Stream sediment samples were collected from undisturbed stream sediment using one-time-use LEXAN sample tubes. All samples were collected in active water channels with the lowest velocity, at a depth of 0 to 6 inches below the stream bottom. Sediment samples were homogenized and digested using EPA Method SW3050B. Total metals were analyzed using EPA Method SW6020. Mercury and methylmercury samples were analyzed using EPA Methods 1631 and 1630, respectively, using cold vapor atomic fluorescence spectrometry (CVAFS) (ARCADIS 2008a).

The sample collection, handling, and analysis methods for the stream sediment samples were generally consistent among all sampling events, with the following minor deviations. Due to high water conditions during the 2007 sample event, sample locations GRSE and CCBW were collected downstream of the designated sampling location at the first favorable deposition location. Four metals analytes were added in 2008 that were not tested in 2007: bismuth, molybdenum, tin, and vanadium (ARCADIS 2008a).

Analytical results for total metals from the 2008 sediment sampling event are shown in Table 3.7-12. Concentrations of bismuth, cadmium, molybdenum, sodium, and tin were all below the detection limits (ARCADIS 2008a). While there are no regulatory criteria established for sediment (Section 3.7.1.2.3), TELs and PELs recommended for use by ADEC in its Contaminated Sites program (2013b) are provided in Table 3.7-12 for comparison purposes. Arsenic and nickel exceeded the TEL level in all samples, and mercury exceeded it in six of nine samples. Arsenic also exceeded the PEL level in five of nine samples, mercury exceeded it in one sample (DCBO) and nickel slightly exceeded it in one sample (CCAG).

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STREAM SEDIMENT SAMPLE LOCATIONS AND MERCURY DISTRIBUTION, CROOKED CREEK WATERSHED

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FIGURE 3.7-8

**Table 3.7-12: Summary of Total Metals Results for Proposed Mine Area Stream Sediment Samples, 2008**

| Station Sample ID[1] | DCBO | FLAT | GRSE | CCAG | CCAC | CCBW | ANDA | CCBO | AMER | TEL/PEL[2] |
|---|---|---|---|---|---|---|---|---|---|---|
| **Analyte** | | | | | | | | | | |
| Aluminum (mg/Kg) | 14,500 | 15,500 | 16,300 | 19,900 | 13,200 | 14,400 | 16,300 | 9,920 | 19,000 | – |
| Antimony (mg/Kg) | ND | 0.189 | ND | 0.269 | 0.287 | 0.199 | ND | 1.04 | 0.5 | – |
| Arsenic (mg/Kg) | 9.64 | 9.44 | 10.3 | 21.5 | 30.3 | 17.9 | 12.1 | 47.8 | 132 | 5.9/17 |
| Barium (mg/Kg) | 174 | 280 | 400 | 293 | 143 | 193 | 406 | 140 | 296 | – |
| Beryllium (mg/Kg) | 0.426 | 0.519 | 0.645 | 0.714 | 0.537 | 0.422 | 0.664 | 0.602 | 0.538 | – |
| Bismuth (mg/Kg) | ND | ND | ND | ND | ND | ND | ND | ND | ND | – |
| Cadmium (mg/Kg) | ND | ND | ND | ND | ND | ND | ND | ND | ND | 0.596/3.53 |
| Calcium (mg/Kg) | 2,600 | 2,090 | 2,060 | 2,320 | 2,970 | 2,320 | 5,990 | 2,640 | 3,360 | – |
| Chromium (mg/Kg) | 26.9 | 19.9 | 21.9 | 30.3 | 26.9 | 22.9 | 20.9 | 21.8 | 24 | 37.3/90 |
| Cobalt (mg/Kg) | 14.3 | 15 | 15.5 | 15.5 | 14.2 | 11.8 | 13.9 | 13.1 | 14.4 | – |
| Copper (mg/Kg) | 13.3 | 17.3 | 20.7 | 22.8 | 16.8 | 15 | 25.4 | 26.1 | 22.4 | 35.7/197 |
| Iron (mg/Kg) | 34,800 | 19,000 | 16,000 | 21,200 | 35,000 | 27,800 | 27,300 | 40,600 | 37,500 | – |
| Lead (mg/Kg) | 5.78 | 4.98 | 4.89 | 5.55 | 6.86 | 5.9 | 8.55 | 6.82 | 9.88 | 35/91.3 |
| Magnesium (mg/Kg) | 6,240 | 2,870 | 2,030 | 3,580 | 5,000 | 4,750 | 4,090 | 3,860 | 4,770 | – |
| Manganese (mg/Kg) | 760 | 449 | 654 | 442 | 651 | 507 | 1,050 | 1,100 | 1,000 | – |
| Mercury (ng/g) | 1,080 | 192 | 234 | 242 | 178 | 216 | 130 | 140 | 133 | 174/486 |
| Molybdenum (mg/Kg) | ND | ND | ND | ND | ND | ND | ND | ND | ND | – |
| Nickel (mg/Kg) | 35.5 | 35.6 | 31.9 | 36.6 | 35.6 | 30.9 | 27.9 | 33.8 | 34.1 | 18/36 |
| Potassium (mg/Kg) | 769 | 597 | 569 | 759 | 773 | 646 | 861 | 644 | 965 | – |
| Selenium (mg/Kg) | ND | ND | ND | ND | ND | ND | ND | ND | 1.18 | – |
| Silver (mg/Kg) | ND | ND | ND | ND | ND | ND | ND | ND | 0.291 | – |
| Sodium (mg/Kg) | ND | ND | ND | ND | ND | ND | ND | ND | ND | – |
| Thallium (mg/Kg) | 0.0456 | 0.0577 | 0.0703 | 0.077 | 0.0408 | 0.0574 | 0.0961 | 0.0406 | 0.106 | – |
| Tin (mg/Kg) | ND | ND | ND | ND | ND | ND | ND | ND | ND | – |
| Solids (%) | 68.7 | 56.4 | 51.5 | 43.8 | 74.6 | 62.6 | 36.3 | 77.9 | 50.7 | – |
| Vanadium (mg/Kg) | 40.5 | 38.5 | 40.7 | 44.1 | 37.9 | 33.5 | 43.5 | 36 | 39 | – |

**Table 3.7-12: Summary of Total Metals Results for Proposed Mine Area Stream Sediment Samples, 2008**

| Station Sample ID[1] | DCBO | FLAT | GRSE | CCAG | CCAC | CCBW | ANDA | CCBO | AMER | TEL/PEL[2] |
|---|---|---|---|---|---|---|---|---|---|---|
| Zinc (mg/Kg) | 88.9 | 91.5 | 96.3 | 103 | 86.8 | 78.3 | 81.4 | 82.7 | 95.1 | 123/315 |

**Notes:**

1 Samples collected from Crooked Creek watershed at locations shown on Figure 3.7-8 in September 2008.
2 NOAA SQuiRT values for freshwater sediment (ADEC 2013d; Buchman 2008).

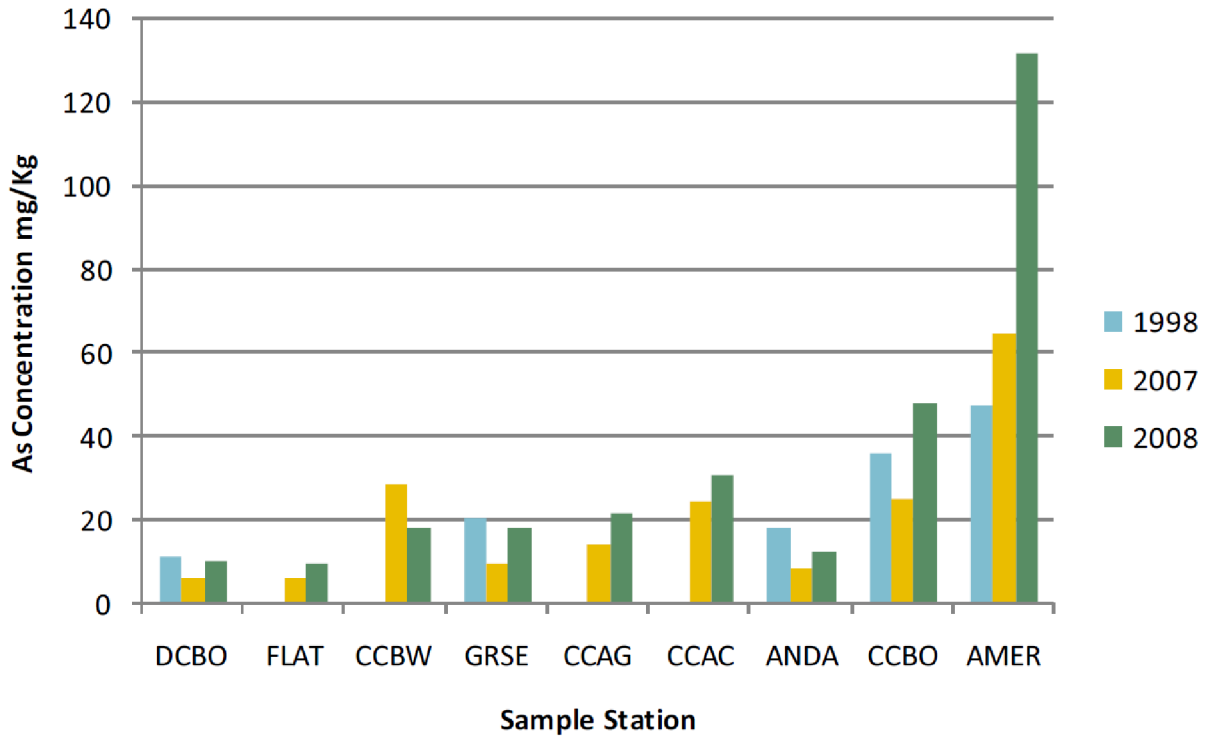
**Abbreviations:**

– = No value established
mg/Kg = milligrams per kilogram
ND = Not detected
ng/g = nanograms per gram (same as micrograms per kilogram (ug/Kg))
NOAA = National Oceanic and Atmospheric Administration
PEL = Probable Effects Level
TEL = Threshold Effects Level
SQuiRT = Screening Quick Reference Tables

Source: ARCADIS 2008a.

The mean concentration of arsenic in the sediment was 32.3 mg/kg, and the highest concentration of arsenic was measured in the American Creek sample at a concentration of 132 mg/kg, almost an order of magnitude higher than the PEL (Table 3.7-12). A summary of arsenic results for three years (1998, 2007, and 2008), shown on Figure 3.7-9, indicates that concentrations are greatest in streams that drain the known mineralized area (ARCADIS 2007b, 2008). Elevated concentrations of arsenic at locations CCBO and AMER are likely attributable to the proximity of sampling sites to the ore body, and for the Crooked Creek samples, may also be related to the influence of past placer mining activities upstream (ARCADIS 2008a). In addition, variability is likely caused by the heterogeneous nature of the sediments, as the sediment data are based on analysis of bulk sediment samples and no size fractionation was performed prior to analysis. Sediment concentrations are known to vary with grain size, with fine-grained deposits typically exhibiting higher concentrations.

Concentrations of total mercury measured in sediment samples from the Crooked Creek watershed during the 2006-2008 sampling events ranged from 38 to 1,080 ng/g dry weight, as shown on Figure 3.7-8 and Figure 3.7-10. The highest of these was located at station DCBO on Donlin Creek between the Ophir and Dome creek confluences upstream of historical placer mining in the area. It is possible that mineralization trends to the northeast of the mine site are contributing to the elevated mercury concentrations at this location (see Section 3.1, Geology). Based on a review of available published data, the average mercury concentration in regional stream sediment from the USGS Sleetmute quadrangle, which covers an area of about 7,000 square miles south and east of the proposed mine site, was reported to be 100 ng/g (Gray et al. 1997b; Miller et al. 1998; Theodorakos et al., 1992). Most of the proposed mine area results are higher than this regional average (ARCADIS 2007c).




Data Sources: Arcadis 2007a, 2008

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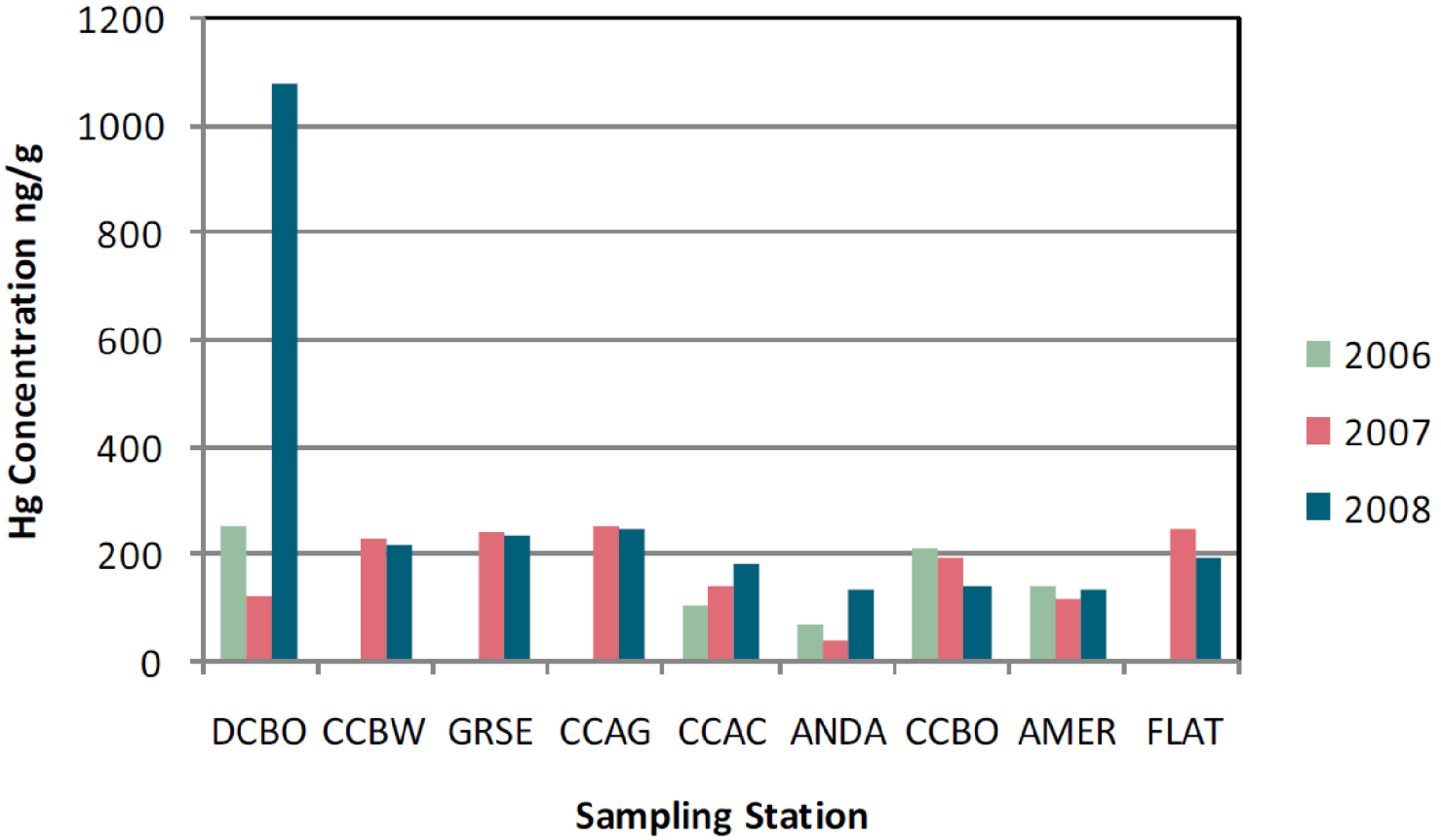
ARSENIC CONCENTRATIONS IN STREAM SEDIMENT, CROOKED CREEK WATERSHED

NOVEMBER 2015

FIGURE 3.7-9




Data Sources: Arcadis 2007b, 2008

Hg = mercury
ng/g = nanograms per gram (same as ug/Kg)

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MERCURY CONCENTRATIONS IN STREAM SEDIMENT, CROOKED CREEK WATERSHED

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FIGURE 3.7-10

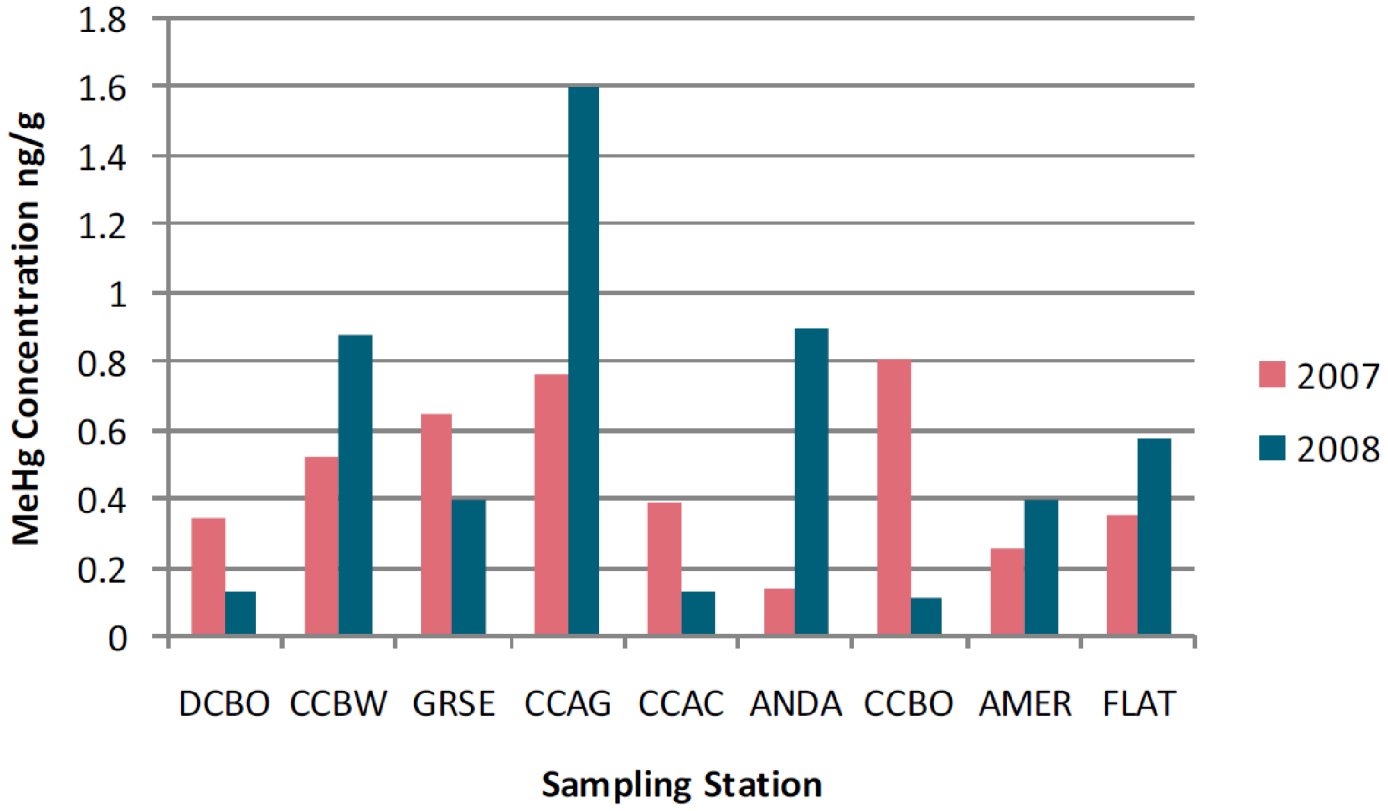
Methylmercury was measured in sediment samples collected from the Crooked Creek watershed during the 2007 and 2008 sediment studies. Methylmercury is more toxic than elemental mercury due to its ability to cross cell membranes and interact with biological systems (Section 3.7.2.1.1 and Figure 3.7-2). Methylmercury concentrations ranged from 0.111 ng/g to 1.60 ng/g dry weight in samples collected during the 2007 and 2008 sampling events (Figure 3.7-11). Differences in methylmercury concentrations between the two sampling events were most pronounced at CCAG and ANDA which more than doubled in 2008, and at CCBO which dropped substantially in 2008. As described above, no size fractionation was performed prior to analysis; thus, the wide range of methylmercury results may be indicative of grain size heterogeneity in the samples (ARCADIS 2008a).

The impact of mercury on aquatic systems may depend on the amount that is methylated. Mercury methylation requires inorganic mercury and methylating bacteria. The predominant (though not exclusive) methylators of mercury are sulfate-reducing bacteria, which require the presence of anoxic conditions, sulfate, and an organic carbon source. Sediment concentrations of methylmercury are often greater than those measured in aqueous samples because sediments are more likely to provide the anoxic conditions and electron acceptors requisite for the activity of sulfate-reducing bacteria responsible for mercury methylation; however, concentrations of methylmercury in the water, not sediment, are generally accepted as the key factor that determines the concentrations and accumulation of mercury in biota (Morel et al. 1998).

#### 3.7.2.3.2 TRANSPORTATION FACILITIES: KUSKOKWIM RIVER TRANSPORTATION CORRIDOR

Donlin Gold Baseline Sediment Sampling Program

The primary source of information related to sediment quality in the Kuskokwim River transportation corridor is the baseline sediment sampling program conducted by Donlin Gold, which involved collection at eight stations located along the Kuskokwim River, from above Crooked Creek to the mouth of the Kuskokwim, during August 2007 and June 2010 (RWJ Consulting Inc. [RWJ] 2008a, 2010a). Comparable stations were used for both sampling events, located (from downriver to upriver) at Helmick Point, Bethel Dock, upriver of Bethel (near Straight Slough), Birch Tree Crossing, Aniak, Jungjuk Creek, Crooked Creek, and George River (Figure 3.7-12). As described in RWJ 2010a, these sites are located in the main channel of the Kuskokwim River. The “Crooked Creek” site is located in the Kuskokwim River at its confluence with Crooked Creek, and so it is not comparable to Crooked Creek tributary sampling summarized in the previous section. A total of 299 and 390 samples were collected in 2007 and 2010, respectively (including QA samples). All samples were analyzed for trace metals, hydrocarbons, and various organics.




Data Sources: Arcadis 2007a, 2008

MeHg = methylmercury
ng/g = nanograms per gram (same as ug/Kg)

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METHYLMERCURY CONCENTRATIONS IN STREAM SEDIMENT, CROOKED CREEK WATERSHED

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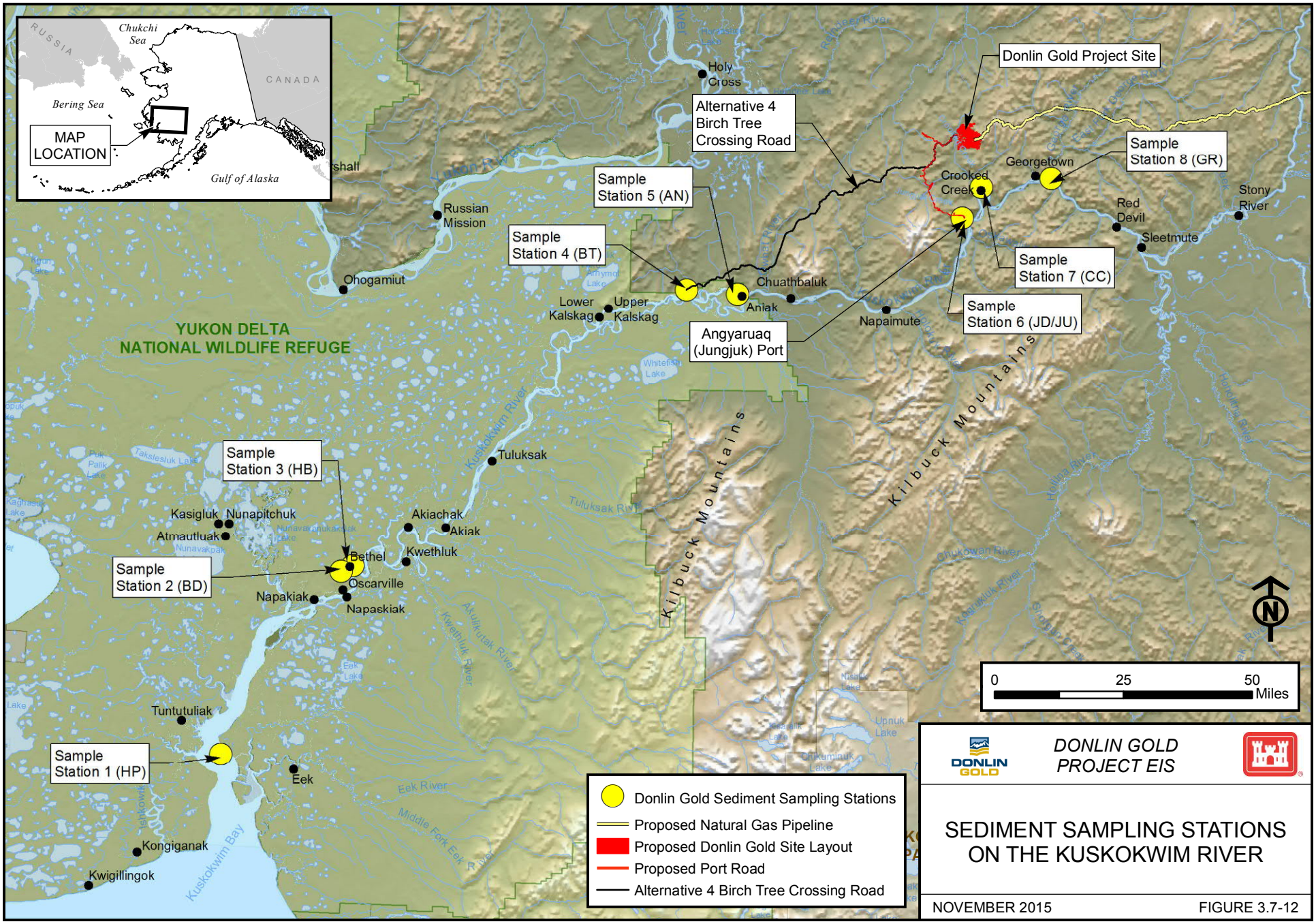
FIGURE 3.7-11


RUSSIA
Chukchi Sea
CANADA
Bering Sea
MAP LOCATION
Gulf of Alaska
Donlin Gold Project Site
Holy Cross
Alternative 4 Birch Tree Crossing Road
Sample Station 8 (GR)
Georgetown
Crooked Creek
Stony River
Red Devil
Sleetmute
Sample Station 5 (AN)
Russian Mission
Sample Station 4 (BT)
Sample Station 7 (CC)
Ohogamiut
Chuathbaluk
Lower Kalskag
Upper Kalskag
Aniak
Napaimute
Sample Station 6 (JD/JU)
Angyaruaq (Jungjuk) Port
YUKON DELTA NATIONAL WILDLIFE REFUGE
Kilbuck Mountains
Sample Station 3 (HB)
Tuluksak
Kasigluk
Nunapitchuk
Atmautluak
Akiachak
Akiak
Kwethluk
Bethel
Sample Station 2 (BD)
Oscarville
Napakiak
Napaskiak
Tuntutuliak
Sample Station 1 (HP)
Eek
Kongiganak
Kwigillingok
Kuskokwim Bay
0
25
50
Miles
N
Donlin Gold Sediment Sampling Stations
Proposed Natural Gas Pipeline
Proposed Donlin Gold Site Layout
Proposed Port Road
Alternative 4 Birch Tree Crossing Road
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SEDIMENT SAMPLING STATIONS ON THE KUSKOKWIM RIVER
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FIGURE 3.7-12

Mean concentrations of trace metals are shown in Table 3.7-13 and Table 3.7-14. RWJ (2008a, 2010a) interpreted the results compared to the most stringent of several different sediment quality criteria: Canadian ISQGs (CCME 2014), NOAA TELs/PELs recommended for use by ADEC (2013d), Washington State marine sediment quality criteria (WMSQC), and ADEC soil cleanup levels. Six trace metals (arsenic, chromium, copper, lead, mercury, and nickel) exceeded these criteria for at least one of the statistical summary measures at all stations in 2007; and four metals (arsenic, copper, mercury and nickel) were also elevated in 2010. Mean arsenic was elevated relative to the ISQG at all stations sampled, and all samples collected from the Crooked Creek and George River stations exceeded the ISQG for arsenic (RWJ 2010a). One Crooked Creek sample also contained a slightly elevated level of cadmium (0.709 mg/Kg) relative to the ISQG of 0.6 mg/kg. For copper, the only two samples that exceeded the ISQG were offshore of the Bethel Dock in the slowest moving portion of the river on the inside bend where several inches of soft material had accumulated (RWJ 2008a).

In both 2007 and 2010, the furthest upriver sampling stations (Crooked Creek and George River) showed generally higher concentrations for trace metals relative to the lower river stations. Sediment samples collected from Crooked Creek and George River, known to be in some of the most highly mineralized portions of the river drainage, contained the highest concentrations of arsenic (RWJ 2008a). Data from the 2007 sampling event indicate that samples collected from the Kuskokwim River at the George River location exceeded the ISQG and TEL for mercury of 0.17 mg/kg with concentrations up to 0.34 mg/kg, which generally decrease in a downstream direction.

Overall, the Kuskokwim River sediment results suggested that background trace metal concentrations were relatively high for at least six metals when compared to the most stringent criteria, at levels not unexpected for an area rich in metallic mineral deposits. For values that exceeded the ISQG and/or PEL, the results indicate that such levels could cause biological effects for some organisms exposed to them (RWJ 2010a).

For pesticides measured as part of the RWJ (2010a) study, results indicated that none of the samples exceeded Sediment Quality Guidelines (SQGs) recommended by ADEC (2013b) for use at contaminated sites. Gasoline range organics (GRO) were not detected in 2010 at any of the eight stations sampled. Diesel range organics (DRO) and residual range organics (RRO) representing anthropogenic hydrocarbons, were detected at concentrations lower than guideline levels (Table 3.7-15) (RWJ 2010a).

**Table 3.7-13: Summary of Total Metals Results[1] in Kuskokwim River Sediment, 2007 Sampling Event**

| Trace Metal (Units) | Eek Island (n=2) | Helmick Point (n=6) | Bethel Dock (n=3) | Upriver of Bethel (n=5) | Birch Tree Crossing (n=5) | Aniak (n=2) | Crooked Creek (n=5) | George River (n=3) | TEL/PEL[2] |
|---|---|---|---|---|---|---|---|---|---|
| Aluminum (%) | 7.80 | 7.23 | 10.17 | 7.93 | 7.95 | 6.91 | 11.37 | 11.46 | - |
| Antimony (mg/Kg) | 0.06 | 0.07 | 0.18 | 0.15 | 0.21 | 0.15 | 0.38 | 0.29 | - |
| Arsenic (mg/Kg) | 9.47 | 6.82 | 10.2 | 6.99 | 10.4 | 6.66 | 18.5 | 11.3 | 5.9/17 |
| Barium (mg/Kg) | 57.9 | 68.0 | 106 | 88.2 | 121 | 82.0 | 181 | 193 | - |
| Beryllium (mg/Kg) | 0.24 | 0.22 | 0.30 | 0.29 | 0.31 | 0.23 | 0.44 | 0.42 | - |
| Bismuth (mg/Kg) | 0.05 | 0.05 | 0.12 | 0.07 | 0.10 | 0.08 | 0.20 | 0.09 | - |
| Boron (mg/Kg) | 5.22 | 4.00 | 3.48 | 3.00 | 2.98 | 2.61 | 4.18 | 4.89 | - |
| Cadmium (mg/Kg) | 0.32 | 0.23 | 0.34 | 0.25 | 0.33 | 0.25 | 0.48 | 0.40 | 0.596/3.53 |
| Calcium (mg/Kg) | 3,860 | 3,510 | 5,680 | 2,910 | 4,970 | 4,200 | 8,900 | 5,390 | - |
| Chromium (mg/Kg) | 17.8 | 15.7 | 18.8 | 18.8 | 19.9 | 15.2 | 25.7 | 25.1 | 37.3/90 |
| Cobalt (mg/Kg) | 7.29 | 6.97 | 7.35 | 7.42 | 7.32 | 6.16 | 10.3 | 10.5 | - |
| Copper (mg/Kg) | 17.2 | 10.2 | 16.8 | 12.8 | 16.9 | 11.8 | 26.0 | 22.5 | 35.7/197 |
| Iron (%) | 17.1 | 14.6 | 18.6 | 16.3 | 17.4 | 15.8 | 25.0 | 24.1 | - |
| Lead (mg/Kg) | 4.85 | 3.95 | 6.17 | 4.83 | 5.39 | 3.33 | 9.36 | 7.38 | 35/91.3 |
| Magnesium (mg/Kg) | 4,300 | 3,963 | 4,720 | 4,460 | 4,610 | 4,490 | 5,360 | 4,980 | - |
| Manganese (mg/Kg) | 374 | 266 | 361 | 296 | 525 | 461 | 640 | 852 | - |
| Mercury (µg /Kg) | 30.5 | 24.9 | 46.8 | 48.0 | 36.3 | 20.9 | 165 | 341 | 174/486 |
| Methylmercury (µg/Kg) | 0.03 | 0.04 | 0.11 | 0.01 | 0.13 | 0.01 | 0.99 | 0.40 | - |
| Molybdenum (mg/Kg) | 0.24 | 0.23 | 0.62 | 0.21 | 0.21 | 0.38 | 0.58 | 0.45 | - |
| Nickel (mg/Kg) | 19.5 | 18.7 | 21.9 | 21.3 | 21.5 | 17.4 | 28.0 | 28.8 | 18/36 |
| Potassium (mg/Kg) | 777 | 618 | 953 | 717 | 941 | 626 | 1,358 | 945 | - |
| Selenium (mg/Kg) | 0.31 | 0.29 | 0.53 | 0.24 | 0.27 | 0.10 | 0.42 | 0.44 | - |

**Table 3.7-13: Summary of Total Metals Results[1] in Kuskokwim River Sediment, 2007 Sampling Event**

| Trace Metal (Units) | Eek Island (n=2) | Helmick Point (n=6) | Bethel Dock (n=3) | Upriver of Bethel (n=5) | Birch Tree Crossing (n=5) | Aniak (n=2) | Crooked Creek (n=5) | George River (n=3) | TEL/PEL[2] |
|---|---|---|---|---|---|---|---|---|---|
| Silver (mg/Kg) | 0.08 | 0.05 | 0.10 | 0.06 | 0.09 | 0.12 | 0.19 | 0.12 | - |
| Sodium (mg/Kg) | 287 | 227 | 181 | 153 | 173 | 114 | 221 | 170 | - |
| Thallium (mg/Kg) | 0.07 | 0.07 | 0.08 | 0.03 | 0.04 | 0.07 | 0.13 | 0.09 | - |
| Tin (mg/Kg) | 0.89 | 0.84 | 1.07 | 0.99 | 1.10 | 0.97 | 1.44 | 1.37 | - |
| Vanadium (mg/Kg) | 28.8 | 26.1 | 28.5 | 27.1 | 27.9 | 25.9 | 35.9 | 36.2 | - |
| Zinc (mg/Kg) | 52.6 | 46.3 | 61.8 | 54.5 | 59.7 | 48.3 | 89.2 | 80.1 | 123/315 |

**Notes:**

1 Mean concentrations on a dry weight basis.
2 NOAA SQuiRT values for freshwater sediment (ADEC 2013d; Buchman 2008).
Shaded values indicate concentrations in excess of the sediment Quality Guidelines (SQGs) recommended by ADEC (2013b) for use at contaminated sites including Threshold Effects Levels (TELs) and Probable Effects Levels (PELs) published in NOAA Screening Quick Reference Tables for both fresh and marine water sediment (Buchman 2008).

**Abbreviations:**

mg/kg = milligrams per kilogram
µg/kg = micrograms per kilogram (equivalent to nanograms per gram [ng/g])
n = number of discrete samples collected

Source: RWJ 2010a.

**Table 3.7-14: Summary of Total Metals Results[1] in Kuskokwim River Sediment, 2010 Sampling Event**

| Trace Metal (Units) | Helmick Point (n=6) | Bethel Dock (n=6) | Upriver of Bethel (n=6) | Birch Tree Crossing (n=6) | Aniak (n=5) | Jungjuk Creek | | Crooked Creek (n=5) | George River (n=3) | TEL/PEL[2] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | JD (n=4) | JU (n=3) | | | |
| Aluminum (%) | 11.48 | 10.26 | 8.66 | 9.78 | 8.41 | 9.55 | 9.87 | 10.38 | 7.94 | - |
| Antimony (mg/Kg) | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.11 | 0.08 | 0.04 | 0.05 | - |
| Arsenic (mg/Kg) | 10.4 | 11.6 | 8.72 | 9.13 | 9.53 | 13.95 | 13.12 | 12.67 | 12.3 | 5.9/17 |
| Barium (mg/Kg) | 97 | 125 | 104 | 132 | 138 | 156 | 141 | 160 | 144 | - |
| Beryllium (mg/Kg) | 0.33 | 0.38 | 0.29 | 0.34 | 0.33 | 0.30 | 0.31 | 0.33 | 0.34 | - |
| Bismuth (mg/Kg) | 0.04 | 0.05 | 0.04 | 0.12 | 0.10 | 0.09 | 0.10 | 0.08 | 0.20 | - |
| Cadmium (mg/Kg) | 0.26 | 0.33 | 0.24 | 0.24 | 0.24 | 0.24 | 0.25 | 0.21 | 0.22 | 0.596/3.53 |
| Calcium (mg/Kg) | 4,380 | 4,246 | 3,034 | 3,586 | 3,213 | 4,070 | 5,133 | 4,055 | 5,120 | - |
| Cobalt (mg/Kg) | 9.60 | 8.52 | 8.60 | 7.49 | 7.68 | 8.33 | 7.73 | 8.18 | 9.41 | - |
| Chromium (mg/Kg) | 21.8 | 22.3 | 20.7 | 22.5 | 21.6 | 20.9 | 19.2 | 19.9 | 22.7 | 37.3/90 |
| Copper (mg/Kg) | 20.3 | 21.5 | 16.5 | 17.6 | 16.8 | 15.0 | 16.6 | 14.7 | 18.7 | 35.7/197 |
| Iron (%) | 21.8 | 20.9 | 19.0 | 20.6 | 19.5 | 20.8 | 21.5 | 20.0 | 18.8 | - |
| Lead (mg/Kg) | 5.66 | 6.43 | 35.8 | 5.38 | 4.44 | 5.31 | 5.69 | 5.25 | 6.80 | 35/91.3 |
| Magnesium (mg/Kg) | 5,450 | 5,100 | 4,630 | 4,860 | 4,333 | 4,520 | 4,233 | 4,068 | 4,770 | - |
| Manganese (mg/Kg) | 524 | 422 | 373 | 397 | 554 | 777 | 618 | 622 | 561 | - |
| Mercury (µg/Kg) | 63.6 | 61.2 | 34.1 | 34.5 | 32.0 | 43.7 | 105 | 80.1 | 65.6 | 174/486 |
| Methylmercury (µg/Kg) | 0.05 | 0.11 | 0.04 | 0.09 | 0.01 | 0.05 | 0.10 | 0.30 | 0.11 | - |
| Molybdenum (mg/Kg) | 0.22 | 0.27 | 0.26 | 0.49 | 0.55 | 0.61 | 0.56 | 0.42 | 0.60 | - |
| Nickel (mg/Kg) | 24.0 | 25.4 | 25.4 | 25.2 | 25.6 | 24.9 | 24.3 | 23.6 | 30.8 | 18/36 |
| Phosphorus (mg/Kg) | 740.40 | 644.60 | 601.60 | 584.80 | 566.00 | 597.00 | 543.33 | 516.50 | 513.50 | - |
| Potassium (mg/Kg) | 980.00 | 945.40 | 718.20 | 916.40 | 915.50 | 867.00 | 1,005.33 | 839.25 | 986.00 | - |
| Selenium (mg/Kg) | 0.28 | 0.49 | 0.30 | 0.40 | 0.31 | 0.50 | 0.44 | 0.47 | 0.59 | - |

**Table 3.7-14: Summary of Total Metals Results[1] in Kuskokwim River Sediment, 2010 Sampling Event**

| Trace Metal (Units) | Helmick Point (n=6) | Bethel Dock (n=6) | Upriver of Bethel (n=6) | Birch Tree Crossing (n=6) | Aniak (n=5) | Jungjuk Creek | | Crooked Creek (n=5) | George River (n=3) | TEL/PEL[2] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | JD (n=4) | JU (n=3) | | | |
| Silver (mg/Kg) | 0.12 | 0.12 | 0.07 | 0.09 | 0.08 | 0.08 | 0.11 | 0.08 | 0.16 | - |
| Sodium (mg/Kg) | 608 | 178 | 134 | 172 | 171 | 126 | 137 | 110 | 102 | - |
| Thallium (mg/Kg) | 0.11 | 0.10 | 0.08 | 0.09 | 0.09 | 0.10 | 0.12 | 0.09 | 0.10 | - |
| Tin (mg/Kg) | 0.22 | 0.21 | 0.39 | 0.92 | 0.81 | 0.99 | 1.03 | 0.98 | 1.25 | - |
| Vanadium (mg/Kg) | 35.4 | 32.2 | 29.0 | 30.4 | 31.9 | 27.7 | 25.9 | 26.7 | 30.1 | - |
| Zinc (mg/Kg) | 70.3 | 72.0 | 62.1 | 65.2 | 55.6 | 62.9 | 63.0 | 60.4 | 73.2 | 123/315 |

**Notes:**

1 Mean concentrations on a dry weight basis.

2 NOAA SQuiRT values for freshwater sediment (ADEC 2013d; Buchman 2008).

Shaded values indicate concentrations in excess of the Sediment Quality Guidelines (SQGs) recommended by ADEC (2013) for use at contaminated sites including Threshold Effects Levels (TELs) and Probable Effects Levels (PELs) published in NOAA Screening Quick Reference Tables for both fresh and marine water sediment (Buchman 2008).

**Abbreviations:**

mg/kg = milligrams per kilogram
µg/kg = micrograms per kilogram (equivalent to nanograms per gram [ng/g])
n = number of discrete samples collected

Source: RWJ 2010a.

**Table 3.7-15: Summary of Non-Metal Analytes in Sediments on the Main Channel of the Kuskokwim River from Helmick Point to Georgetown**

| | Units | Helmick Point | Bethel Dock | Upriver of Bethel | Birch Tree Crossing | Aniak | Jungjuk Creek | | Crooked Creek | George River | Sediment Quality Guideline |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | JD | JU | | | |
| **n** | | 6 | 3 | 5 | 5 | 2 | 5 | 5 | 5 | 3 | |
| **Grain Size** | | | | | | | | | | | |
| Percent gravel | % | 0 | 0 | 0 | 20.6 | 25 | 30.25 | 10.67 | 30 | 49 | - |
| Percent sand | % | 17.8 | 50.14 | 60.22 | 51.72 | 54.75 | 62.2 | 56.87 | 55.975 | 40.35 | - |
| Percent sand/silt or mud | % | 82.2 | 49.86 | 39.78 | 27.68 | 20.25 | 7.55 | 32.47 | 14.025 | 10.65 | - |
| Percent finer than 0.02 mm | % | 26 | 18.8 | 12 | 10.2 | 4.75 | 3.75 | 10.67 | 5.25 | 1.5 | - |
| **Inorganics** | | | | | | | | | | | |
| Cyanide | mg/Kg | 0.04 | 0.03 | 0.04 | 0.03 | 0.03 | 0.06 | 0.05 | 0.06 | 0.05 | - |
| **Organics** | | | | | | | | | | | |
| Diesel Range Organics | mg/Kg | 17.20 | 24.24 | 13.74 | 13.34 | 44.10 | 38.00 | 20.65 | 65.27 | 25.70 | 100[1] |
| Residual Range Organics | mg/Kg | 134.32 | 147.24 | 62.34 | 81.6 | 36.60 | 176.00 | 98.65 | 192.40 | 23.05 | 2,000[1] |
| Total organic carbon | % | 1.01 | 0.96 | 0.54 | 0.58 | 0.28 | 0.90 | 0.86 | 1.00 | 0.56 | - |
| **BTEX** | | | | | | | | | | | |
| Toluene | µg/Kg | ND | 13.32 | 5.92 | ND | ND | ND | ND | ND | ND | - |
| **Pesticides** | | | | | | | | | | | |
| 4,4'-DDT | µg/Kg | ND | 0.64 | ND | ND | ND | ND | ND | ND | ND | 1.19/4.77[2] |
| 4,4'-DDD | µg/Kg | ND | 0.65 | ND | ND | ND | ND | ND | ND | ND | 3.54/8.51[2] |

**Notes:**

1 SQGs for organics are the most stringent ADEC recommended clean-up levels for contaminated soils in non-arctic zones (ADEC 2000).
2 SQGs for pesticides are TEL / PEL from Buchman (2008).

**Abbreviations:**

mg/kg = milligrams per kilogram
µg/kg = micrograms per kilogram (equivalent to nanograms per gram [ng/g])
n = number of discrete samples collected

Previous Studies

Several previous studies have measured mercury levels in the sediments of the Kuskokwim River and some of the surrounding tributaries (Bailey and Gray 1997; Gray et al. 1991, 1994; Nelson et al. 1977). Nelson et al. (1977) analyzed mercury in 299 bulk bottom sediment samples collected from throughout the Kuskokwim River and tributary system as part of a study to determine patterns of mercury dispersal from lode sources in the Kuskokwim River drainage. Throughout areas identified as mercury source areas in the upper Kuskokwim River and tributaries, median background concentrations of mercury were reported as 0.1 mg/kg in bulk sand and silt bottom sediments. The median background concentrations of mercury in bulk bottom sediment generally decreased with distance downriver, and were reported as 0.06 mg/kg in bulk bottom sediment collected from the lower Kuskokwim River and Kuskokwim Bay. This finding suggests that mercury-bearing sediment eroded from upstream sources does not substantially enrich the mercury content of downstream bottom sediments at a watershed scale (Nelson et al. 1977). In addition, a comprehensive study of the Kuskokwim River conducted for the USGS in June 1997 included measurements of the spatial distribution of mercury in sediments of the Kuskokwim River watershed (Wang 1999). This study found similar results: values between 0.01 and 1 mg/kg, with total mercury concentrations in the Kuskokwim River decreasing downstream from McGrath. These data trends are similar to those described above for the project area, where mercury concentrations in sediments are highest between George River and Jungjuk, and generally decrease downstream (see Figure 3.7-12 and Table 3.7-13).

In suspended sediment and filtered water samples, the highest recorded mercury concentrations were measured in samples collected near the largest mineralized areas; concentrations declined substantially with distance downstream (Nelson et al. 1977). The authors suggest that most mercury enters the river system as particulate cinnabar in bottom sediment and that the diluting effects of water discharge and suspended sediment discharge are sufficient to disperse the influence of mercury-enriched bottom sediments over short distances. The distribution of total mercury in Kuskokwim River sediments can be described as a series of stationary, localized, persistent hotspots that diminish over short spatial scales due to the diluting and dispersing effects of river discharge (Nelson et al. 1977).

### 3.7.2.4 GEOCHEMICAL CHARACTERIZATION

As stated on the Alaska Department of Natural Resources (ADNR) website: "Mining 101 – rock chemistry drives water quality and mine design." In the natural environment, rocks are broken down into soil through exposure to air and water in a process called weathering. During weathering, minerals react with air and water to release some of their constituents (ions) into the surrounding environment, aqueous and otherwise. In many cases, the primary minerals are transformed into secondary residual minerals during this process. The ions that go into solution may be transported away by runoff, streams, and groundwater, and therefore have a large influence on water quality. If a mineralized deposit is buried beneath other rocks and soil, it naturally weathers very slowly. However, when a mineralized deposit is excavated during mining, the weathering process can increase substantially because previously unexposed rocks are broken up and exposed to rain, snow, and air at the surface.

Both the ore and non-ore rocks in many mineral deposits contain minerals (mainly sulfides) that can produce acid during weathering. The resulting acidic water is known as acid rock drainage (ARD). Metals and other potentially hazardous constituents can also be released during weathering in a process called metal leaching (ML). Most metals are released more rapidly in acidic water. However, some other constituents, including metalloids such as arsenic, and salts such as sulfate, can be released into the environment even if the water draining the rock has a neutral or basic pH (e.g., Smith, 2007).

The task of geochemical characterization at a proposed mine site is to identify the potential of the rocks in and surrounding the mineralized deposit to produce ARD and/or ML that could affect water quality in surface water and/or groundwater. The characterization process involves studies of the mineralogy of the rocks, the quantities of minerals with potential to generate or neutralize acid, the amounts of potentially hazardous constituents in the rocks, and the rates of weathering/release of these minerals and constituents expected during mining. Several studies have been undertaken over a number of years to evaluate the potential for ARD and/or ML for the proposed project. A brief summary of these studies follows.

In some mineralized deposits, rock type alone can be a good indicator of whether a rock will potentially produce ARD and/or ML. However, gold mineralization at the proposed mine site occurs mainly within the sulfide minerals pyrite ($FeS_2$) and arsenopyrite (FeAsS), which are contained in clastic sedimentary rocks (mainly greywackes and shales) that have been intruded by rhyodacite dikes and sills (SRK 2007). The geology of the deposit is described in detail in Section 3.1, Geology, and shown on Figure 3.1-3. Because the hot, ore-forming fluids that produced mineralization at the Donlin deposit have already chemically reacted with the surrounding rocks, it is not sufficient to only use rock type as the indicator of which rocks are potentially acid generating (PAG). Extensive drilling was conducted to determine ore zones. Rock material from the drill holes was then used for testing. Initial geochemical studies (MDAG 2006) found substantial variability in both the composition of rock material and the way the material reacts over time to weathering conditions.

Because of the geochemical variability in the rocks, the selected approach was to look at the material that would be mined each year. The annual area mined was estimated by developing a block model. (The block model is a computer model that shows the three-dimensional location of each type of rock and the likely order of mining.) Based on the block model, over the life of the proposed mine, there would be about 556 million tons of ore, 3 billion tons of waste rock, and about 50 million tons of overburden mined from the proposed open pit. Rock material was assessed based on whether the material would take a long time to react – developing acid or losing neutralizing potential – and whether the material would be processed to end up in tailings or set aside as waste rock, in order to design waste management strategies.

Based on the results obtained from integrating the geochemical studies with the block model, the majority of the rocks that would be mined from the Donlin Gold deposit do not have the potential for acid generation and could be considered substantially acid neutralizing. However, most rocks do have the potential to leach certain constituents, mainly arsenic and sulfate. These results will be discussed in more detail in the next few sections.

#### 3.7.2.4.1 WASTE ROCK

Acid Rock Drainage

Typically, rocks are predicted to be non-acid generating (NAG) or potentially acid generating (PAG) based on the relative amounts of constituent minerals that can form acid and those that can neutralize acid. The most typical and strongest acid-generating mineral is pyrite. It forms sulfuric acid ($H_2SO_4$) when it reacts with oxygen and water during weathering:

$$FeS_2(s) + 15/4\ O_2 + 7/2\ H_2O = 2\ H_2SO_4 + Fe(OH)_3(s)$$

Other sulfides and a few other types of minerals can also form acid, but to a lesser extent. The acid-generation potential (AP) of a rock is the total capacity of that rock to generate acid if all of its acid-generating minerals react to completion during weathering.

The best and most common acid neutralizing mineral is calcite, one of the polymorphs of calcium carbonate ($CaCO_3$):

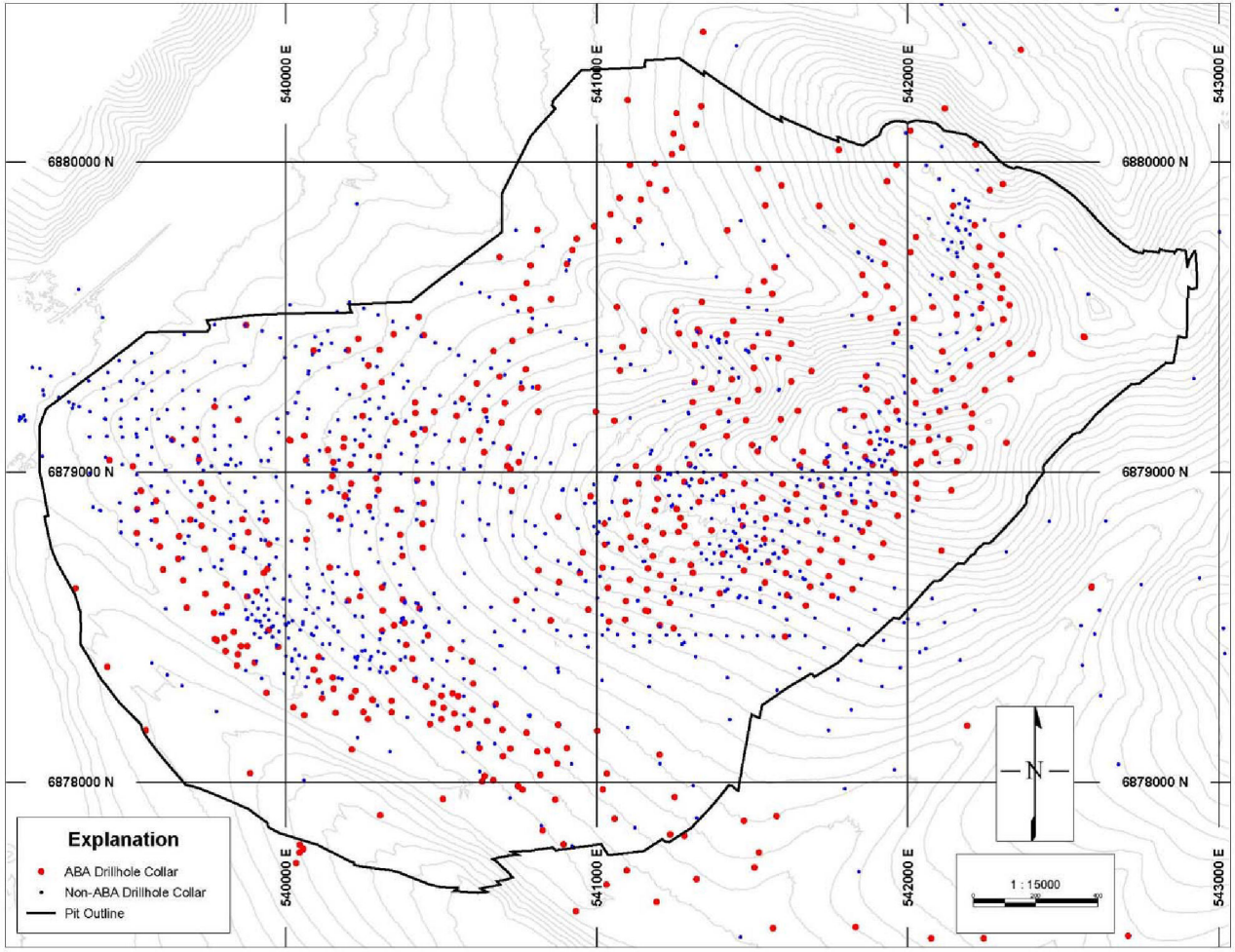
$$CaCO_3(s) + H_2SO_4 = Ca^{2+} + SO_4^{2-} + H_2O + CO_2(g)$$

Other carbonates, including dolomite [$CaMg(CO_3)_2$] and ankerite [$Ca(Fe,Mg,Mn)(CO_3)_2$], can also neutralize acid to varying extents. In contrast, siderite ($FeCO_3$), is not considered to have neutralization potential, due to its iron content, unless it has magnesium or calcium substituting for some of the iron. Similar to the definition of AP, the acid-neutralization potential (NP) of a rock is its total capacity to neutralize acid if all its carbonate minerals react to completion.

Acid-Base Accounting (ABA) is the series of laboratory tests designed to estimate a rock's AP and NP. Both AP and NP are expressed in units of tons of calcium carbonate equivalent per 1,000 tons of material (t $CaCO_3$/kt) to allow direct comparisons. Corrections must be made when the respective minerals are not all pyrite or calcite.

For the proposed project, the NP and AP terms were developed through extensive study of the chemistry and mineralogy of the various rock types at the site. This included ABA using the standard Sobek et al. (1978) method on more than 2,300 rock samples collected from more than 170 drill holes blanketing the proposed mine area (Figure 3.7-13; SRK 2007, 2011). The mineralogical characterization included analysis of 40 samples by thin section, Rietveld XRD, and/or ion microprobe to determine carbonate minerals, including detailed analysis of 617 carbonate mineral grains, as well as investigation of 132 sulfide mineral grains from 16 samples (SRK 2011). Based on mineralogical analysis, the NP was found to be mainly ankerite and dolomite, followed by calcite. Siderite (with about 20-25 percent magnesium substituting for iron) was found to be prevalent, especially in sediments. The AP was found to be mainly pyrite and arsenopyrite. Corrections were made to the standard ABA calculations to account for these minerals (SRK 2007, 2011).

The most common measure of whether a rock is NAG or PAG is its ratio of NP to AP. That ratio is referred to as NP*/AP in the Donlin geochemical studies, where the * denotes that corrections were made to the standard NP measurement to account for the relative amounts and different neutralization potentials of each of the various types of carbonate minerals found at the site (SRK 2007, 2011).




Data Source: SRK 2011, Figure 1

DONLIN GOLD

*DONLIN GOLD PROJECT EIS*

DRILLHOLES SAMPLED FOR ACID-BASE ACCOUNTING

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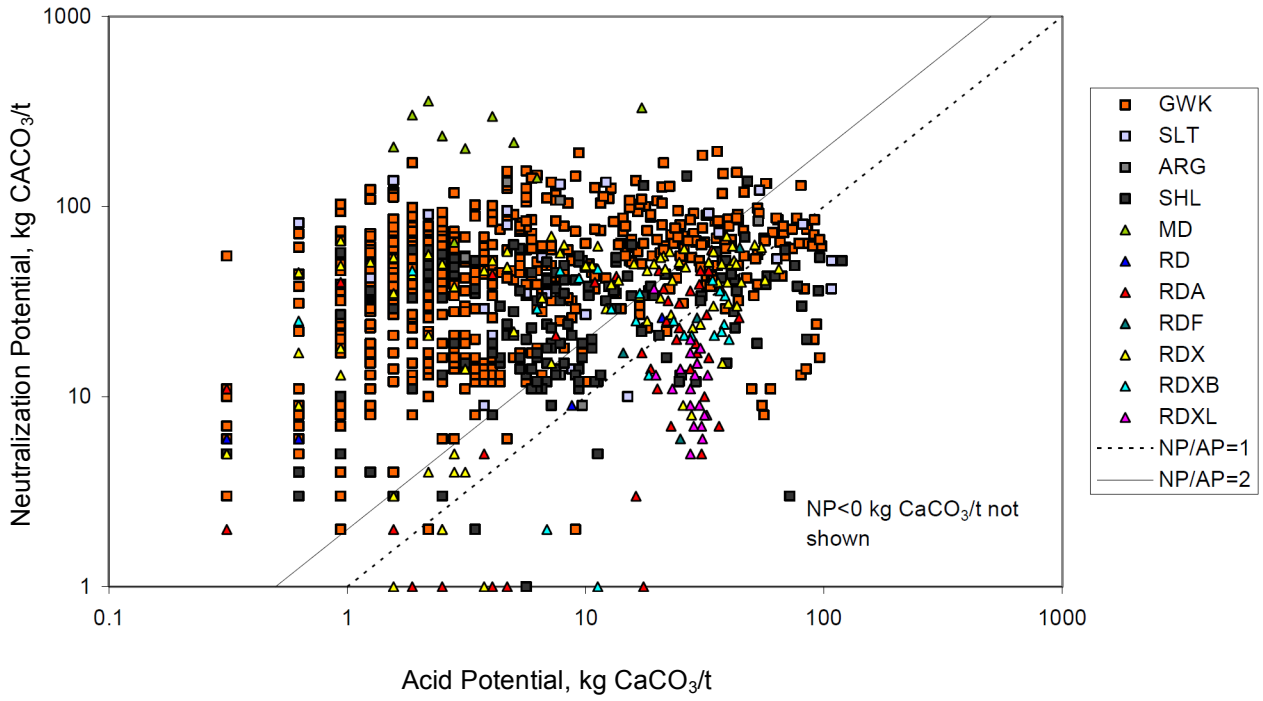
FIGURE 3.7-13

For the proposed project waste rock, the NP and AP showed substantial variation both within and across rock types (Figure 3.7-14). The AP distributions of greywackes (GWK) and shales (SHL) were both bimodal (i.e., each rock type had two local maxima in the probability distribution curve) with good separation between modes. The lower AP mode for shales was higher than that for greywackes, probably due to the presence of non-mineral-related diagenetic pyrite. Unlike AP, NP distributions for sedimentary rocks were more complex, not easily separable into modal groups.

The rhyodacite AP was typically higher than that for sedimentary rocks, but it also spanned a large range depending on the form of the rhyodacite. Unlike that of the sedimentary rocks, the rhyodacite NP was separable into two populations at an NP value of 34.5 t $CaCO_3$/kt. Aphanitic rhyodacite (RDA) and lathe-rich rhyodacite (RDXL) tended to have higher AP. Due to low NP, they were mostly PAG (NP/AP <1). Mafic dykes had the highest NP/AP of all the rock types (SRK 2007).

The block model mentioned in Section 3.7.2.4 was used in combination with the geochemical and mineralogical studies to estimate ARD potential during each proposed mining year. Each block in the block model was assigned a sulfur content value and a neutralizing carbonate content value, the combination of which were used to determine whether or not that block is PAG or NAG material. The sulfur and carbonate content values in the block model were assigned by geostatistically interpolating sulfur and carbonate values from drill core assays. If the carbonate content in a particular block was more than sufficient to neutralize any acid generating potential, the block was generally characterized as NAG.

Based on integrating the block model with the geochemical and mineralogical studies, the tonnage-weighted average NP*/AP ratio of the waste rock expected to be mined during the lifetime of the mine is estimated to be 5.5 (Enos 2013c). This means that the waste rock as a whole has the capacity to neutralize 5.5 times more acid than those same rocks can generate. The red line in Figure 3.7-15 shows how the ratio varies from year to year as different rocks are expected to be mined, with the lowest average ratio in the first and last years of operation. However, in all cases the annual average NP*/AP is greater than 2.6. Different states and countries have set different criteria for considering rocks to be non-acid generating. Typically a NP/AP ratio of 2 is used unless a less stringent ratio can be shown to be valid for a particular site. California at one time used the more stringent ratio of 3 as the criterion to divide NAG and PAG rock. Based on even the more stringent criterion, the waste rock at the proposed project site as a whole is considered non-acid generating.




Rock Types:
ARG = Argillite, GWK = greywacke, MD = mafic dykes, RDA = aphanitic rhyodacite, RDF = fault-zone rhyodacite, RDX = crowded crystalline rhyodacite, RDXB = blue rhyodacite, RDXL = lathe-rich rhyodacite, SHL = shale, SLT = siltstone

Data Sources: SRK 2007

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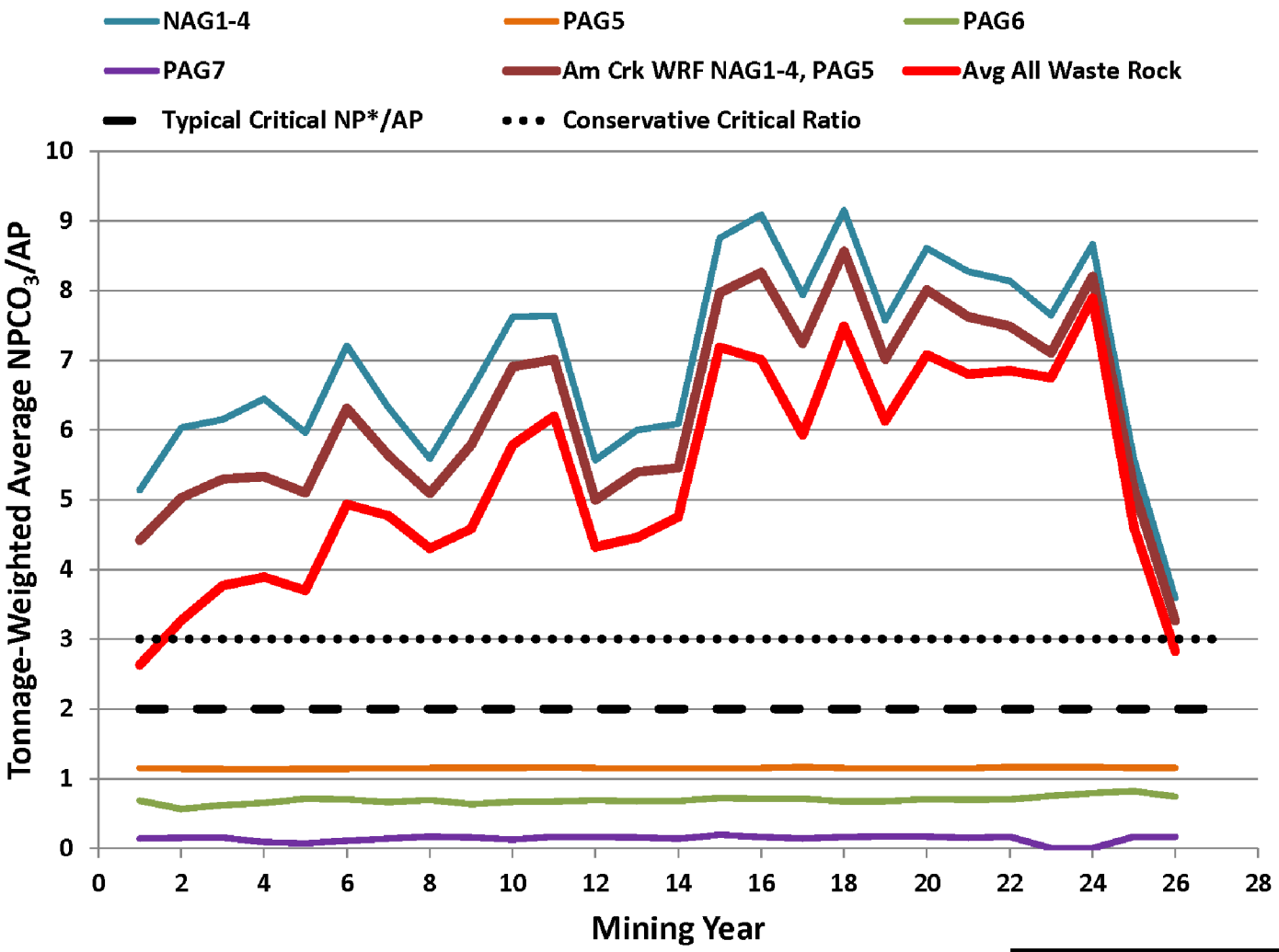
ACID- NEUTRALIZATION POTENTIAL VS. ACID-GENERATION POTENTIAL BY ROCK TYPE

NOVEMBER 2015

FIGURE 3.7-14




Data Sources: BGC 2011b

Tonnage-Weighted Annual Averages for the Ratio of Neutralizing Potential (NP) to Acid Producing Potential (AP) for Waste Rock of Various Categories

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TONNAGE-WEIGHTED ANNUAL AVERAGE OF NP/AP FOR WASTE ROCK CATEGORIES

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FIGURE 3.7-15

Because some rocks were found to be PAG, Donlin further classified the rocks into several additional waste rock management categories (WRMCs) based on their NP*/AP and their tendency to leach arsenic. Table 3.7-16 [SRK 2007, 2011, 2012b] shows the classification scheme, which was developed in two stages. The development process will be discussed in some detail later in this section.) The classification scheme was then used to design an appropriate waste rock management strategy for each category of rock from low-reactivity mostly NAG rocks (NAG 1-4, with NP*/AP > 1.3) to rocks with high potential to generate acid in a short time period (PAG 7, with NP*/AP ≤ 0.2). (The annual average NP*/AP values for each of these classifications are shown as the thinner lines on Figure 3.7-15.) The NAG 1-4 rocks constitute about 92.5 percent of the total waste rock. Of these, over 90 percent are NAG 1 and NAG 2 rocks, and less than 10 percent are NAG 3 or NAG 4. The most reactive PAG 7 rocks constitute less than 0.09 percent of the total waste rock (SRK 2007). The waste rock facility (WRF) and water treatment plant were designed based on the conclusions of the waste characterization reports regarding the percentage of waste rock that is PAG, as well as the leachability of metals and metalloids such as arsenic (BGC 2011b).

**Table 3.7-16: Preliminary and Revised Waste Rock Management Categories for Proposed Donlin Gold Project**

| | | SRK 2007 (Preliminary) | | Revised 2011 |
|---|---|---|---|---|
| **Waste Rock Management Category** | **Category Description** | **NP*/AP Range and AP** | **As/S (As in mg/kg and S in %)** | **NP*/AP Range and AP** |
| NAG 1 | Very unlikely to generate ARD and "low" arsenic leaching | AP<3 kg CaCO3/t or NP*/AP >2 | As/S<196 and As<260 | Not Used |
| NAG 2 | Very unlikely to generate ARD and arsenic leaching potentially significant | AP<3 kg CaCO3/t or NP*/AP > 2 | As/S>196 or AS>250 | AP<3 kg CaCO3/t or NP*/AP > 2 |
| NAG 3 | Unlikely to generate ARD and "low" arsenic leaching | 1.4<NP*/AP<2 | As/S<196 and As<250 | Not Used |
| NAG 4 | Unlikely to generate ARD and arsenic leaching potentially significant | 1.4 <NP*/AP <2 | As/S>196 or As>250 | 1.3 <NP*/AP <2 |
| PAG 5 | PAG but with very long delays (several decades) to onset of ARD | 1.0 <NP*/AP <1.4 | All | 1.0 <NP*/AP <1.3 |
| PAG 6 | PAG in the life of the mine (possibly less than a decade) | 0.2 <NP*/AP <1.0 | All | 0.2 <NP*/AP <1.0 |
| PAG 7 | PAG but with shorter delays to onset (less than a few years) | NP*/AP <0.2 | All | NP*/AP <0.2 |

**Notes:**

* Revised site-specific $NPCO_3 = 0.76 \bullet NP + 4.8$ (SRK 2011).

Source: SRK 2012e.

The ABA test is called a static test because it measures the total amount of acid-generating material and acid-neutralizing material and assumes that both react to completion. It gives no indication of relative reaction rates. In order to investigate relative rates, kinetic geochemical

tests are used to simulate weathering. For the proposed project, kinetic tests included 40 laboratory humidity cell tests (HCTs) and 10 on-site barrel tests.

HCTs mimic weathering in the laboratory by exposing a sample to a weekly weathering cycle consisting of 3 days of wet air, 3 days of dry air, and a day in which the sample is rinsed with water to simulate rain. The leachate from the water rinse is collected each week. The Donlin HCTs were conducted on samples of individual rock types, in two phases: Phase 1 consisted of 16 HCTs and Phase 2 consisted of 24 additional HCTs. Twelve of the Phase 1 HCTs were continued for 84 weeks; while 3 were continued for over 8 years and 1 is still continuing after almost 12 years. The three longer-term Phase 1 HCTs included two intrusives with NP/AP values of <0.1 (sample 63762m PAG 7) and 0.3 (sample 674322, PAG 6); and one sedimentary sample with a NP/AP of 2.3 (sample 213138, PAG 2), respectively, on Figure 3.7-16). The continuing sample is number 216377, from a fault zone in sediment. It has a NP/AP of 1.0 (PAG 5).Three of the Phase 1 HCTs (one PAG 6 and two PAG 7 samples) produced acidic leachates throughout the test. The PAG 6 sample 674322 began producing acidic leachate after more than 200 weeks.

In 2008, 24 additional HCTs were started to test a broader range of geochemical characteristics that matched the seven preliminary WRMCs shown in Table 3.7-16. The Phase 2 HCTs were evaluated after approximately two years (SRK, 2011). Most of these HCTs were continued for another two years thereafter, and seven are still continuing. Information on the geology and partial geochemistry of the samples used for the HCTs is given in Table 3.7-17, from SRK 2011. Leachate pH and sulfate for these samples are shown in Figure 3.7-17. Only one of the Phase 2 samples produced acidic leachate in almost seven years of tests. The pH has started to decrease in another sample (shale sample 683340, PAG 5), but is still neutral. The sulfate release rates (and thus sulfide oxidation rates) from the Phase 1 and 2 tests were found to be highly correlated to the sulfide content of the samples. This correlation allowed estimates of the delay to acid formation for various classes of PAG rock, as given in Table 3.7-16—from less than a few years for PAG 7 rocks to several decades for PAG 5 rocks.

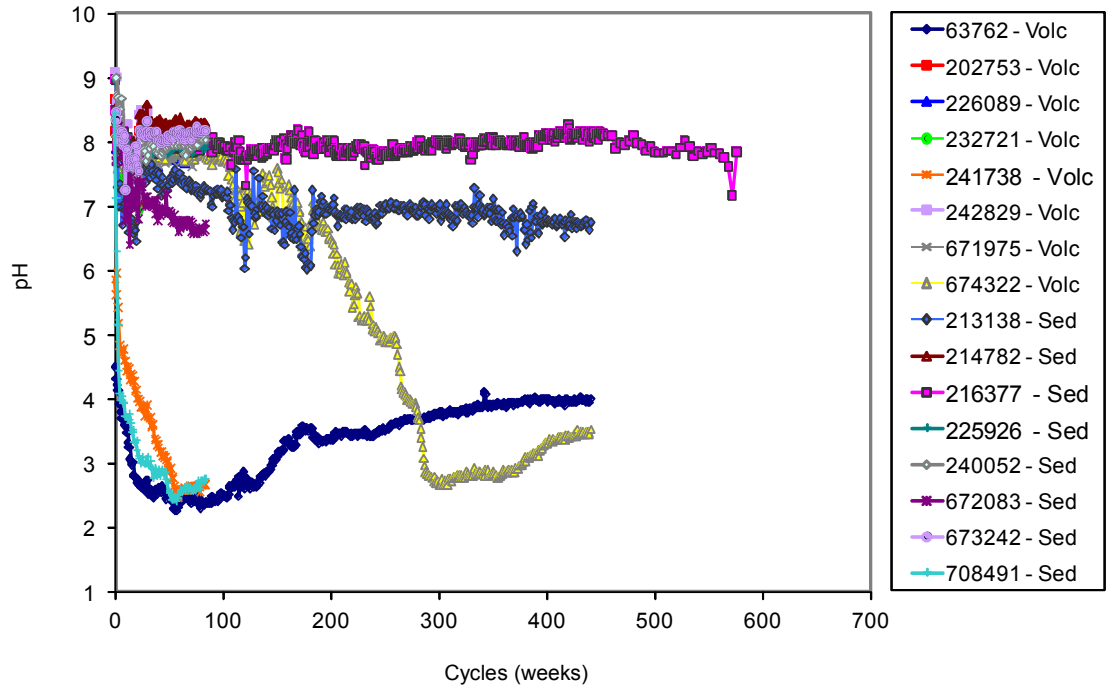


Figure 3.7-16A: Selected Phase 1 Humidity Cell Test Results: pH

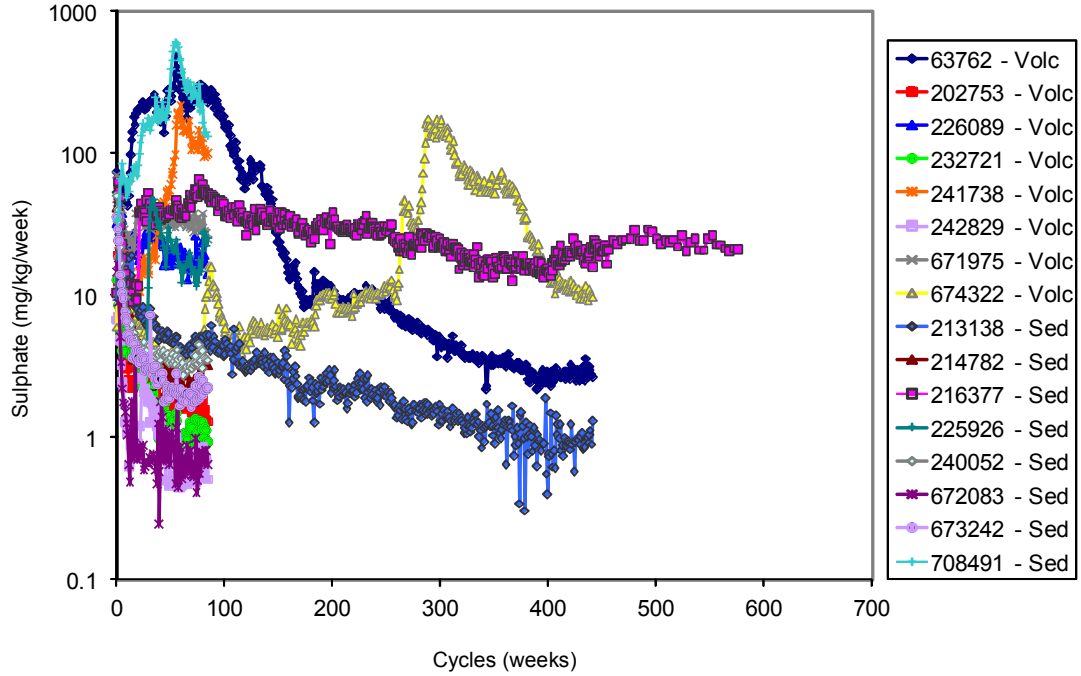


Figure 3.7-16B: Selected Phase 1 Humidity Cell Test Results: Sulfate Loading

Data Source: SRK 2011

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PHASE 1 HUMIDITY CELL TEST RESULTS FOR pH AND SULFATE

NOVEMBER 2015 FIGURE 3.7-16

**Table 3.7-17: Characteristics of Rock Samples in Humidity Cell Tests**

| Phase | HCT | Date Started | Date Stopped | Logged Geology | WRMC | Paste pH | Total S %, S | Sulfate %, S | AP kg $CaCO_3$/t | NP* kg $CaCO_3$/t | NP*/AP | Arsenic mg/kg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 216377 | 7/14/2004 | Continuing | Fault Zone | 5 | 7.8 | 1.75 | 0.03 | 55 | 54.2 | 1.0 | 2,690 |
| 1 | 63762 | 7/14/2004 | 12/26/2012 | RDA | 7 | 3.6 | 0.94 | 0.12 | 29 | -2 | -0.1 | 1,825 |
| 1 | 202753 | 7/14/2004 | 2/22/2006 | RDXB | 2 | 8.2 | 0.06 | -0.01 | 2 | 39.76 | 21.2 | 53.4 |
| 1 | 226089 | 7/14/2004 | 2/22/2006 | RDX | 6 | 7.8 | 1.44 | 0.02 | 45 | 35.2 | 0.8 | 2,860 |
| 1 | 232721 | 7/14/2004 | 2/22/2006 | RDXB | 6 | 5.6 | 0.22 | 0.01 | 7 | 2 | 0.3 | 1,555 |
| 1 | 241738 | 7/14/2004 | 2/22/2006 | RDA | 7 | 4.5 | 0.56 | 0.03 | 18 | 1 | 0.1 | 519 |
| 1 | 242829 | 7/14/2004 | 2/22/2006 | RDX | 2 | 8.7 | 0.07 | -0.01 | 2 | 47.4 | 21.7 | 17.4 |
| 1 | 671975 | 7/14/2004 | 2/22/2006 | RDX | 6 | 7.9 | 1.38 | 0.02 | 43 | 27.6 | 0.6 | 5,630 |
| 1 | 674322 | 7/14/2004 | 12/26/2012 | RDA | 6 | 7.7 | 0.73 | 0.01 | 23 | 7 | 0.3 | 812 |
| 2 | 678622 | 10/2/2008 | 12/27/2012 | RDA | 1 | 8.1 | 0.58 | 0.01 | 18.1 | 22 | 1.2 | 7.39 |
| 2 | 683388 | 10/2/2008 | 12/27/2012 | RDXL | 4 | 8.8 | 0.68 | 0.06 | 21 | 36.0 | 1.7 | 582 |
| 2 | 725741 | 10/4/2008 | Continuing | RDX | 5 | 8.5 | 1.58 | 0.03 | 49 | 48.9 | 1.0 | 1,940 |
| 2 | 733611 | 10/4/2008 | 1/5/2013 | RDXL | 7 | 7.7 | 0.93 | 0.02 | 29 | 4 | 0.1 | 1,250 |
| 2 | 746703 | 10/2/2008 | 12/27/2012 | RDX | 1 | 8.5 | 0.03 | <0.01 | 1 | 24. 6 | 26.2 | 10.8 |
| 2 | 747402 | 10/2/2008 | 12/27/2012 | RDA | 4 | 8 | 1.05 | 0.02 | 33 | 36.0 | 1.1 | 265 |
| 2 | 747406 | 10/2/2008 | Continuing | RDA | 2 | 8.5 | 0.47 | 0.03 | 15 | 41.3 | 2.8 | 270 |
| 2 | 748001 | 10/4/2008 | 1/5/2013 | RDX | 5 | 8.3 | 1.37 | <0.01 | 43 | 43.6 | 1.0 | 2,590 |
| 2 | 751417 | 10/2/2008 | Continuing | RDX | 1 | 9.1 | 0.15 | 0.01 | 5 | 69.4 | 14.8 | 20.6 |
| 2 | 758527 | 10/4/2008 | 1/5/2013 | RDX | 5 | 8.2 | 1.1 | 0.02 | 34 | 32.2 | 0.9 | 2,340 |
| 2 | 758533 | 10/2/2008 | Continuing | RDX | 4 | 8.2 | 0.86 | 0.03 | 27 | 43.6 | 1.6 | 809 |
| 1 | 213138 | 7/14/2004 | 12/26/2012 | GWK | 2 | 7.7 | 0.11 | -0.01 | 3 | 8 | 2.3 | 1,520 |
| 1 | 214782 | 7/14/2004 | 2/22/2006 | ARG | 2 | 8 | 0.25 | -0.01 | 8 | 86.9 | 11.1 | 188 |

**Table 3.7-17: Characteristics of Rock Samples in Humidity Cell Tests**

| Phase | HCT | Date Started | Date Stopped | Logged Geology | WRMC | Paste pH | Total S %, S | Sulfate %, S | AP kg $CaCO_3$/t | NP* kg $CaCO_3$/t | NP*/AP | Arsenic mg/kg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 225926 | 7/14/2004 | 2/22/2006 | GWK | 4 | 8 | 0.89 | 0.01 | 28 | 45.8 | 1.6 | 1,190 |
| 1 | 240052 | 7/14/2004 | 2/22/2006 | SHL | 6 | 7.6 | 0.79 | 0.02 | 25 | 12 | 0.5 | 168 |
| 1 | 672083 | 7/14/2004 | 2/22/2006 | SHL | 6 | 5.7 | 0.18 | 0.07 | 6 | 1 | 0.02 | 256 |
| 1 | 673242 | 7/14/2004 | 2/22/2006 | SLT | 1 | 7.6 | 0.32 | 0.01 | 10 | 25.3 | 2.5 | 59.6 |
| 1 | 708491 | 7/14/2004 | 2/22/2006 | GWK | 7 | 6.7 | 1.79 | 0.03 | 56 | 8 | 0.1 | 4,720 |
| 2 | 680671 | 10/2/2008 | 12/27/2012 | GWK | 2 | 7.8 | 0.07 | 0.01 | 2 | 18 | 8.2 | 134 |
| 2 | 681142 | 10/2/2008 | 12/27/2012 | SHL | 1 | 8.2 | 0.25 | 0.02 | 8 | 21 | 2.7 | 34 |
| 2 | 683340 | 10/4/2008 | Continuing | SHL | 5 | 7 | 0.25 | <0.01 | 8 | 8 | 1.0 | 149 |
| 2 | 745975 | 10/4/2008 | 1/5/2013 | SHL | 5 | 7.9 | 0.33 | 0.02 | 10 | 19 | 1.8 | 356 |
| 2 | 751720 | 10/2/2008 | 12/27/2012 | GWK | 1 | 9.2 | 0.1 | 0.02 | 3 | 28.4 | 9.1 | 14.4 |
| 2 | 754502 | 10/2/2008 | Continuing | GWK | 4 | 8.5 | 2.24 | 0.02 | 70 | 95.2 | 1.4 | 1,580 |
| 2 | 760063 | 10/4/2008 | 1/5/2013 | SHL | 4 | 8.3 | 3.25 | 0.01 | 102 | 137 | 1.3 | 1,550 |
| 2 | 760101 | 10/2/2008 | Continuing | GWK | 3 | 8.3 | 1.69 | 0.02 | 53 | 74.7 | 1.4 | 549 |
| 2 | 779151 | 10/4/2008 | 1/5/2013 | GWK | 5 | 8.7 | 0.03 | 0.04 | 9 | 13 | 1.4 | 30.9 |

**Notes:**

* Revised site-specific $NPCO_3$ = 0.76 NP + 4.8 (SRK 2011)

ARG = Argillite
GWK = greywacke
MD = mafic dykes
RDA = aphanitic rhyodacite
RDX = crowded crystalline rhyodacite
RDXB = blue rhyodacite
RDXL = lathe-rich rhyodacite
SHL = shale
SLT = siltstone

Source: SRK 2011b.

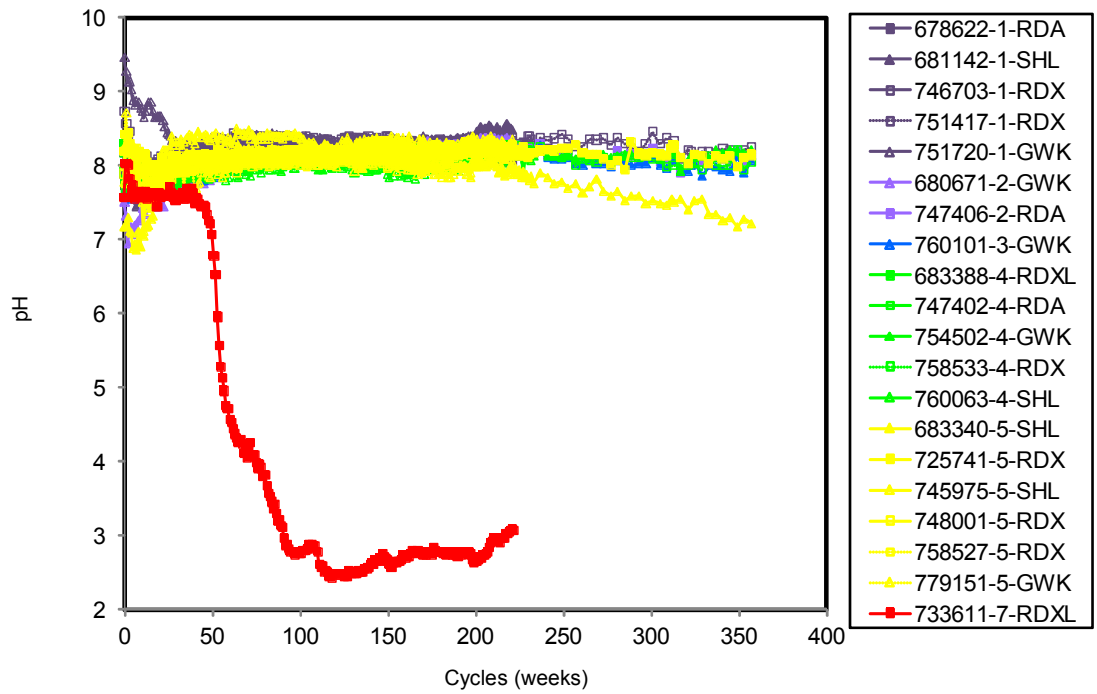


Figure 3.7-17A: Selected Phase 2 Humidity Cell Test Results: pH

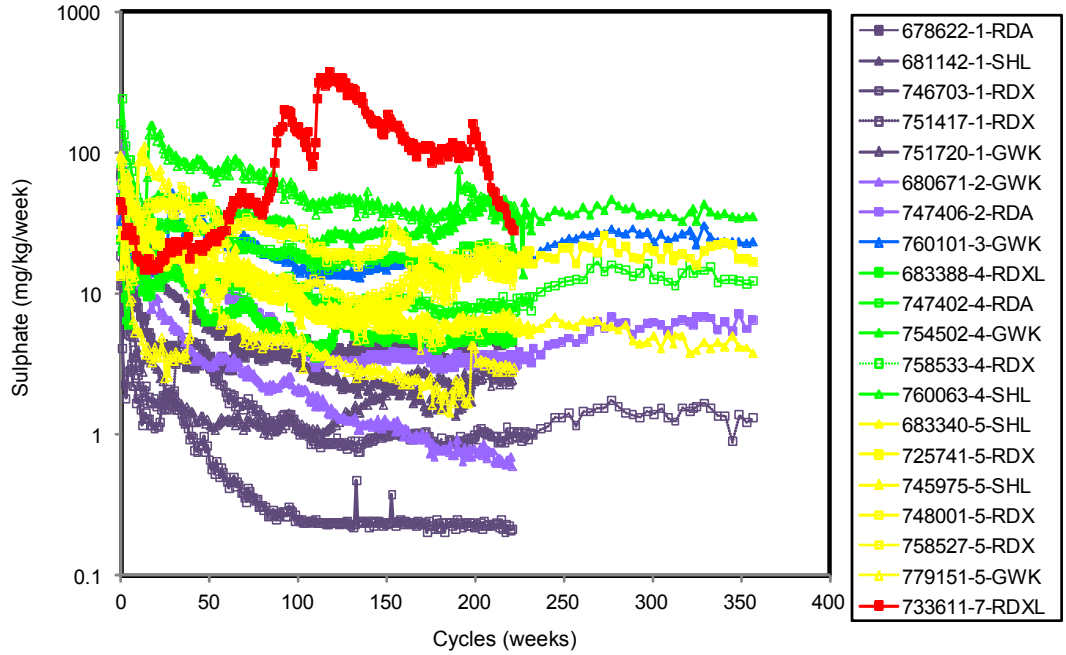


Figure 3.7-17B: Selected Phase 2 Humidity Cell Test Results: Sulfate Loading

Data Source: SRK 2011

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PHASE 2 HUMIDITY CELL TEST RESULTS FOR pH AND SULFATE

NOVEMBER 2015 FIGURE 3.7-17

Four on-site/field barrel tests were begun in 2006. Each of these contained about 550 to 600 pounds of rock in a barrel exposed to the on-site weathering conditions. The tests included two composite sediment and two composite rhyodacite samples—one of each rock type had high sulfur and high arsenic contents; the other had low sulfur and low arsenic contents (Table 3.7-18). Six additional barrel tests (three volumes: 200, 400, and 600 —pounds each for two composite samples) were conducted for a flow path experiment beginning in 2008. One of the composite samples had essentially the tonnage-weighted average NP/AP value of 5.4 and a low arsenic value of 31.6 mg/kg. The other was a PAG 6 composite with a NP/AP value of 0.9 and an arsenic value of 1,020 mg/kg. (This arsenic value is below average for rhyodacite rocks, but above average for sediments). All of the barrel tests are still ongoing.

All of the barrel test leachates have had circumneutral pH values throughout the several-year duration of the tests. However, most barrels show a decrease of pH over time and there appears to be a seasonal pattern with a pH minimum in late summer in all cases (Figure 3.7-18). (In 2009, only one sample was collected due to exceptionally dry conditions at the site.)

The preliminary NAG and PAG classifications (Table 3.7-16) were based on about 70 to 140 weeks of data on the 16 HCTs that began in 2004. The HCTs indicated that oxidation of sulfide minerals was strongly positively correlated with the sulfur content of the rock. For rock samples with the highest total sulfur content, the molar ratio of the release of calcium plus magnesium (the carbonate neutralization components of the rocks) to sulfur [(Ca+Mg)/$SO_4$] tended toward a value of 1.3:1. This ratio became the basis for the revised criterion separating NAG from PAG rock in Table 3.7-16. Selection of this ratio was further justified by the (Ca+Mg)/$SO_4$ results to-date from the on-site barrel tests, which take into account actual on-site temperature and precipitation conditions (Figure 3.7-19). Modeling of oxidation rates from the HCTs suggests that PAG 5 waste rock would potentially generate acidic conditions after a long time delay on the order of several decades; whereas PAG 6 is potentially acid-generating within the life of the mine (possibly less than a decade), and PAG 7 waste rock could potentially generate acidic conditions within less than a few years (SRK 2007).

**Table 3.7-18: Characteristics of Samples Used in On-Site Barrel Tests**

| Barrel | Sample Description | Rock Type | Description | Paste pH | Total Sulfur % S | Sulfate Sulfur | AP kg $CaCO_3$/t | NP kg $CaCO_3$/t | NP/AP | Arsenic mg/kg |
|---|---|---|---|---|---|---|---|---|---|---|
| ARD-1 | 761001 +2mm | Sediments | NAG 1 | 8.6 | 0.24 | <0.01 | 7.5 | 68 | 9.1 | 90.8 |
| | 761001 -2mm | | | 8.4 | 0.23 | <0.01 | 7.2 | 74 | 10.3 | 109 |
| ARD-2 | 761002 +2mm | Rhyodacite | NAG 2 | 8.7 | 0.43 | <0.01 | 13.4 | 33 | 2.5 | 686 |
| | 761002 -2mm | | | 8.5 | 0.55 | 0.01 | 16.9 | 33 | 2.0 | 725 |
| ARD-3 | 761003 +2mm | Sediments | PAG 5 | 8.3 | 1.57 | 0.02 | 48.4 | 60 | 1.2 | 3,810 |
| | 761003 -2mm | | | 8.1 | 1.68 | 0.03 | 51.6 | 68 | 1.3 | 4,000 |
| ARD-4 | 761004 +2mm | Rhyodacite | NAG 4 | 8.9 | 0.62 | 0.01 | 19.1 | 34 | 1.8 | 2,650 |
| | 761004 -2mm | | | 8.7 | 0.8 | 0.01 | 24.7 | 34 | 1.4 | 2,590 |
| WRMC 1 | 884003 | Composite | NAG 1 | 9.0 | 0.35 | 0.01 | 11 | 59.5 | 5.4 | 31.6 |
| WRMC 6 | 884004 | Composite | PAG 6 | 8.2 | 1.05 | 0.02 | 33 | 28.4 | 0.9 | 1,020 |

Source: SRK 2007.

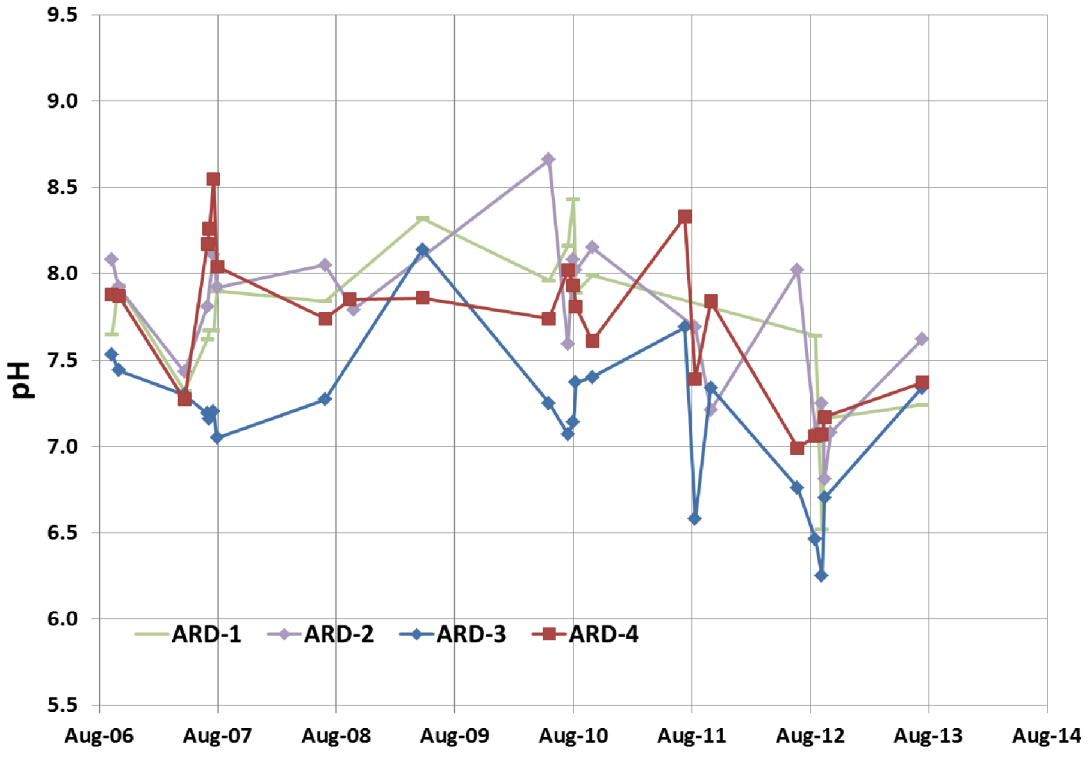


Figure 3.7-18A: Barrel Test Leachate pH: 2006 Barrel Tests

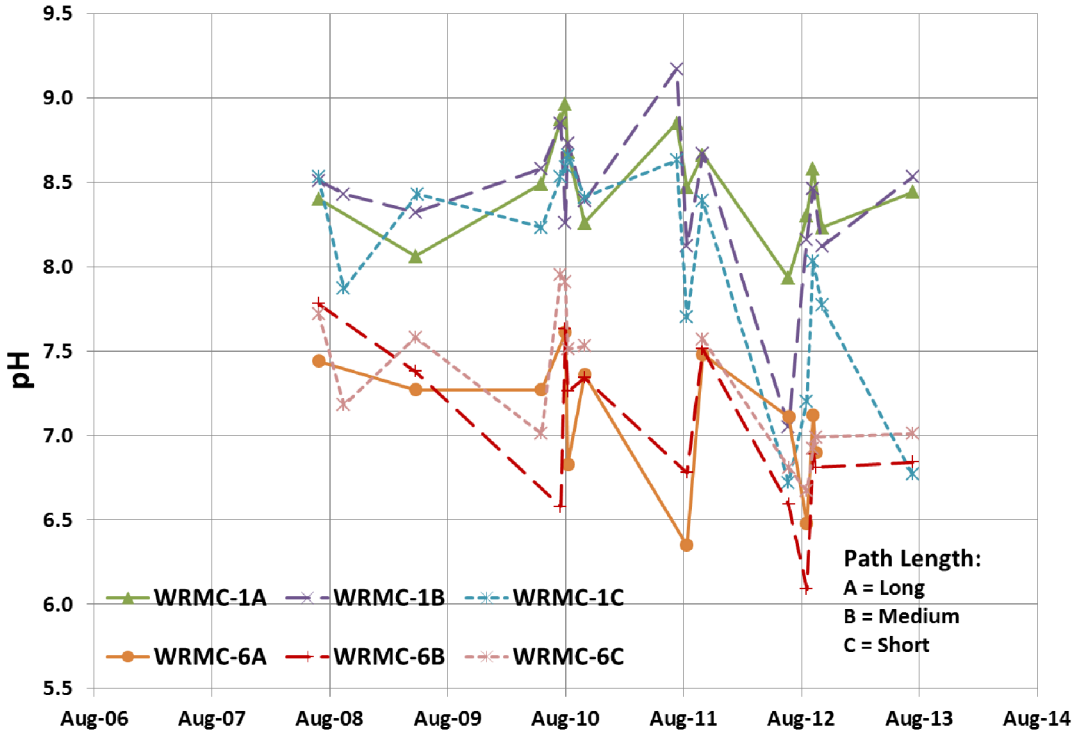


Figure 3.7-18B: Barrel Test Leachate pH: 2008 Flow Path Experiment

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BARREL TEST LEACHATE pH: 2006 BARREL TESTS AND 2008 FLOW PATH EXPERIMENT

Data Source: SRK 2011

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FIGURE 3.7-18

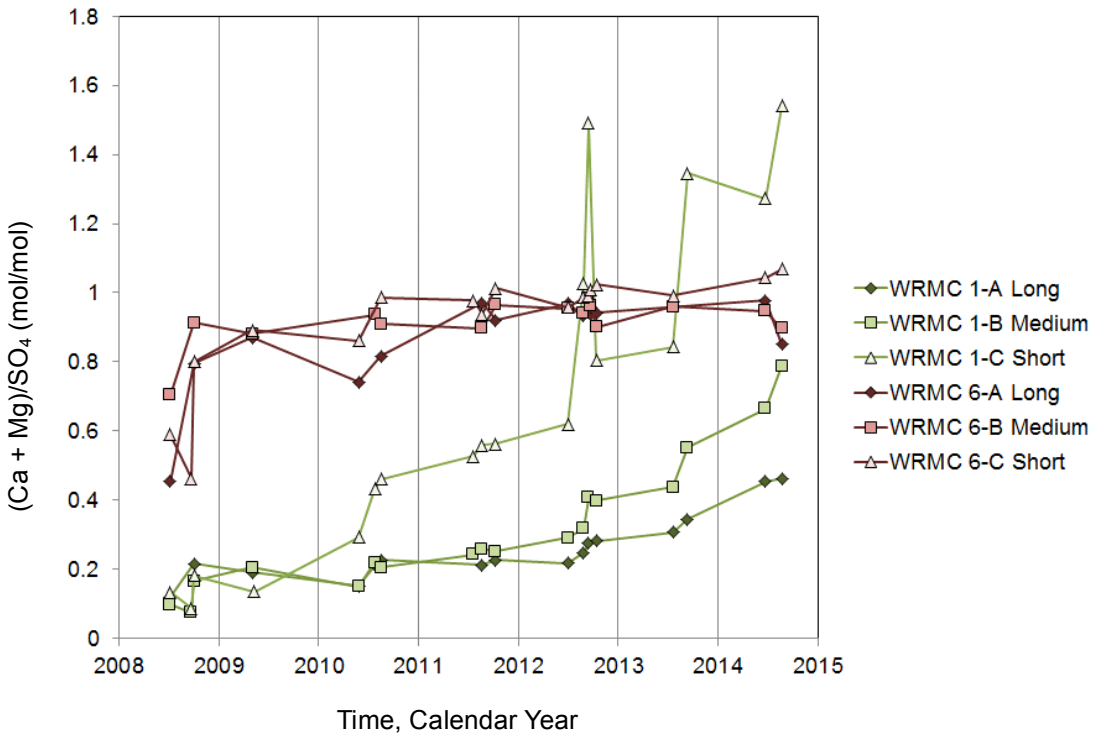


Figure 3.7-19A

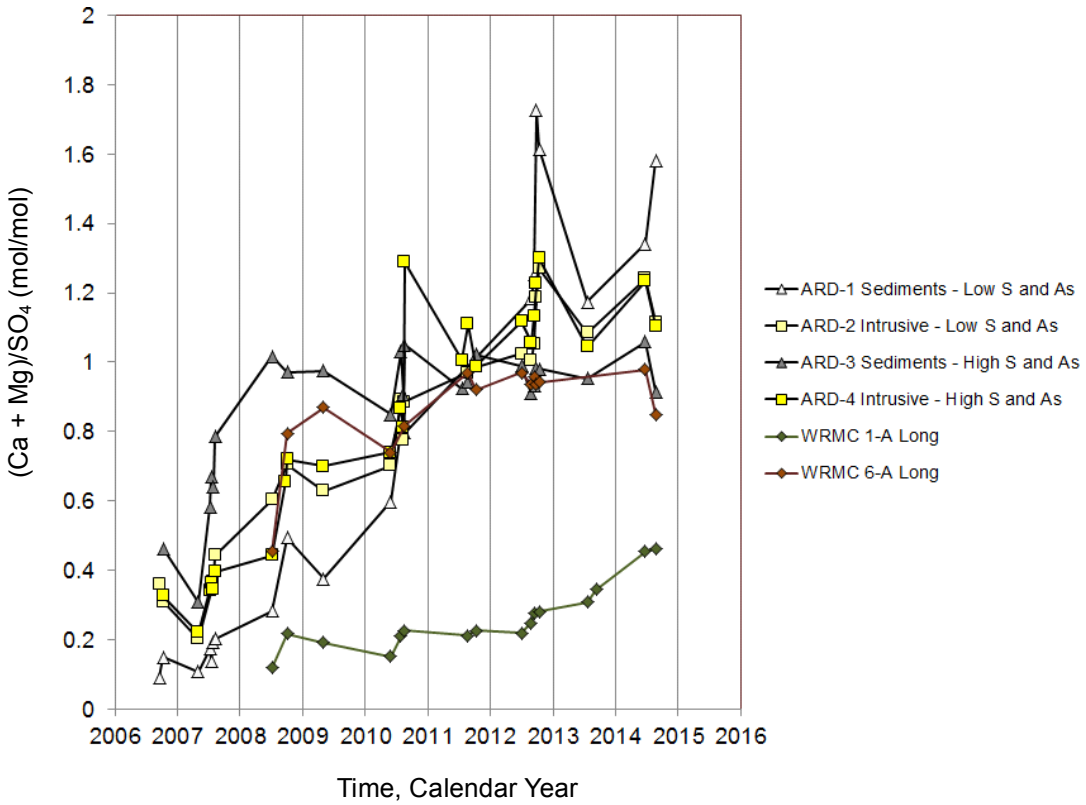


Figure 3.7-19B

Data Source: SRK 2011

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TEMPORAL VARIATION OF MOLAR RATIO OF (Ca +Mg)/$SO_4$ IN NAG 4 (ARD-4), PAG 5 (ARD-3) AND PAG 6 (WRMC-6) BARREL TESTS

NOVEMBER 2015 FIGURE 3.7-19

Metals and Other Potential Contaminants

To investigate metals and other potential contaminants, three types of investigations were conducted. The first investigated the total concentrations of constituents; the other two investigated short-term and longer-term leaching potential of these constituents. To determine whole-rock concentrations, more than 2,200 samples were subjected to bulk geochemical analysis (Table 3.7-19). This analysis allowed comparison of concentrations of selected constituents with average crustal abundance data (from Price 1997) for similar rock types.

The bulk analyses indicated that the most enriched constituents were silver, arsenic, mercury, and antimony. Most base metals (cadmium, cobalt, copper, lead, nickel, zinc) are not enriched (SRK 2007). Arsenic was the main enriched element. It occurs mainly in arsenopyrite with some realgar, orpiment, and arsenian pyrite, and shows a similar bimodal distribution among rock types as sulfur. The rhyodacite rock type group appears mostly well mineralized; whereas the sedimentary greywacke and shale groups were largely weakly mineralized, although the average arsenic concentrations were well above global averages for these rock types. Antimony and mercury concentrations are strongly correlated with arsenic (Figure 3.7-20) (SRK 2007); this geochemical coherence allows arsenic distributions to be used as a proxy for the distribution of these two constituents as well.

**Table 3.7-19: Distribution Statistics for Selected Elements in Waste Rock**

| Rock Type | Statistic | S % | As mg/kg | Cd mg/kg | Cu mg/kg | Hg mg/kg | Sb mg/kg | Se mg/kg | Zn mg/kg | AP $kgCaCO_3/t$ | NP $kgCaCO_3/t$ | NP/AP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GWK | n | 1,543 | 1,488 | 1,488 | 1,488 | 1,488 | 1,487 | 1,488 | 1,488 | 1,543 | 1,543 | 1,543 |
| | Min | 0.01 | 1.4 | 0.01 | 0.6 | 0.01 | 0.03 | 0.4 | 53 | 0.15 | 3 | 0.28 |
| | P5 | 0.01 | 5.1 | 0.1 | 15 | 0.06 | 0.56 | 1 | 72 | 0.15 | 15 | 2.3 |
| | Median | 0.07 | 32 | 0.25 | 33 | 0.25 | 3.4 | 2 | 100 | 2.2 | 58 | 26 |
| | Average | 0.26 | 290 | 0.34 | 36 | 0.68 | 16 | 2 | 110 | 8.3 | 71 | 9.6 |
| | P95 | 1.3 | 1,400 | 0.68 | 65 | 2.1 | 31 | 3 | 150 | 43 | 150 | 180 |
| | Max | 5.5 | 10,000 | 58 | 430 | 90 | 3,300 | 10 | 5,900 | 170 | 470 | 870 |
| MD | n | 375 | 355 | 355 | 355 | 355 | 355 | 355 | 355 | 375 | 375 | 375 |
| | Min | 0.01 | 1.6 | 0.01 | 0.8 | 0.09 | 0.19 | 0.5 | 96 | 0.6 | 3.9 | 0.14 |
| | P5 | 0.05 | 15 | 0.2 | 38 | 0.14 | 1.3 | 1 | 110 | 1.8 | 17 | 1.3 |
| | Median | 0.23 | 47 | 0.64 | 67 | 0.39 | 4.2 | 3 | 150 | 8.1 | 44 | 5.4 |
| | Average | 0.43 | 250 | 0.61 | 67 | 0.6 | 13 | 2.9 | 150 | 14 | 63 | 4.9 |
| | P95 | 1.7 | 1,100 | 1.1 | 97 | 1.6 | 30 | 5 | 180 | 56 | 140 | 35 |
| | Max | 4.1 | 10,000 | 1.8 | 130 | 14 | 950 | 5 | 460 | 140 | 210 | 93 |
| RDA | n | 77 | 76 | 76 | 7 | 76 | 76 | 76 | 76 | 77 | 77 | 77 |
| | Min | 0.03 | 5.5 | 0.04 | 11 | 0.12 | 0.64 | 0.5 | 63 | 0.9 | 67 | 3 |
| | P5 | 0.048 | 22 | 0.06 | 20 | 0.16 | 2.6 | 0.5 | 68 | 1.6 | 140 | 4.1 |
| | Median | 0.1 | 190 | 0.12 | 32 | 0.54 | 20 | 2 | 79 | 3.8 | 260 | 67 |
| | Average | 0.36 | 480 | 0.16 | 33 | 1.1 | 59 | 1.6 | 87 | 12 | 260 | 26 |
| | P95 | 1.5 | 1,900 | 0.34 | 44 | 4.1 | 160 | 3 | 130 | 51 | 360 | 180 |
| | Max | 2.6 | 4,400 | 0.94 | 96 | 5.5 | 1,000 | 4 | 240 | 85 | 390 | 260 |

**Table 3.7-19: Distribution Statistics for Selected Elements in Waste Rock**

| Rock Type | Statistic | S % | As mg/kg | Cd mg/kg | Cu mg/kg | Hg mg/kg | Sb mg/kg | Se mg/kg | Zn mg/kg | AP $kgCaCO_3/t$ | NP $kgCaCO_3/t$ | NP/AP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RDX | n | 45 | 45 | 45 | 45 | 45 | 44 | 45 | 45 | 45 | 45 | 45 |
| | Min | 0.01 | 36 | 0.02 | 1.2 | 0.31 | 5.7 | -0.2 | 20 | 0.3 | 2 | 0.17 |
| | P5 | 0.01 | 57 | 0.02 | 1.4 | 0.35 | 8.6 | -0.2 | 43 | 0.36 | 2.2 | 0.18 |
| | Median | 0.45 | 680 | 0.07 | 4.4 | 1 | 21 | 2 | 64 | 15 | 21 | 1.2 |
| | Average | 0.5 | 1,200 | 0.21 | 8.4 | 1.4 | 110 | 1.4 | 85 | 17 | 23 | 1.5 |
| | P95 | 1.2 | 3,900 | 0.89 | 28 | 3.6 | 210 | 2 | 220 | 40 | 51 | 12 |
| | Max | 1.3 | 5,100 | 1.5 | 60 | 6.5 | 2,400 | 3 | 280 | 45 | 64 | 17 |
| SHL | n | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 | 167 |
| | Min | 0.01 | 8.2 | 0.01 | 1.3 | 0.05 | 1.5 | 0.5 | 26 | 0.3 | 3.2 | 0.17 |
| | P5 | 0.01 | 17 | 0.03 | 2.5 | 0.1 | 2 | 0.5 | 40 | 0.61 | 11 | 0.5 |
| | Median | 0.29 | 330 | 0.06 | 9.2 | 0.75 | 14 | 1 | 62 | 10 | 45 | 4.4 |
| | Average | 0.53 | 1,100 | 0.19 | 12 | 1.3 | 20 | 1.4 | 79 | 17 | 46 | 2.9 |
| | P95 | 1.6 | 5,100 | 0.55 | 40 | 4.3 | 43 | 3 | 140 | 50 | 80 | 74 |
| | Max | 2.1 | 9,500 | 9.2 | 75 | 14 | 330 | 7 | 1,200 | 66 | 99 | 230 |

**Notes:**

Rock Types:
GWK = greywacke MD = mafic dykes RDA = aphanitic chyodacite RDX = crowded crystalline rhyodacite SHL = shale

Source: SRK 2011 (Table 8).

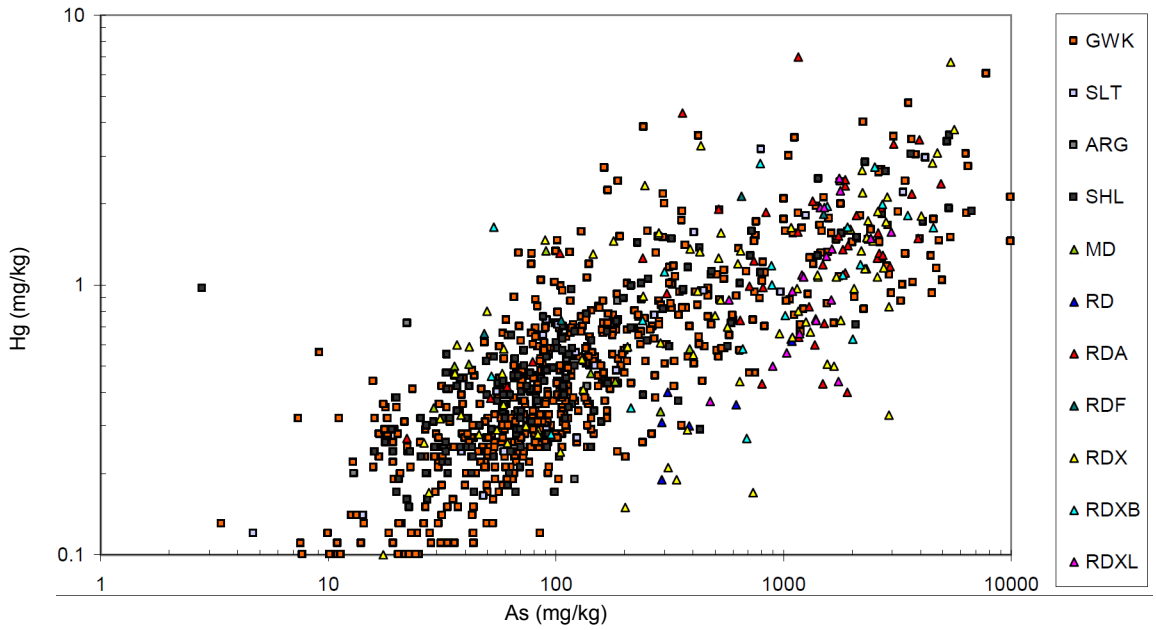


Figure 3.7-20 A: Arsenic correlation with mercury in waste rock.

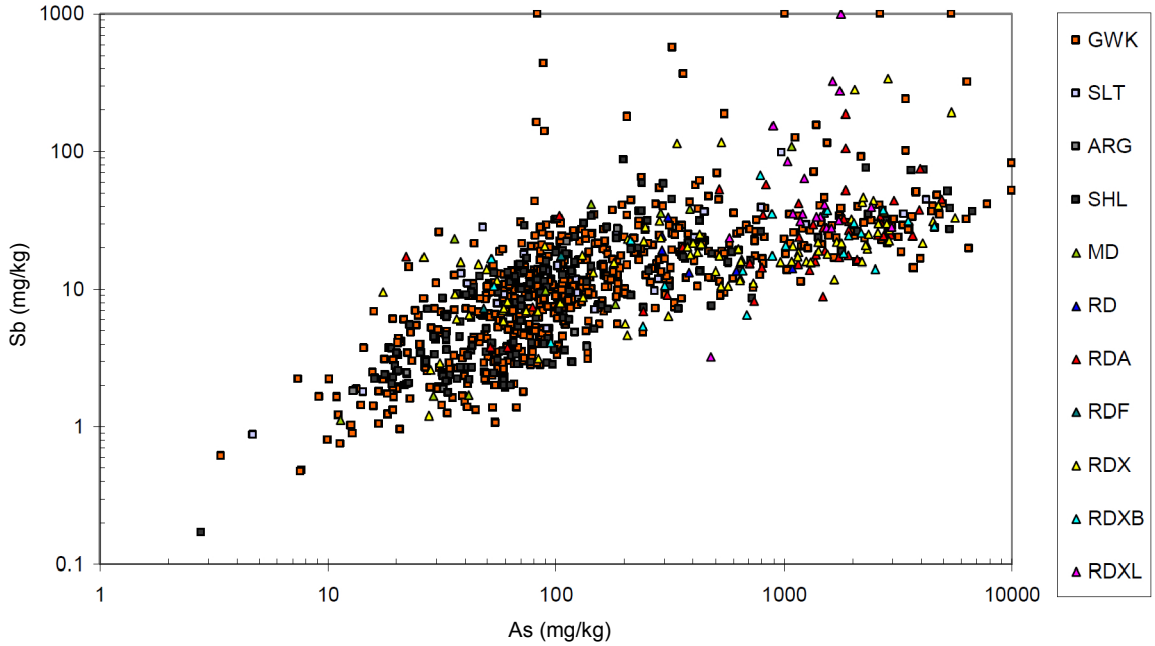


Figure 3.7-20 B: Arsenic correlation with antimony in waste rock.

Data Source: SRK 2007

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ARSENIC CORRELATIONS WITH MERCURY AND ANTIMONY IN WASTE ROCK

NOVEMBER 2015 FIGURE 3.7-20

To determine the potential for ML, a modification of the Nevada Division of Environmental Protection's Meteoric Water Mobility Procedure (MWMP) was conducted on 20 composite samples for short-term leaching characteristics. The MWMP modification consisted of sequentially leaching a series of sub-samples of a given rock with the same leach water to allow assessment of the build-up of leachates along a flow path (SRK 2007). All samples but one produced basic leachate (Table 3.7-20). The basic leachates contained arsenic concentrations up to 10 mg/L and antimony up to 1.1 mg/L. Selenium concentrations tended to be higher in sedimentary (up to 0.12 mg/L) than intrusive rocks.

Data were collected on the leachates from the kinetic HCTs and barrel tests to investigate longer-term leaching. The four longer-term Phase 1 HCTs included samples with a range of arsenic concentrations—from a low of 812 mg/kg for intrusive sample 674322 to a high arsenic content of 2,690 mg/kg for the fault-zone sample 216377 (Table 3.7-17). As mentioned previously, the barrel test samples were specifically chosen to include a range of arsenic values (Table 3.7-18). The HCT and barrel test results corroborated the MWMP results and indicated that arsenic has the potential to be leached at both acid and neutral-to-basic pH values, even from NAG rocks (Figure 3.7-21) (see also Table 3.7-16 regarding WRMC classification based on arsenic). Leachate arsenic tended to decrease with time initially in almost all HCTs. However, after some time, the arsenic concentration then tended to level out. In the fault-zone sample 216377, after an initial decrease, the arsenic concentrations again increased before leveling out (Figure 3.7-21). In the acidic rhyodacite PAG 7 sample 733611, arsenic concentrations varied almost cyclically with time.

In the ongoing barrel tests, calcium and magnesium have tended to increase with time in most barrels, suggesting that carbonate dissolution and acid neutralization has been an ongoing process in the barrels. Sulfate, iron, and zinc concentrations have tended to increase slightly with time in the PAG barrels ARD-3 and WRMC 6, suggesting continued pyrite oxidation over time. Leachate arsenic, antimony, and molybdenum concentrations have decreased with time (Table 3.7-21), whereas most other trace elements showed relatively stable behavior. In general, arsenic concentrations in the leachate tended to correlate with the concentration of arsenic in the solid (SRK 2011, 2015c). Decreasing arsenic leaching over time suggests that the initial oxidation of arsenopyrite is being hindered, perhaps through the formation of a protective oxidized coating on the arsenopyrite surface (SRK 2015b). Seasonal behavior has been observed for major ions, arsenic and most other constituents, as it was for pH. Concentrations tended to increase in summer, perhaps due to initial melting of ice and flushing of salts, with a subsequent drop later in the year as a result of rainfall and lower temperatures (SRK 2015b).

**Table 3.7-20: Waste Rock Leachate Concentrations in the Final Step of Sequential Meteoric Water Mobility Procedure**

| | Solids | | Leachate Chemistry | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Rock Type | Arsenic mg/kg | Sulfur % | Antimony µg/L | Arsenic µg/L | Cobalt µg/L | Nickel µg/L | pH s.u. | Selenium µg/L | Sulfate mg/L | Zinc µg/L |
| ARG | 68 | 0.18 | 220 | 220 | <10 | 52 | 8.05 | 110 | 250 | <10 |
| ARG | 76 | 0.19 | 240 | 7,700 | 17 | 54 | 7.62 | 51 | 450 | <10 |
| GWK | 64 | 0.07 | 57 | 140 | <10 | 12 | 8.11 | 43 | 70 | 10 |
| GWK | 81 | 0.07 | 170 | 150 | <10 | 17 | 8.15 | 24 | 110 | <10 |
| GWK | 1,745 | 0.80 | 160 | 1,400 | 35 | 170 | 7.73 | 7.7 | 330 | 57 |
| MD | 231 | 0.12 | 480 | 2,200 | 14 | 190 | 7.93 | 8.1 | 230 | <10 |
| MD | 746 | 0.15 | 1,100 | 5,400 | 10 | 370 | 8.11 | 8.8 | 120 | 12 |
| RD | 110 | 0.25 | 220 | 150 | <10 | 38 | 7.83 | <5 | 210 | 11 |
| RD | 129 | 0.26 | 85 | 76 | 16 | 62 | 7.79 | <5 | 730 | <10 |
| RD | 1,244 | 0.38 | 200 | 530 | <10 | 44 | 7.75 | <5 | 260 | 28 |
| RD | 82 | 0.70 | 310 | 180 | 13 | 49 | 7.87 | <5 | 600 | 20 |
| RD | 1,720 | 1.17 | 220 | 10,000 | 32 | 100 | 7.6 | 13 | 640 | <10 |
| RD | 1,783 | 0.98 | 200 | 1,100 | <10 | 36 | 7.74 | 12 | 480 | 13 |
| SED | 1,464 | 0.11 | 32 | 230 | <10 | 20 | 7.06 | <5 | 110 | 83 |
| SED | 68 | 0.85 | 170 | 100 | <10 | 58 | 8.11 | 37 | 510 | 11 |
| SED | 2,034 | 0.99 | 120 | 2,400 | 18 | 77 | 7.7 | 37 | 820 | 10 |
| SED | 1,561 | 0.13 | 14 | 2,200 | 26 | 120 | 7.75 | 68 | 210 | 13 |
| SED | 117 | 1.50 | 410 | 310 | 29 | 140 | 8.23 | 120 | 770 | <10 |
| SHL | 2,543 | 1.90 | 46 | 320 | 1,000 | 2,500 | 5.49 | 44 | 1,600 | 4,200 |
| SHL | 1,835 | 1.53 | 280 | 420 | 12 | 77 | 7.44 | 14 | 460 | 27 |

**Rock Types:**

ARG = Argillite GWK = greywacke MD = mafic dykes RD = rhyodacite SED = sedimentary SH = shale

Source: SRK 2007.

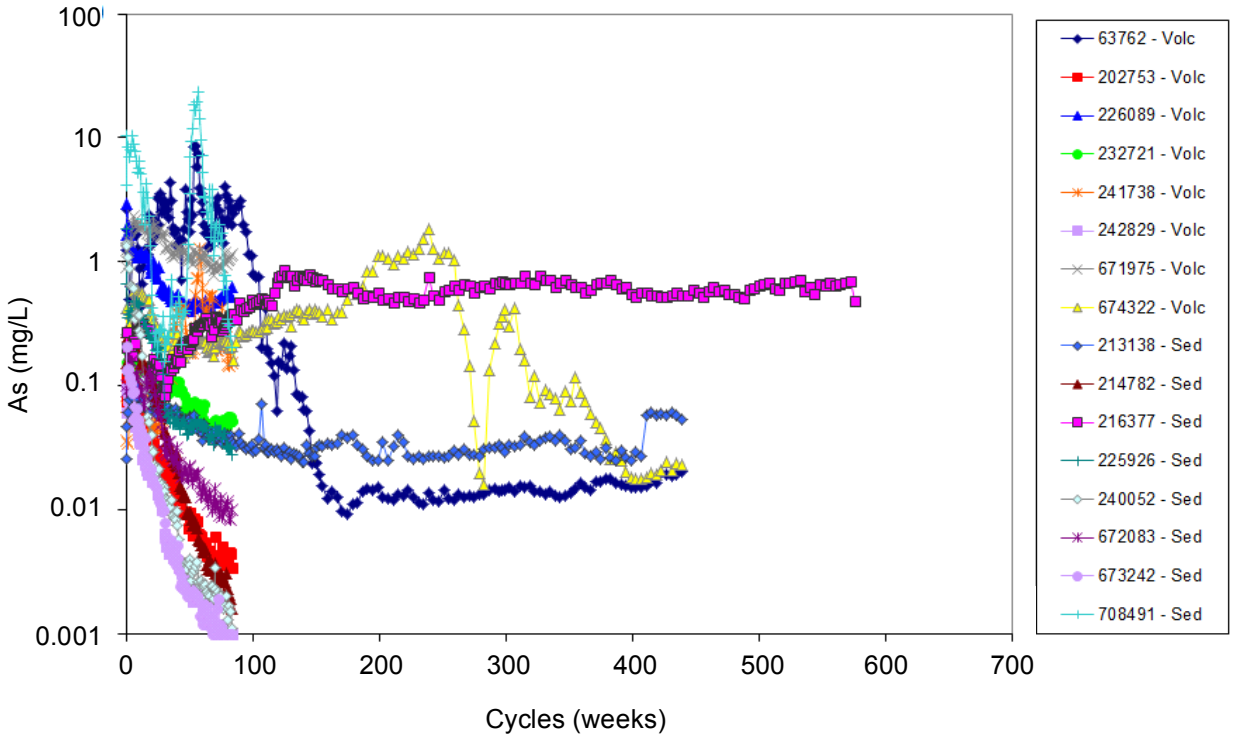


Figure 3.7-21A: Humidity Cell Test Arsenic Loading Results: Phase 1

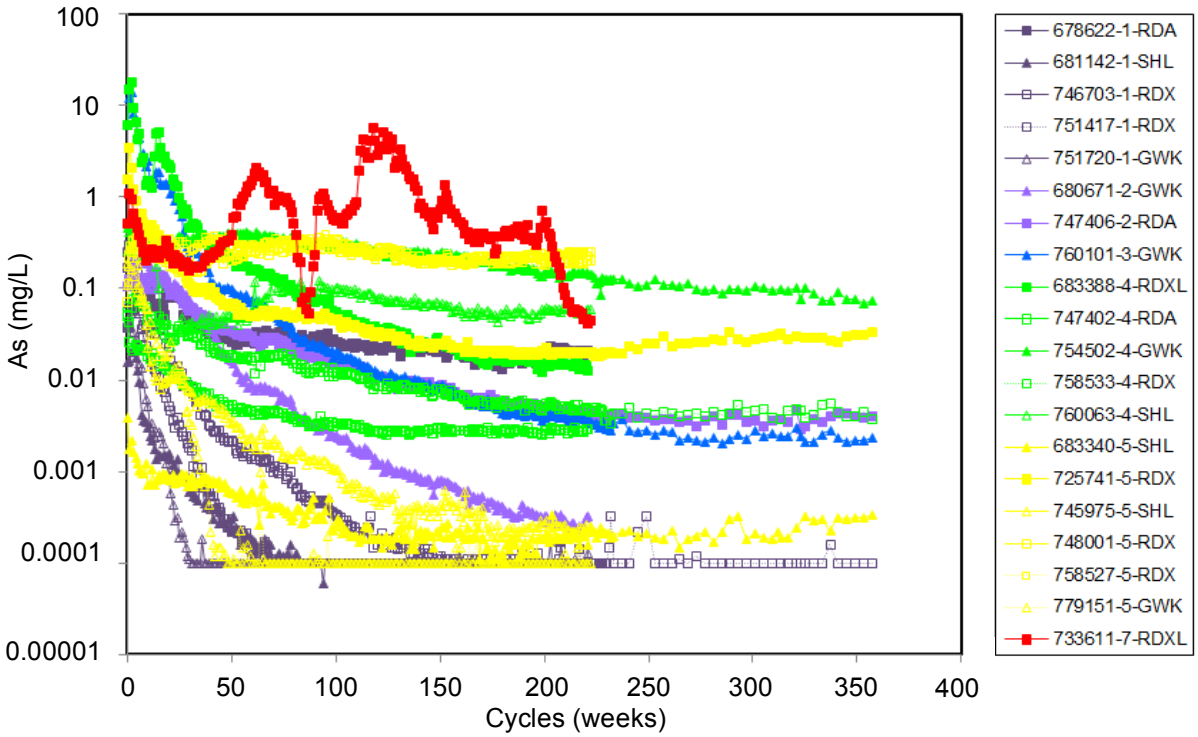


Figure 3.7-21B: Humidity Cell Test Arsenic Loading Results: Phase 2

Data Source: Weglinski 2015e

Note:
Scale change for cycles axis

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HUMIDITY CELL TEST ARSENIC LOADING RESULTS: PHASE 1 AND PHASE 2

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FIGURE 3.7-21

**Table 3.7-21: Grouping of Major and Trace Element Leaching Trends with Time for Barrel Tests (2006-2014)**

| Decreasing | Stable | Increasing | Undetected |
|---|---|---|---|
| Nitrate, Chloride<br><br>Sodium<br><br>Arsenic, Antimony, Manganese, Molybdenum | Alkalinity, Sulfate<br><br>Potassium<br><br>Aluminum, Barium, Boron, Cadmium, Chromium, Cobalt, Copper, Fluoride, Lead, Lithium, Manganese (ARD 3, WRMC 6-A), Mercury, Nickel, Selenium, Zinc | Sulfate (ARD 3, WRMC 6-A)<br><br>Calcium, Magnesium<br><br>Iron, Zinc (ARD 3, WRMC 6-A) | Silver, Thallium, Cyanide, Vanadium, Beryllium |

Source: SRK 2015b, Table 2.

In the barrel flow path experiments, selenium, nitrate, chloride, and lithium concentrations have increased along the flow path in both the NAG 1 (WRMC 1) and PAG 6 (WRMC 6) barrels (Table 3.7-22). However, the NAG and PAG barrels have shown a clear difference in the major ion chemistry, likely due to oxidation of pyrite and concomitant dissolution of even the less reactive carbonates dolomite and dolomite-ankerite: Sulfate, calcium, magnesium, potassium, copper, and zinc concentrations have increased along the flow path in the PAG barrels, whereas the concentrations of all of these constituents except calcium have stabilized in the NAG barrels. Calcium concentrations have been highest in the shortest flow path for the NAG barrels, whereas arsenic and antimony concentrations have been highest in the shortest flow path for the PAG barrels. Leachate pH values have increased along the flow path in the NAG barrels, but have not shown consistent trends with time in either the NAG or PAG barrels. In general, the PAG barrels have produced a lower average pH (7.1) than the NAG barrels (pH 8.2).

**Table 3.7-22: Grouping of Major and Trace Element Leaching Trends Along the Flow Path for Barrel Tests (2006-2014)**

| Waste Rock Management Category | Decreasing Along Flow Path | Stabilizing Along Flow Path | Increasing Along Flow Path | Highest in Shortest Flow Path | Undetected/ Inconclusive |
|---|---|---|---|---|---|
| WRMC1 | -- | Sulfate<br><br>Potassium, Magnesium<br><br>Arsenic, Copper, Zinc | pH, Alkalinity<br><br>Sodium<br><br>Antimony, Boron, Fluoride, Manganese, Molybdenum, Nickel | Calcium | -- |
| WRMC 6 | -- | Sodium<br><br>Boron, Fluoride, Molybdenum, Nickel, Manganese | Sulfate<br><br>Calcium, Magnesium, Potassium<br><br>Copper, Zinc | Arsenic, Antimony | pH, Alkalinity |
| WRMC 1 and WRMC 6 | Barium | Aluminum, Cadmium, Cobalt, Iron, Lead, Mercury | Chloride, Nitrate, Selenium, Lithium | -- | Beryllium, Silver, Thallium, Vanadium |

Source: SRK 2015b, Table 3.

#### 3.7.2.4.2 OVERBURDEN

Overburden is the soil and other material overlying a mineral deposit, which must be removed during mining. At the proposed mine site, the overburden is composed mainly of coarser-grained materials, consisting of colluvium and terrace gravels, and finer-grained materials, consisting of organic material, loess, and alluvium. The coarser-grained material would be stored mainly in the South Overburden (SOB) Stockpile and the finer-grained material in the North Overburden (NOB) Stockpile (SRK 2012a). Thirty-three samples of overburden collected as part of exploratory drilling were subjected to ABA using the Sobek method (SRK 2013c). Twelve of these samples came from the pit area. The remaining samples were from other parts of the mine site. One of the locations in the pit area was sampled at multiple depths. Table 3.7-23 presents the data for individual samples from the pit area and summary statistics for the miscellaneous samples. The total and sulfide sulfur increased with depth in the one set of samples from multiple depths in the pit area. The two deepest samples are PAG. These results suggest that the overburden at depth in the pit area may be PAG. The maximum measured carbonate was 0.52 percent carbon and the maximum measured sulfide was 0.24 percent sulfur. The overburden from miscellaneous areas around the mine site typically is pH-inert, with essentially no NP or AP. In other words, these results suggest that the overburden from the miscellaneous areas has low potential for ARD, but also has essentially no acid neutralizing, or buffering, potential. Arsenic concentrations were also analyzed for the ABA overburden samples. The results suggest two populations: Those samples from the pit area have substantially higher arsenic concentrations than the overburden samples from other parts of the mine site.

Six samples of overburden were collected as part of mine site feasibility studies and subjected to standard MWMP (SRK 2007). The leachate water pH ranged from 6.3 to 6.8 (Table 3.7-23). The concentrations of most metals were near or below the lower limit of detection. However, dissolved iron and aluminum were highly variable, with iron reaching 5.9 mg/L and aluminum 4.2 mg/L in the sample of coarse terrace gravels. Dissolved arsenic slightly exceeded 0.01 mg/L in the fine terrace gravels sample from the mineralized area, and in the coarse colluvium sample, in agreement with the higher arsenic concentrations in ABA overburden samples from the pit area (Table 3.7-24). These results suggest that arsenic leaching from overburden excavated from the pit area could exceed Alaska Water Quality Standards.

#### 3.7.2.4.3 LOW-GRADE ORE

Dependent on the price of gold at any particular time, rock with a given percentage of gold could be considered either ore or waste rock. Ore with a relatively low percentage of gold is called low-grade ore and is planned to be placed in a low-grade ore stockpile between the pit and the CWP (SRK 2012b). At Donlin, arsenopyrite is the predominant gold-bearing mineral. It is typically found associated in quartz veins with pyrite (Goldfarb et al. 2004). The veins often contain subordinant dolomite and ankerite, as well as younger stibnite ($Sb_2S_3$). According to SRK 2012e, this rock is PAG 7.

**Table 3.7-23: Acid-Base Accounting Data for Pit-Area Overburden and Distribution Statistics for Other Miscellaneous Mine-Site Overburden**

| Hole ID | Depth | | Paste pH | Total Sulfur % S | Sulfide Sulfur % S | Sulfate Sulfur % S | NP kg CaCO3/kt | AP kg CaCO3/kt | NP/AP | Total Carbonate % C | Arsenic mg/kg |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | From | To | | | | | | | | | |
| **Pit Area** | | | | | | | | | | | |
| DC07-1597 | 6 | 12 | 6.8 | 0.01 | 0 | 0.01 | 3 | 0.3 | 9.6 | 0.025 | 419 |
| DC07-1597 | 12 | 18 | 6.2 | 0.03 | 0.025 | 0.005 | 3 | 0.9 | 3.2 | 0.025 | 390 |
| DC07-1597 | 18 | 24 | 5.4 | 0.04 | 0.035 | 0.05 | 3 | 1.3 | 2.4 | 0.16 | 354 |
| DC07-1597 | 24 | 30 | 5.0 | 0.08 | 0.075 | 0.005 | 3 | 2.5 | 1.2 | 0.22 | 591 |
| DC07-1597 | 30 | 35 | 5.2 | 0.26 | 0.24 | 0.02 | 3 | 8.1 | 0.37 | 0.08 | 854 |
| DR97-339 | 0 | 3 | 5.0 | 0.03 | -- | -- | 0 | 0.9 | 0 | 0.025 | 163 |
| DC98-483 | 0 | 4 | 7.4 | 0.08 | 0.08 | 0.0055 | 18 | 2.5 | 7.2 | 0.24 | 276 |
| DGT06-1179 | 4 | 8 | 6.9 | 0.08 | 0.07 | 0.01 | 12 | 2.5 | 4.8 | 0.52 | 335 |
| DC02-723 | 11 | 14 | 6.7 | 0.01 | 0.01 | 0.005 | 1 | 0.25 | 3.2 | 0.025 | 333 |
| DC02-745 | 5 | 8 | 6.9 | 0.03 | 0.02 | 0.005 | 13 | 0.9 | 14 | 0.25 | 57.8 |
| DC06-1249 | 4 | 9 | 8.2 | 0.03 | -- | -- | 15 | 1.3 | 12 | | 57.8 |
| **Other Misc. Mine Site (Statistical Summary)** | | | | | | | | | | | |
| $P_5$ | 0 | 1 | 5.4 | 0.01 | 0.005 | 0.005 | 2.0 | 0.2 | 5.8 | 0.025 | 6.4 |
| $P_{25}$ | 0 | 2 | 5.9 | 0.01 | 0.005 | 0.006 | 6.3 | 0.2 | 20 | 0.025 | 10.3 |
| $P_{50}$ | 0 | 3 | 6.5 | 0.01 | 0.005 | 0.010 | 8.0 | 0.3 | 30 | 0.025 | 13.9 |
| $P_{75}$ | 1 | 5 | 7.0 | 0.01 | 0.010 | 0.010 | 9.8 | 0.3 | 51 | 0.025 | 19.8 |
| $P_{95}$ | 3 | 6 | 7.4 | 0.02 | 0.020 | 0.020 | 14 | 0.6 | 70 | 0.025 | 105 |
| Maximum | 5 | 6 | 7.5 | 0.04 | 0.040 | 0.020 | 55 | 1.3 | 352 | 0.08 | 109 |

Source: SRK 2013c and associated documentation.

**Table 3.7-24: Selected Meteoric Water Mobility Procedure Results for Overburden Samples**

| Parameter | Unit | Colluvium Coarse | Colluvium Medium | Colluvium Fine | Terrace Gravels Coarse | Terrace Gravels Medium Mineralized Area | Terrace Gravels Fine Mineralized Area |
|---|---|---|---|---|---|---|---|
| **Major Constituents** | | | | | | | |
| pH | pH Units | 6.76 | 6.26 | 6.57 | 6.4 | 6.48 | 6.36 |
| Calcium | mg/L | 0.94 | 39 | 9.5 | 1.2 | 1.2 | <0.5 |
| Total Alkalinity | mg/L as $CaCO_3$ | 6 | 20 | 22 | 4 | 10 | 4 |
| Magnesium | mg/L | <0.5 | 4.4 | 1.3 | 0.71 | <0.5 | <0.5 |
| Potassium | mg/L | <0.5 | 4.2 | 0.72 | 0.68 | <0.5 | <0.5 |
| Sodium | mg/L | 3.2 | 11 | 8.8 | 5.9 | 2.2 | 1.7 |
| Chloride | mg/L | 1.9 | 4.6 | 3.1 | 1.9 | <1 | <1 |
| Fluoride | mg/L | 0.34 | 0.22 | 0.17 | 0.19 | 0.33 | 0.23 |
| Sulfate | mg/L | 3.4 | 67 | 11 | 3.2 | <1 | <1 |
| **Metals** | | | | | | | |
| Aluminum[3] | µg/L | 490 | 230 | 800 | 4,200 | <45 | <45 |
| Antimony | µg/L | <2.5 | <2.5 | <2.5 | <2.5 | <2.5 | <2.5 |
| Arsenic | µg/L | 11 | <5 | <5 | <5 | 6 | 12 |
| Barium | µg/L | 13 | 380 | 58 | 57 | <10 | <10 |
| Beryllium | µg/L | <1 | <1 | <1 | <1 | <1 | <1 |
| Cadmium | µg/L | <1 | <1 | <1 | <1 | <1 | <1 |
| Copper | µg/L | <50 | <50 | <50 | <50 | <50 | <50 |
| Iron | µg/L | 460 | 280 | 1,200 | 5,900 | 17 | 45 |
| Lead | µg/L | <10 | <10 | <10 | <10 | <10 | <10 |
| Manganese | µg/L | 19 | 480 | 86 | 120 | <5 | 6.3 |
| Nickel | µg/L | <10 | <10 | <10 | <10 | <10 | <10 |

**Table 3.7-24: Selected Meteoric Water Mobility Procedure Results for Overburden Samples**

| Parameter | Unit | Colluvium Coarse | Colluvium Medium | Colluvium Fine | Terrace Gravels Coarse | Terrace Gravels Medium Mineralized Area | Terrace Gravels Fine Mineralized Area |
|---|---|---|---|---|---|---|---|
| Selenium | µg/L | <5 | <5 | <5 | <5 | <5 | <5 |
| Zinc | µg/L | <10 | 14 | 19 | 49 | <10 | <10 |

**Notes:**

1 All metals are dissolved concentrations.

Source: SRK 2007.

#### 3.7.2.4.4 TAILINGS

Gold is removed from ore-bearing rocks in a process that includes crushing, grinding, flotation, pressure oxidation, and cyanide leaching. The finely-ground rock and process water mixture remaining after the gold is removed is called tailings. In the proposed project, the tailings would be deposited in a large impoundment called the Tailings Storage Facility (TSF).

For the proposed project, the approach to studying gold recovery methods to be used in the process facilities was developed in multiple phases. Phase 1 was laboratory scale testing followed by an initial pilot-plant test that provided a preliminary understanding of the ore types, metallurgy, and necessary refinements to the beneficiation process. The results of Phase 1 justified a Phase 2 pilot plant test. Phase 2 was a stand-alone study and included what was learned during Phase 1 (Day 2013).The tails from Phase 2 are more representative of the combined ore types that would be processed through the process facilities. More comprehensive analysis for mercury was also performed on the different phases of the pilot plant.

Mineralogical studies of tailings samples produced by the phased pilot tests in the laboratory (SRK 2007) show them to be mainly silicates; carbonates; residual sulfides (mainly pyrite and arsenopyrite); and the oxidation products of pyrite, including jarosite, hematite, and gypsum (Table 3.7-25). The NP for the tailings was calculated with appropriate corrections for ankerite and dolomite; AP was calculated with appropriate corrections for jarosite (SRK 2007, 2011).

**Table 3.7-25: Mineralogy and Acid-Base Accounting on Tailings Samples**

| Parameter | Unit | 2006 Pilot Tails FT-1 | 2007 Phase 1 Pilot Tails FT-4 |
|---|---|---|---|
| Pyrite | %, wt | 1.19 | 0.45 |
| Arsenopyrite | %, wt | 0.05 | 0.26 |
| Gypsum | %, wt | 0.95 | 1.55 |
| Jarosite | %, wt | 0.57 | 0.17 |
| Ankerite | %, wt | 1.77 | 1.89 |
| Dolomite | %, wt | 0.41 | 1.10 |
| Magnesite | %, wt | Not reported | 0.23 |
| Hematite | %, wt | 0.02 | 1.00 |
| Paste pH | s.u. | 7.65 | 7.39 |
| Total Sulfur | S,% | 0.780 | 0.578 |
| Sulfide | S,% | 0.15 | 0.11 |
| Sulfate | S,% | 0.63 | 0.47 |
| Estimated Sulfate as Jarosite | S,% | 0.14 | 0.03 |
| NP | kg $CaCO_3$/t | 24.5 | 11.9 |
| AP as Sulfide | kg $CaCO_3$/t | 4.7 | 3.4 |
| NP/AP (Sulfide AP) | ratio | 5.2 | 3.5 |

**Table 3.7-25: Mineralogy and Acid-Base Accounting on Tailings Samples**

| Parameter | Unit | 2006 Pilot Tails FT-1 | 2007 Phase 1 Pilot Tails FT-4 |
|---|---|---|---|
| AP as Jarosite | kg $CaCO_3$/t | 3.4 | 0.8 |
| NP/AP | ratio | 3.0 | 2.8 |
| Carbonate | %, $CO_3$ | 1.03 | 0.753 |

Source: SRK 2007.

In 2007 and 2011, SRK found that the Phase I pilot plant tailings have an uncertain potential for ARD, based on NP/AP values from samples ranging from 1.1 to 3.0. The same firm reported NP/AP values, for a Phase 2 final tailings sample analyzed in 2008, of 12.5 (SRK 2012e). The values show a high variation because both the NP and the AP were low. (The Phase 1 NP was 11.9 kg $CaCO_3$/t and the 2008 Phase 2 NP was 28.5 kg $CaCO_3$/t; whereas Phase 1 AP was 3.4 kg $CaCO_3$/t and the 2008 Phase 2 AP was 2.28 kg $CaCO_3$/t.)

**Table 3.7-26: Acid-Base Accounting for Tailings Samples Submitted for Humidity Cell Testing**

| Tailings Sample | Acid Potential Indicated by Different Mineralogical Forms | | | Neutralization Potential by Analysis and Mineralogy | | $NP_{Ca,Mg}$ /AP |
|---|---|---|---|---|---|---|
| | Sulfide kg CaCO3/t | Jarosite kg CaCO3/t | Total AP kg CaCO3/t | Total kg CaCO3/t | Ca,Mg CO3 kg CaCO3/t | |
| FT Neutralized Prussian Blue Test | 5.3 | 2.3 | 7.6 | 39.5 | 19.8 | 2.6 |
| FT + CSS Neut. Slurry + CN Detox Tls (Air/$SO_2$) | 4.7 | 4.5 | 9.2 | 25.9 | 10.4 | 1.1 |
| Final Tails - CN Detox by Air/$SO_2$ | 4.7 | 3.4 | 8.1 | 24.5 | 10.4 | 1.3 |
| FT Neutralized Slurry + CN Detox Tails | 4.7 | 0.7 | 5.4 | 12.2 | 9.8 | 1.8 |

Source: SRK 2011.

Four HCTs were conducted on rinsed final tailings samples with the characteristics shown in Table 3.7-26 (SRK 2011). As was done for the waste rock samples, the NP was calculated based on the calcium, magnesium carbonate mineralogy. One of the HCTs was terminated after about two years. The other three have been ongoing for over four years. The leachate chemistry from the HCTs is mostly calcium and sulfate. Arsenic leaching increased initially in all HCTs, reached a peak, and declined thereafter. Leaching of most other constituents has been low, near the detection limits (SRK 2011). Leachate from the tests remained at near-neutral pH values throughout the tests (SRK 2011). However, calculations also predicted that tailings solutions could have concentrations of sulfate possibly in excess of 10,000 mg/L and arsenic concentrations on the order of 2 to 20 mg/L due to recycling of tailings water into the flotation and hydrometallurgical processes (SRK 2007). Sulfate is expected to increase beyond that expected in equilibrium with gypsum, because test work indicates that magnesium concentrations would exceed calcium concentrations in the tailings discharge (SRK 2011). Most

of the reagents used in the metallurgical process would be expected to be oxidized during the metallurgical process. Breakdown of residual reagents would be expected during the neutralization step at the process facilities and in the process.

Phase 1 (2006) and Phase 2 (2007) final tailings samples were subjected to standard MWMP leaching. The resulting leachates were near neutral pH (Table 3.7-27). The leachate chemistries were dominated by sulfate, calcium, and magnesium, reflecting mainly gypsum dissolution. Arsenic leaching was in the range of 0.16 to 0.41 mg/L.

A 2007 Phase 2 final tailings sample was subjected to not only the standard MWMP, but also to a series of rinses to simulate the exposure of beach tailings to natural precipitation after deposition in the tailings storage facility. The TDS and sulfate concentrations decreased somewhat with the rinses (Table 3.7-28); however, the dissolved arsenic concentrations stayed relatively constant (Table 3.7-29).

**Table 3.7-27: Meteoric Water Mobility Procedure Results for Tailings Samples**

| Parameter | Units | Most Stringent Applicable Water Quality Criterion | 2006 Tailings Final Tailings With CN Detox By Air/$SO_2$ | 2007 Tailings FT Neutralized Slurry + CN Detox Tails ($S0_2$/Air) |
|---|---|---|---|---|
| **Major Constituents** | | | | |
| pH | -- | 6.5-8.5[1] | 7.06 | 7.47 |
| Alkalinity | mg/L as $CaCO_3$ | 20 (min)[2b] | 10 | 28 |
| Calcium | mg/L | -- | 521 | 483 |
| Magnesium | mg/L | -- | 188 | 304 |
| Potassium | mg/L | -- | 25.2 | 28.1 |
| Sodium | mg/L | -- | 49.9 | 31.0 |
| Chloride | mg/L | 230[2b] | 9.8 | 4.2 |
| Fluoride | mg/L | 1[2e] | 0.65 | 0.37 |
| Sulfate | mg/L | 250[1] | 2400 | 2700 |
| Nitrite | as N mg/L | -- | <0.06 | <0.6 |
| Nitrate | as N mg/L | -- | 2.38 | <0.5 |
| Total Ammonia | as N mg/L | 0.179[2g] | 6.4 | 7.6 |
| Total Cyanide | mg/L | -- | <0.01 | 0.05 |
| WAD Cyanide | mg/L | 0.0052[2b] | <0.01 | 0.04 |
| Free Cyanide | mg/L | -- | <0.02 | <0.05 |
| Cyanate | mg/L | -- | <1 | <1 |
| Thiocyanate | mg/L | -- | 13 | 0.8 |
| Silver | µg/L | 34.9[2ab] | <0.05 | <5 |

**Table 3.7-27: Meteoric Water Mobility Procedure Results for Tailings Samples**

| Parameter | Units | Most Stringent Applicable Water Quality Criterion | 2006 Tailings Final Tailings With CN Detox By Air/$SO_2$ | 2007 Tailings FT Neutralized Slurry + CN Detox Tails ($S0_2$/Air) |
|---|---|---|---|---|
| **Metals** | | | | |
| Aluminum | µg/L | 87/750[2ab] | <10 | 28.2 |
| Antimony | µg/L | 6[2d] | 130 | 58.8 |
| Arsenic | µg/L | 10[2d] | 162/168 | 406 |
| Cadmium | µg/L | 0.64[2ab] | 0.17 | 0.13 |
| Cobalt | µg/L | 50[2e] | 13.5 | 39.5 |
| Copper | µg/L | 29[2ab] | 10.6 | 4.6 |
| Iron | µg/L | 1,000[2b] | 20 | 120 |
| Lead | µg/L | 10.9[2ab] | 0.29 | 0.29 |
| Manganese | µg/L | 50[2f] | 5,250 | 8,250 |
| Molybdenum | µg/L | 10[2e] | 120 | 64.6 |
| Nickel | µg/L | 168[2ab] | 28.2 | 16.6 |
| Selenium | µg/L | 4.6[2b] | 5 | 14 |
| Thallium | µg/L | 1.7[2f] | 0.5 | 0.3 |
| Zinc | µg/L | 379[2ac] | 27.9 | 14.7 |

**Notes:**

1 18 AAC 70. ADEC, Alaska Water Quality Standards. Amended as of April 8, 2012.

2 Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances. Amended through December 12, 2008. Most stringent criteria used. Criteria are expressed in terms of dissolved metal in the water column, except for aluminum and mercury, which are in terms of total recoverable metal.

2a Aquatic life for fresh water hardness-dependent criteria. Per ADEC 2008, the maximum hardness value shall not exceed 400 mg/l even if the actual ambient hardness is greater than 400 mg/l as calcium carbonate. A hardness of 400 mg/L was used for all calculations. For aluminum, if pH≥7.0 and hardness ≥50, then 750 µg/L.

2b Aquatic life for fresh water (chronic) criteria. Free cyanide measured as weak acid dissociable (WAD) cyanide.

2c Aquatic life for fresh water (acute) criteria.

2d Drinking water primary maximum contaminant levels.

2e Irrigation water criteria.

2f Human health criteria for non-carcinogens (for consumption of water + aquatic organisms).

2g Aquatic life for fresh water (chronic) criteria based on pH and temperature when early life stages of fish are present. The ADEC numeric water quality standard for ammonia depends upon both the temperature and the pH of the matrix water, but not the hardness. Because the measured or predicted temperature and pH of the water may vary over a wide range of values depending on time of year, sample location, and other factors, the most conservative possible numeric standard for ammonia in freshwater (0.179 mg/L; ADEC 2008a) is used as a basis for comparison for all of the waters considered in this section.

Source: SRK 2007.

**Table 3.7-28: Meteoric Water Mobility Procedure and Subsequent Rinsing of Tailings, General Water Quality Parameters**

| Parameter | Unit | Most Stringent Applicable Water Quality Criterion | Leachate | 1st DI Rinse | 2nd DI Rinse | 3rd DI Rinse | 4th DI Rinse |
|---|---|---|---|---|---|---|---|
| **Major Constituents** | | | | | | | |
| pH | | 6.5-8.5[1] | 6.85 | 6.86 | 6.83 | 6.65 | 7.06 |
| Calcium | mg/L | - | 528 | 512 | 555 | 326 | 378 |
| Magnesium | mg/L | - | 140 | 122 | 52 | 8.72 | 5.58 |
| Potassium | mg/L | - | 17.2 | 15.9 | 11.5 | 5.16 | 4.7 |
| Sodium | mg/L | - | 85.5 | 38.5 | 1.,76 | 0.34 | 0.69 |
| Chloride | mg/L | 230[3] | 3.2 | <2 | <2 | <2 | <2 |
| Fluoride | mg/L | 1[2e] | 0.45 | 0.50 | 0.47 | 0.30 | 0.27 |
| Sulfate | mg/L | 250[1] | 2000 | 1900 | 1500 | 850 | 1600 |
| Alkalinity | mg/L as $CaCO_3$ | >20[2b] | 28 | 32 | 35 | 20 | 27 |
| Acidity | mg/L as $CaCO_3$ | - | <2 | <2 | <2 | <2 | <2 |
| Conductivity | µS/cm | - | 2,960 | 2,770 | 2,350 | 1,390 | 1,440 |
| Carbonate | mg/L as $CaCO_3$ | - | <2 | <2 | <2 | <2 | <2 |
| Bicarbonate | mg/L as $CaCO_3$ | - | 28 | 32 | 35 | 20 | 27 |
| OH | mg/L as $CaCO_3$ | - | <2 | <2 | <2 | <2 | <2 |
| Total Ammonia | as N mg/L | 0.18[2g] | 0.8 | 0.4 | 0.1 | <0.1 | 0.2 |
| Nitrite | as N mg/L | 1[2d] | 8.63 | 3.54 | 1.27 | 0.38 | 1.84 |
| Nitrate | as N mg/L | 10[2d] | <0.5 | <0.5 | <0.5 | <0.05 | 0.16 |
| Total Dissolved Solids | mg/L | 500[1] | 2,900 | 2,820 | 2,370 | 1,160 | 1,440 |
| Total Suspended Solids | mg/L | - | 5 | 3 | 2 | 3 | 2 |

**Table 3.7-28: Meteoric Water Mobility Procedure and Subsequent Rinsing of Tailings, General Water Quality Parameters**

| Parameter | Unit | Most Stringent Applicable Water Quality Criterion | Leachate | 1st DI Rinse | 2nd DI Rinse | 3rd DI Rinse | 4th DI Rinse |
|---|---|---|---|---|---|---|---|
| **Cyanide** | | | | | | | |
| Total Cyanide | µg/L | - | 40 | 12 | 14 | 18 | 31 |
| WAD Cyanide | µg/L | 5.2[2b] | <10 | <5 | <5 | <5 | 7 |

**Notes:**

Shaded cells exceed most stringent water quality standard.

AWQC:

1 18 AAC 70. ADEC, Alaska Water Quality Standards. Amended as of April 8, 2012, maximum drinking water levels

2 Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances. Amended through December 12, 2008. Most stringent criteria used. Criteria are expressed in terms of dissolved metal in the water column, except for aluminum and mercury, which are in terms of total recoverable metal.

2a Aquatic life for fresh water hardness-dependent criteria. A hardness of 400 mg/L was used for all calculations. For aluminum, if pH≥7.0 and hardness ≥50, then 750 ug/L.

2b Aquatic life for fresh water (chronic) criteria. Free cyanide measured as weak acid dissociable (WAD) cyanide.

2c Aquatic life for fresh water (acute) criteria.

2d Drinking water primary maximum contaminant levels.

2e Irrigation water criteria.

2f Human health criteria for non-carcinogens (for consumption of water + aquatic organisms).

2g Aquatic life for fresh water (chronic) criteria based on pH and temperature when early life stages of fish are present. The ADEC numeric water quality standard for ammonia depends upon both the temperature and the pH of the matrix water, but not the hardness. Because the measured or predicted temperature and pH of the water may vary over a wide range of values depending on time of year, sample location, and other factors, the most conservative possible numeric standard for ammonia in freshwater (0.179 mg/L; ADEC 2008a) is used as a basis for comparison for all of the waters considered in this section.

Source: SRK 2012b: Table 4-5, 2007 Phase 2 pilot transitional final tailings samples.

**Table 3.7-29: Meteoric Water Mobility Procedure and Subsequent Rinsing of Tailings, Metals Results**

| Parameter | Unit | Most Stringent Applicable Water Quality Criterion | Leachate | 1st DI Rinse | 2nd DI Rinse | 3rd DI Rinse | 4th DI Rinse |
|---|---|---|---|---|---|---|---|
| Aluminum | µg/L | 87[2a,b] | <10 | <10 | 20 | 20 | 10 |
| Antimony | µg/L | 6[2d] | 39.3 | 44.8 | 43.1 | 23.9 | 22.2 |
| Arsenic | µg/L | 10[2d] | 463 | 506 | 500 | 412 | 402 |
| Barium | µg/L | 2,000[2d] | 16 | 18.5 | 18.9 | 13.1 | 42.8 |
| Beryllium | µg/L | 4[2d] | <0.02 | <0.02 | <0.02 | <0.02 | <0.02 |
| Boron | µg/L | 750[2e] | 160 | 158 | 73.6 | 20.7 | 31.6 |
| Bismuth | µg/L | -- | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Cadmium | µg/L | 0.64[2a,b] | 0.083 | 0.061 | 0.043 | 0.017 | 0.045 |
| Cerium | µg/L | -- | <0.07 | <0.07 | <0.07 | <0.07 | <0.07 |
| Chromium, total | µg/L | 100[2e] | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Cobalt | µg/L | 50[2e] | 6.65 | 5.84 | 3.62 | 1.5 | 1.89 |
| Copper | µg/L | 29[2a,b] | 7.8 | 5.2 | <3 | 1.5 | 3.6 |
| Gallium | µg/L | -- | 0.02 | 0.05 | 0.04 | 0.05 | 0.06 |
| Germanium | µg/L | -- | 0.15 | 0.15 | 0.08 | 0.04 | 0.05 |
| Hafnium | µg/L | -- | 0.098 | 0.0048 | 0.061 | 0.018 | 0.02 |
| Indium | µg/L | -- | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Iron | µg/L | 1,000[2b] | 30 | 50 | 20 | <10 | 30 |
| Lanthanum | µg/L | -- | <0.04 | <0.04 | <0.04 | <0.04 | <0.04 |
| Lead | µg/L | 11[2a,b] | 0.22 | 3.6 | 0.8 | 0.56 | 0.2 |
| Lithium | µg/L | 2,500[2e] | 2 | 2 | 2 | 2 | 2 |
| Manganese | µg/L | 50[2f] | 3,270 | 3,140 | 2,060 | 870 | 966 |
| Molybdenum | µg/L | 10[2e] | 36.8 | 30.9 | 11.5 | 2.68 | 4.77 |
| Nickel | µg/L | 168[2ab] | 14.2 | 12.2 | 7.3 | 3.3 | 18.5 |
| Niobium | µg/L | -- | 0.002 | 0.006 | <0.001 | <0.001 | <0.001 |
| Rubidium | µg/L | -- | 9.33 | 7.95 | 4.84 | 2.39 | 1.86 |
| Rhenium | µg/L | -- | <0.2 | <0.1 | <0.1 | <0.1 | <0.1 |
| Selenium | µg/L | 4.6[2b] | 4 | 3 | <1 | <1 | <1 |
| Silicon | µg/L | -- | 2,870 | 3,560 | 3,520 | 1,830 | 2,030 |

**Table 3.7-29: Meteoric Water Mobility Procedure and Subsequent Rinsing of Tailings, Metals Results**

| Parameter | Unit | Most Stringent Applicable Water Quality Criterion | Leachate | 1st DI Rinse | 2nd DI Rinse | 3rd DI Rinse | 4th DI Rinse |
|---|---|---|---|---|---|---|---|
| Silver | µg/L | 34.9[2ab] | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Strontium | µg/L | -- | 1,900 | 1,860 | 1,820 | 94.1 | 0.3 |
| Tantalum | µg/L | -- | 0.013 | 0.008 | 0.01 | 0.04 | 0.001 |
| Tellurium | µg/L | -- | <0.03 | <0.06 | <0.03 | <0.03 | <0.03 |
| Thallium | µg/L | 1.7[2f] | 0.058 | 0.046 | 0.02 | 0.004 | 0.01 |
| Thorium | µg/L | -- | 0.841 | 0.519 | 0.634 | 0.042 | 1.49 |
| Tin | µg/L | -- | 0.14 | 0.32 | 0.35 | 0.35 | 0.45 |
| Titanium | µg/L | -- | 0.3 | 0.6 | 0.3 | 0.3 | 0.3 |
| Tungsten | µg/L | -- | 0.19 | 0.24 | 0.23 | 0.11 | 0.16 |
| Uranium | µg/L | -- | 1.19 | 1.77 | 0.978 | 0.565 | 0.956 |
| Vanadium | µg/L | 100[2e] | 0.25 | 0.41 | 0.3 | 0.6 | 0.59 |
| Yttrium | µg/L | -- | 0.01 | 0.013 | 0.008 | 0.005 | 0.009 |
| Zinc | µg/L | 379[2ac] | 8 | 7 | 4 | 3 | 10 |
| Zirconium | µg/L | -- | 0.14 | 0.07 | 0.32 | 0.23 | 0.03 |
| Mercury | ng/L | 12[2b] | 10 | 10 | 7 | 5 | 3 |

**Notes:**

Shaded cells exceed most stringent water quality standard.

AWQC:

1 18 AAC 70. ADEC, Alaska Water Quality Standards. Amended as of April 8, 2012, maximum drinking water levels

2 Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances. Amended through December 12, 2008. Most stringent criteria used. Criteria are expressed in terms of dissolved metal in the water column, except for aluminum and mercury, which are in terms of total recoverable metal.

- 2a Aquatic life for fresh water hardness-dependent criteria. A hardness of 400 mg/L was used for all calculations. For aluminum, if pH≥7.0 and hardness ≥50, then 750 µg/L; otherwise, 87 µg/L.
- 2b Aquatic life for fresh water (chronic) criteria. Free cyanide measured as weak acid dissociable (WAD) cyanide.
- 2c Aquatic life for fresh water (acute) criteria.
- 2d Drinking water primary maximum contaminant levels.
- 2e Irrigation water criteria.
- 2f Human health criteria for non-carcinogens (for consumption of water + aquatic organisms).

Source: SRK 2012b: Table 4-6, 2007 Phase 2 pilot transitional final tailings samples.

#### 3.7.2.5 CLIMATE CHANGE

Climate change is affecting resources in the EIS Analysis area and trends associated with climate change are projected to continue into the future. Section 3.26.3, Climate Change, discusses climate change trends and impacts to key resources in the physical environment including atmosphere, water resources, and permafrost. Current and future effects to water quality are tied to changes in water resources (discussed in Section 3.26.3.2, Climate Change).

### 3.7.3 ENVIRONMENTAL CONSEQUENCES

Levels of effects discussed throughout the analysis of water quality impacts are related to general criteria described in Table 3.7-30 below.

**Table 3.7-30: Impact Criteria for Effects on Surface Water Quality, Groundwater Quality, and Sediment Quality**

| Type of Effect | Impact Component | Effects Summary | | |
|---|---|---|---|---|
| **Changes to surface water quality, groundwater quality, and sediment quality** | Magnitude or Intensity | **Low**: Effects are below water quality regulatory limits or sediment quality guidelines. Effects may not be noticeable or measurable. | not applicable | **High**: Effects are sufficient to exceed water quality regulatory limits and baseline ranges; mitigation measures are not effective. |
| | Duration | **Temporary**: Water quality or sediment quality would be reduced infrequently but not longer than the span of the project construction and would be expected to return to pre-activity levels at the completion of the activity. | **Long-term**: Water quality or sediment quality would be reduced through the life of the mine and for a duration of up to 100 years after the end of construction; however, would return to pre-activity levels sometime during that period. | **Permanent**: Water quality or sediment quality would be reduced and would not be anticipated to return to previous levels or would take longer than 100 years to do so. |
| | Geographic Extent | **Local:** Affects water or sediment quality only locally; discrete portions of the project area affected. Impacts can be contained from moving downstream or throughout a waterbody. | **Regional:** Affects water or sediment quality beyond a local area, potentially throughout the EIS Project Area or outside the project footprint. Impacts affect hydraulically connected waters. | **Extended:** Affects water or sediment quality beyond the EIS Analysis Area. Impacts affect hydraulically connected waters. |
| | Context | **Common:** Affects areas of common water or sediment quality or where there is an abundance of water or sediment resources. | **Important:** Affects areas with high water or sediment quality or water or sediment resources that are considered important in the region. | **Unique:** Affects areas of high water or sediment quality that are protected by legislation. |

### 3.7.3.1 ALTERNATIVE 1 – NO ACTION

Under the No Action Alternative, construction, operations, and closure activities associated with the proposed project would not take place and the required water quality-related permits would not be issued. The rocks at the mine site would continue to slowly weather in place as they are presently doing. For these reasons, no project-related geochemical processes or impacts to surface water, groundwater, or sediment quality would occur under this alternative. Consequently, there would be no new effects, neither adverse nor beneficial, on these resources from implementation of the No Action Alternative.

### 3.7.3.2 ALTERNATIVE 2 – DONLIN GOLD'S PROPOSED ACTION

#### 3.7.3.2.1 GEOCHEMISTRY OF MINE WATERS

Mine Site

Under Alternative 2, geochemical water-quality impacts are tied to several components of the Donlin Gold Project, specifically:

- The Waste Rock Facility (WRF);
- NOB and SOB Stockpiles;
- The Low-Grade Ore Stockpile;
- The Lower and Upper Contact Water Dam (CWD);
- Haul roads built with waste rock;
- The Tailings Storage Facility (TSF);
- The TSF Seepage Recovery System (SRS); and
- Open Pit and Pit Lake

Each of these components, except for haul roads, is discussed at length in Appendix H – Geochemistry. The haul roads are discussed in Section 3.7.3.2.2, Surface Water Quality, and Section 3.7.3.2.3, Groundwater Quality.

Summaries of the predicted chemistries of surface waters related to these components are given in the following subsections for mine water that would replace the natural environment (surface water). These include the Lower and Upper CWD, the TSF impoundment, and SRS during operations, and the pit lake post-closure. Although these process-related waters would not be considered waters of the State of Alaska or subject to the APDES permitting program while on site, they may be treated and discharged to Crooked Creek, when necessary for water management, and they could represent a potential environmental impact, particularly for wildlife (e.g., see Section 3.12, Wildlife). Their expected water chemistries are presented in this section in comparison to most stringent Applicable Water Quality Criteria (AWQC) to provide the reader with a frame of reference for understanding the predicted concentrations of constituents.

*Lower Contact Water Dam Pond (CWD)*

The Lower CWD is located in American Creek with the objective of managing runoff of contact water from the waste rock facility (WRF) and open pit. The Lower CWD will receive runoff from a variety of sources:

- Surface and seepage runoff from the waste rock.
- Runoff from undisturbed ground upgradient of the waste rock.
- Surface runoff within the open pit footprint.
- Horizontal drains from the open pit.
- Runoff collected behind the ore stockpile berm.
- Runoff collected in a sediment pond downstream of the South Overburden (SOB) stockpile.

The Lower CWD is designed to store water that will be used throughout the year as a source of fresh water for the process plant (BGC 2015f). Peak runoff is limited to the spring and summer months, with negligible runoff volumes between mid-October and the beginning of April. These variable flows are in contrast to the constant fresh water demand. During the former period, runoff volumes are in excess of fresh water requirements and this excess water will be stored. The stored water will be a useful source of fresh water during the fall and winter, when inflows are minimal (BGC 2015f).This water would be stored during construction and the Lower CWD would continue to receive water throughout the life of the mine. It would be monitored quarterly (SRK 2012d).

The water quality of the lower CWD would likely be variable, due to the variation in the input sources. However, it would be expected to decrease over time as the PAG rock in the low-grade ore stockpile, the PAG 6 cells of the WRF, and the exposed surfaces of the pit weather. Order-of-magnitude estimates of the water quality of the lower CWD under different input water assumptions are given in Table 3.7-31.

The estimates in Table 3.7-31 were developed using two approaches. The first approach consisted of mixing the predicted water chemistries of the various water sources to the pond (from SRK 2007, 2011; Lorax 2012a; and ARCADIS 2012b) at their annual average relative flows, as given by BGC 2015f, using the USGS geochemical computer code PHREEQC. The assumptions used in the modeling effort are discussed in detail in Appendix H, Geochemistry. For most of the calculations, NAG WRF drainage was assumed to be that given by SRK (2007) for Year 8 of mine life. The chemistry of seepage from rocks in the NAG WRF is predicted to remain relatively constant over time for the first 20 or so years of operations (SRK 2007). However, if the NAG and PAG 5 rocks are not well mixed, the NAG WRF will begin to produce higher-concentration, more acidic seepage by the end of mine life, based on the predictions in SRK (2007) for Year 26.

The results of the Lower CWD PHREEQC modeling suggest that several constituents would exceed the most stringent AWQC for all modeled scenarios. These include sulfate, total dissolved solids (TDS), antimony, arsenic, cadmium, manganese, molybdenum, nickel, selenium, zinc, and mercury. Even though the WRF seepage is only about 11 percent of the total expected inflow to the lower CWD, the quality of blending of NAG and PAG rocks in the WRF appears to have a substantial effect on the pH, certain metals (aluminum, beryllium, cobalt,

copper, iron, and lead), and stored acidity (due to dissolved iron and aluminum) of the water in the lower CWD. The low pH environment caused by seepage from a poorly mixed WRF keeps most metals in solution, even when iron and aluminum minerals are allowed to precipitate because adsorption of cationic metals onto precipitated iron oxyhydroxide (ferrihydrite) is inhibited at low pH. However, the oxyanion arsenic shows its greatest adsorption at the lowest pH, decreasing to less than a fifth of its non-adsorbed concentration (but still above AWQC, i.e., 1,000 µg/L adsorbed vs 5,400 µg/L non-adsorbed). In the circumneutral waters predicted to form assuming seepage from a well-mixed WRF, aluminum, beryllium, copper, iron, and lead exceed standards in both scenarios in which iron and aluminum minerals are not allowed to precipitate. When minerals precipitation and adsorption are allowed, these constituents all adjust to values that do not exceed their AWQC.

The second approach was developed by Hatch (2015) as a design basis for the conceptual AWT system. It consisted of using 50th percentile and 95th percentile values of source terms. The resulting concentrations are given in the last two columns of Table H-6 (Appendix H). The major difference between the two approaches is that the PHREEQC approach predicted that the water would likely eventually turn acid as the PAG rock oxidized, and the acid would trigger higher concentrations of sulfate, TDS, aluminum, and certain metals. Both approaches predicted that sulfate, TDS, antimony, arsenic, cadmium, lead (when not adsorbed), manganese, molybdenum, nickel, selenium, zinc, and mercury concentrations would exceed AWQC.

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**Table 3.7-31:** Predicted Lower CWD Pond Concentrations

| Source Assumptions[3] | | | PHREEQC Mix[3] | | | | | | | | | | Water Treatment Design Basis[8] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pit Walls[4] | | | Avg PAG | | Peak PAG | | Avg PAG | | Peak PAG | | Peak PAG | | 50th | 95th |
| WRF Seep[5] | | | Well mixed Yr 8 | | Well mixed Yr 8 | | Poorly mixed Yr 8 | | Poorly mixed Yr 8 | | Poorly mixed Yr 26 | | Percentile | Percentile |
| Precipitation / Adsorption[5] | | | No | Yes | No | Yes | No | Yes | No | Yes | No | Yes | | |
| | Units | Most Stringent Applicable Water Quality Criterion | | | | | | | | | | | | |
| **Major Constituents** | | | | | | | | | | | | | | |
| pH | S.U. | 6.5-8.5[1] | 7.9 | 7.9 | 7.4 | 7.5 | 5.7 | 4.7 | 5.5 | 4.2 | 3.9 | 2.8 | 7.8 | 8.0 |
| Calcium | mg/L | -- | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 120 | 100 | 100 | 160 | 180 |
| Magnesium | mg/L | -- | 57 | 57 | 69 | 69 | 55 | 55 | 68 | 68 | 290 | 290 | 19 | 25 |
| Potassium | mg/L | -- | 21 | 21 | 21 | 21 | 21 | 19 | 21 | 21 | 18 | 18 | 21 | 27 |
| Sodium | mg/L | -- | 21 | 21 | 24 | 24 | 23 | 23 | 26 | 26 | 26 | 26 | 12 | 27 |
| Chloride | mg/L | 230[2b] | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.0 | 1.4 |
| Fluoride | mg/L | 1[2e] | NR[7] | NR | NR | NR | NR | NR | NR | NR | NR | NR | 0.18 | 0.19 |
| Sulfate | mg/L | 250[1] | 550 | 550 | 640 | 630 | 660 | 590 | 750 | 680 | 2,400 | 2,400 | 460 | 550 |
| Total Dissolved Solids (est.) | mg/L | 500[1] | 790 | 780 | 900 | 890 | 920 | 810 | 1,000 | 930 | 3,300 | 3,100 | 750 | 910 |
| **Metals** | | | | | | | | | | | | | | |
| Aluminum | µg/L | 87/750[2a,b] | 3,600 | 21 | 7,200 | 8.1 | 23,000 | 2,000 | 27,000 | 6,000 | 49,000 | 49,000 | 64 | 144 |
| Antimony | µg/L | 6[2d] | 520 | 520 | 530 | 530 | 520 | 520 | 530 | 530 | 510 | 500 | 700 | 800 |
| Arsenic | µg/L | 10[2d] | 4,700 | 4,700 | 5,400 | 5,100 | 4,400 | 4,400 | 5,100 | 4,000 | 5,400 | 1,000 | 4,000 | 4,700 |
| Barium | µg/L | 2,000[2d] | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 32 | 31 | 82 | 172 |
| Beryllium | µg/L | 4[2d] | 4.2 | 0.33 | 7.9 | 0.014 | 4.2 | 4.2 | 8.0 | 4.7 | 12 | 12 | 0.5 | 0.6 |
| Boron | µg/L | 750[2e] | 740 | 740 | 740 | 740 | 740 | 740 | 740 | 740 | 740 | 740 | 150 | 160 |
| Cadmium | µg/L | 0.64[2a,b] | 1.8 | 1.7 | 2.8 | 2.7 | 1.8 | 1.8 | 2.9 | 2.9 | 6.7 | 6.6 | 1 | 1 |
| Chromium | µg/L | 100[2d] | 21 | 21 | 26 | 26 | 21 | 21 | 26 | 26 | 32 | 31 | 20 | 21 |
| Cobalt | µg/L | 50[2e] | 49 | 49 | 80 | 79 | 50 | 50 | 81 | 81 | 130 | 130 | 50 | 51 |
| Copper | µg/L | 29[2a,b] | 84 | 7.8 | 160 | 3.5 | 220 | 220 | 300 | 300 | 340 | 340 | 8 | 8 |
| Iron | µg/L | 1,000[2b] | 2,400 | 0.22 | 4,400 | 0.58 | 8,200 | 39 | 10,000 | 1,100 | 410,000 | 210,000 | 230 | 470 |
| Lead | µg/L | 10.9[2a,b] | 30 | 2.3 | 32 | 0.79 | 12 | 12 | 15 | 14 | 61 | 61 | 70 | 80 |
| Manganese | µg/L | 50[2f] | 1,700 | 1,700 | 2,100 | 2,100 | 2,300 | 2,300 | 2,700 | 2,700 | 3,100 | 3,100 | 1,500 | 2,000 |
| Molybdenum | µg/L | 10[2e] | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 140 | 140 | 140 | 160 | 200 |

**Table 3.7-31:** Predicted Lower CWD Pond Concentrations

| **Source Assumptions[3]** | | | **PHREEQC Mix[3]** | | | | | | | | | | **Water Treatment Design Basis[8]** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pit Walls[4] | | | **Avg PAG** | | **Peak PAG** | | **Avg PAG** | | **Peak PAG** | | **Peak PAG** | | **50th** | **95th** |
| WRF Seep[5] | | | **Well mixed Yr 8** | | **Well mixed Yr 8** | | **Poorly mixed Yr 8** | | **Poorly mixed Yr 8** | | **Poorly mixed Yr 26** | | **Percentile** | **Percentile** |
| Precipitation / Adsorption[5] | | | **No** | **Yes** | **No** | **Yes** | **No** | **Yes** | **No** | **Yes** | **No** | **Yes** | | |
| Nickel | µg/L | 100[2a,b] | 180 | 170 | 270 | 260 | 180 | 180 | 270 | 270 | 330 | 320 | 310 | 310 |
| Selenium | µg/L | 4.6[2b] | 99 | 99 | 110 | 110 | 98 | 98 | 100 | 100 | 100 | 100 | 200 | 220 |
| Thallium | µg/L | 1.7[2f] | 0.75 | 0.75 | 0.78 | 0.78 | 0.75 | 0.75 | 0.78 | 0.78 | 0.79 | 0.79 | 1 | 1 |
| Zinc | µg/L | 379[2a,c] | 1,500 | 1,300 | 1,900 | 1,600 | 1,300 | 1,300 | 1,800 | 1,800 | 5,100 | 5,000 | 440 | 460 |
| WAD Cyanide | µg/L | 5.2[2b] | NR | NR | NR | NR | NR | NR | NR | NR | NR | NR | 4.3 | 5.0 |
| Mercury | ng/L | 12[2a,b] | 96 | 94 | 98 | 81 | 96 | 96 | 98 | 98 | 99 | 98 | 130 | 150 |
| Minerals Precipitated[6] | | | Ferrihydrite | | Ferrihydrite | | K-Jarosite | | Ferrihydrite | | Ferrihydrite | | | |
| | | | Basaluminite | | Basaluminite | | Basaluminite | | Jurbanite | | | | | |
| | | | | | | | Jurbanite | | | | | | | |

**Notes:**

1 18 AAC 70. ADEC, Alaska Water Quality Standards. Amended as of April 8, 2012.

2 Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances. Amended through December 12, 2008. Most stringent criteria used. Criteria are expressed in terms of dissolved metal in the water column, except for aluminum and mercury, which are in terms of total recoverable metal.

- 2a Aquatic life for fresh water hardness-dependent criteria. A hardness of 400 mg/L was used for all calculations. For aluminum, if pH≥7.0 and hardness ≥50, then 750 µg/L, otherwise, 87 µg/L.
- 2b Aquatic life for fresh water (chronic) criteria. Free cyanide measured as weak acid dissociable (WAD) cyanide.
- 2c Aquatic life for fresh water (acute) criteria.
- 2d Drinking water primary maximum contaminant levels.
- 2e Irrigation water criteria.
- 2f Human health criteria for non-carcinogens (for consumption of water + aquatic organisms).
- 2g Aquatic life for fresh water (chronic) criteria based on pH and temperature when early life stages of fish are present. The ADEC numeric water quality standard for ammonia depends upon both the temperature and the pH of the matrix water, but not the hardness. Because the measured or predicted temperature and pH of the water may vary over a wide range of values depending on time of year, sample location, and other factors, the most conservative possible numeric standard for ammonia in freshwater (0.179 mg/L; ADEC 2008a) is used as a basis for comparison for all of the waters considered in this section.

3 All chemistry calculations using PHREEQC assume (a) The relative flows areas given in Figure 4-3 of BGC 2015f; (b) Undisturbed American Creek watershed and SOB flows were approximated by the average surface water concentrations for Category 2 Locations--background streams in mineralized area (EIS Table 3.7-3); (c) The pit walls have the average ratio of different rock types, as shown in EIS Figure 3.7-14, Tonnage-weighted Annual Average NP/AP for Waste Rock Categories, and (d) The surface water drainage from the WRF has the concentrations used in PitMod.

4 For pit walls: Avg PAG assumes that the PAG rocks on the pit wall produce drainage that is the average of exhausted PAG and peak PAG used in modeling the pit lake; Peak PAG assumes that the PAG rocks are producing drainage at their peak rate.

5 For WRF Seeps, Well mixed Y8, Poorly mixed Y8, and Poorly mixed Y26 have the concentrations given in Table 3.7A-5, Pore-water quality for NAG portions of WRF during Operations (from SRK 2007, Table 2-18). All PAG seepage has the concentrations of Poorly mixed Y8 PAG seepage from the same table.

6 If No, no minerals are allowed to precipitate. If Yes, then aluminum and iron sulfato-hydroxide minerals are allowed to precipitate at saturation and other constituents are allowed to adsorb onto any iron oxyhydroxide mineral.

7 NR = Not reported in SRK 2007 or 2011

8 Hatch 2015

*Upper CWD*

The Upper CWD would receive water from the Lower CWD and runoff from undisturbed areas above the WRF. The relative volumes of the two types of water are predicted to be about 65 percent Lower CWD water and 35 percent runoff from undisturbed areas (BGC 2015f). Parallel to the Lower CWD, two approaches were used to predict the range of water chemistries for the Upper CWD. The first approach used PHREEQC modeling and the second was developed by Hatch (2015) using 50th and 95th percentile data. Because the largest differences between the two approaches for the Lower CWD were between the 50th and 95th percentile data and the PHREEQC model using poorly mixed Peak PAG from Year 26, only this case was modeled. The results for both approaches are given in Table 3.7-32. Sulfate, TDS, antimony, arsenic, cadmium, lead, manganese, molybdenum, nickel, selenium, and mercury are predicted to exceed AWQC for both approaches. Aluminum, cobalt, copper, and iron are also predicted to exceed AWQC using the PHREEQC approach; and ammonia using the Hatch approach.

**Table 3.7-32: Predicted Upper CWD Pond Concentrations**

| Parameter | Units | Most Stringent Applicable Water Quality Criterion | PHREEQC Mix[3] | Water Treatment Design Basis[4] | |
|---|---|---|---|---|---|
| | | | | 50th Percentile | 95th Percentile |
| **Major Constituents** | | | | | |
| pH | S.U. | 6.5-8.5[1] | 2.9 | 7.9 | 8.1 |
| Calcium | mg/L | -- | 76 | 110 | 120 |
| Potassium | mg/L | -- | 12 | 13 | 17 |
| Magnesium | mg/L | -- | 210 | 14 | 18 |
| Sodium | mg/L | -- | 18 | 12 | 22 |
| Strontium | mg/L | -- | -- | 1.6 | 2.1 |
| Chloride | mg/L | 230[2b] | 1.4 | 1.0 | 1.3 |
| Fluoride | mg/L | 1[2e] | -- | 0.15 | 0.16 |
| Sulfate | mg/L | 250[1] | 1,500 | 280 | 330 |
| Silica | mg/L | -- | -- | 16 | 16.9 |
| Total Dissolved Solids | mg/L | 500[1] | 1,900 | 519 | 614 |
| Ammonia | as N mg/L | 0.18[2g] | -- | 0.54 | 0.55 |
| **Cyanide** | | | | | |
| WAD Cyanide | µg/L | 5.2[2b] | -- | 5 | 5 |
| **Metals** | | | | | |
| Aluminum | µg/L | 87/750[2a,b] | 32,000 | 73 | 121 |
| Antimony | µg/L | 6[2d] | 330 | 420 | 480 |
| Arsenic | µg/L | 10[2d] | 270 | 2,400 | 2,900 |
| Barium | µg/L | 2,000[2d] | 39 | 120 | 180 |

**Table 3.7-32: Predicted Upper CWD Pond Concentrations**

| Parameter | Units | Most Stringent Applicable Water Quality Criterion | PHREEQC Mix[3] | Water Treatment Design Basis[4] | |
|---|---|---|---|---|---|
| | | | | 50th Percentile | 95th Percentile |
| Beryllium | µg/L | 4[2d] | 7.8 | 48 | 53 |
| Boron | µg/L | 750[2e] | 480 | 110 | 110 |
| Cadmium | µg/L | 0.64[2a, b] | 4.3 | 0.8 | 0.8 |
| Chromium, total | µg/L | 100[2d] | 20 | 13 | 14 |
| Cobalt | µg/L | 50[2e] | 86 | 32 | 32 |
| Copper | µg/L | 29[2a, b] | 220 | 5 | 5 |
| Iron | µg/L | 1,000[2b] | 87,000 | 300 | 470 |
| Lead | µg/L | 10.9[2a, b] | 40 | 420 | 480 |
| Lithium | µg/L | 2,500[2e] | -- | 62 | 72 |
| Manganese | µg/L | 50[2f] | 2,000 | 950 | 1,300 |
| Molybdenum | µg/L | 10[2e] | 91 | 100 | 120 |
| Nickel | µg/L | 168[2a, b] | 210 | 187 | 190 |
| Selenium | µg/L | 4.6[2b] | 66 | 120 | 140 |
| Thallium | µg/L | 1.7[2f] | 0.65 | 1 | 1 |
| Vanadium | µg/L | 100[2e] | -- | 13 | 18 |
| Zinc | µg/L | 379[2a,c] | 3,300 | 270 | 280 |
| Mercury | ng/L | 12[2b] | 66 | 99 | 110 |

**Notes:**

1 18 AAC 70. ADEC, Alaska Water Quality Standards. Amended as of April 8, 2012.

2 Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances. Amended through December 12, 2008. Most stringent criteria used. Criteria are expressed in terms of dissolved metal in the water column, except for aluminum and mercury, which are in terms of total recoverable metal.

2a Aquatic life for fresh water hardness-dependent criteria. A hardness of 400 mg/L was used for all calculations. For aluminum, if pH≥7.0 and hardness ≥50, then 750 µg/L; otherwise, 87 µg/L.

2b Aquatic life for fresh water (chronic) criteria. Free cyanide measured as weak acid dissociable (WAD) cyanide.

2c Aquatic life for fresh water (acute) criteria.

2d Drinking water primary maximum contaminant levels.

2e Irrigation water criteria.

2f Human health criteria for non-carcinogens (for consumption of water + aquatic organisms).

2g Aquatic life for fresh water (chronic) criteria based on pH and temperature when early life stages of fish are present. The ADEC numeric water quality standard for ammonia depends upon both the temperature and the pH of the matrix water, but not the hardness. Because the measured or predicted temperature and pH of the water may vary over a wide range of values depending on time of year, sample location, and other factors, the most conservative possible numeric standard for ammonia in freshwater (0.179 mg/L; ADEC 2008a) is used as a basis for comparison for all of the waters considered in this section.

3 PHREEQC chemistry calculations used 65% Lower CWD water, assuming Peak PAG, poorly mixed, Year 26, with precipitation of Ferrihydrite +Adsorption (Table H–6) mixed with 35% undisturbed runoff, approximated by the average surface water concentrations for Category 2 Locations--background streams in mineralized area (EIS Table 3.7-3).

4 Hatch 2015, Table 3-3, rounded to two significant figures.

*Tailings Storage Facility*

The TSF is planned to be a fully-lined facility constructed in six stages over the 27.5-year mine life. A SRS is planned immediately downstream of the main tailings dam, which would collect groundwater and any seepage from the lined TSF. This water is expected to be mainly groundwater and would be used as process water or pumped to the TSF pond. Reclaim water from the tailings pond would be recycled back to the process facility from a floating barge via a pipeline (SRK 2012a).

Tailings pond water is formed by recirculation as process water. It is assumed to have a concentration factor of three from initial tailings liquor, due to the recirculation (SRK 2015a). SRK 2015a predicted the recirculated, concentrated TSF pond water using Geochemist's Workbench, a thermodynamic equilibrium code, and allowed precipitation of certain minerals if they had reached saturation in the concentrated water. The results are shown in Table 3.7-33. The "Solubility Constrained" column is checked for those constituents whose concentrations were lowered due to mineral precipitation. Several constituents are predicted to exceed AWQC sulfate, TDS (not shown), fluoride, antimony, arsenic, cadmium, manganese, molybdenum, selenium, and mercury.

**Table 3.7-33: Tailings Pond Water and Pore-Water Quality in Buried Tailings**

| Parameter | Units | Most Stringent Applicable Water Quality Criterion | Solubility Constrained | Tailings Pond Water | Buried Tailings – Process DOC |
|---|---|---|---|---|---|
| **Major Constituents** | | | | | |
| Redox Potential | mV | -- | | 840 | 230 |
| pH | S. U. | 6.5-8.5[1] | X | 6.5 | 5.8 |
| Calcium | mg/L | -- | X | 610 | 1,000 |
| Magnesium | mg/L | -- | X | 440 | 1,000 |
| Potassium | mg/L | -- | X | 120 | 120 |
| Sodium | mg/L | -- | | 1,100 | 1,100 |
| Strontium | mg/L | -- | | 7.9 | 7.9 |
| Chloride | mg/L | 230[2b] | | 26 | 25 |
| Fluoride | mg/L | 1[2e] | X | 2 | 2 |
| Sulfate | mg/L | 250[1] | X | 5,800 | 4,400 |
| Silicon | mg/L | -- | | 7 | 7 |
| Alkalinity | mg/L | 20 (min)[2b] | | 25 | 530 |
| Ammonia | mg/L | 0.18[2g] | | 29 | 29 |
| **Metals** | | | | | |
| Aluminum | µg/L | 87/750[2a,b] | X | 13 | 5.6 |
| Antimony | µg/L | 6[2d] | X | 22 | 1,100 |
| Arsenic | µg/L | 10[2d] | X | 3,300 | 15,000 |

**Table 3.7-33: Tailings Pond Water and Pore-Water Quality in Buried Tailings**

| Parameter | Units | Most Stringent Applicable Water Quality Criterion | Solubility Constrained | Tailings Pond Water | Buried Tailings – Process DOC |
|---|---|---|---|---|---|
| Barium | µg/L | 2,000[2d] | X | 11 | 11 |
| Beryllium | µg/L | 4[2d] | | <0.06 | <0.06 |
| Boron | µg/L | 750[2e] | | 590 | 590 |
| Cadmium | µg/L | 0.64[2a,b] | | 0.73 | 0.73 |
| Chromium | µg/L | 100[2d] | | 12 | 12 |
| Cobalt | µg/L | 50[2e] | | 19 | 19 |
| Copper | µg/L | 29[2a,b] | X | 18 | 18 |
| Iron | µg/L | 1,000[2b] | X | 4.4 | 98,000 |
| Lead | µg/L | 10.9[2a,b] | | 3 | 3 |
| Lithium | µg/L | 2,500[2e] | | <6 | <6 |
| Manganese | µg/L | 50[2f] | X | 2,000 | 2,000 |
| Molybdenum | µg/L | 10[2e] | | 230 | 230 |
| Nickel | µg/L | 168[2a,b] | | 62 | 62 |
| Selenium | µg/L | 4.6[2b] | | 42 | 42 |
| Thallium | µg/L | 1.7[2f] | | 0.41 | 0.41 |
| Vanadium | µg/L | 1,00[2e] | | 4.8 | 4.8 |
| Zinc | µg/L | 379[2a,c] | | 33 | 33 |
| Mercury | ng/L | 12[2a] | | 10,000[3] | 10,000[3] |

**Notes:**

All tailings pond water and pore-water concentrations are "dissolved" and should be used as "average" annual.
Shaded cells exceed most stringent water quality standard.
AWQC:
1 18 AAC 70. ADEC, Alaska Water Quality Standards. Amended as of April 8, 2012.
2 Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances. Amended through December 12, 2008. Most stringent criteria used. Criteria are expressed in terms of dissolved metal in the water column, except for aluminum and mercury, which are in terms of total recoverable metal.
2a Aquatic life for fresh water hardness-dependent criteria. A hardness of >400 mg/L was used for all calculations. For aluminum, if pH≥7.0 and hardness ≥50, then 750 µg/L.
2b Aquatic life for fresh water (chronic) criteria.
2c Aquatic life for fresh water (acute) criteria.
2d Drinking water primary maximum contaminant levels.
2e Irrigation water criteria.
2f Human health criteria for non-carcinogens (for consumption of water + aquatic organisms).
2g Aquatic life for fresh water (chronic) criteria based on pH and temperature when early life stages of fish are present. The ADEC numeric water quality standard for ammonia depends upon both the temperature and the pH of the matrix water, but not the hardness. Because the measured or predicted temperature and pH of the water may vary over a wide range of values depending on time of year, sample location, and other factors, the most conservative possible numeric standard for ammonia in freshwater (0.179 mg/L; ADEC 2008a) is used as a basis for comparison for all of the waters considered in this section.
3 Hatch 2015; Weglinski 2015a).

Source: SRK 2015a.

Along with the tailings pond water, two other types of water are likely to exist in the TSF during mine operations. One is pore water in contact with buried tailings. The other is surficial runoff of snowmelt and rainfall from the beach area. These are discussed in Appendix H, Geochemistry.

*TSF Seepage Recovery System*

A SRS is to be built at the downstream toe of the TSF that consists of a collection pond, groundwater monitoring and collection wells, and pumping system. It is designed to capture two sources of water: (1) potential seepage through the TSF liner and (2) surface water and groundwater that enters the rock underdrains (BGC 2011a). The SRS water may be treated at the WTP and discharged to Crooked Creek, when needed, for water management.

Due to the TSF liner, the seepage is expected to be minimal, ranging from about 1.4 gpm in Year 1 to about 17.6 gpm in Year 27 (BGC 2015f). Flows from surface water and groundwater are expected to vary seasonally, with higher flow rates in summer than in winter. Flows are expected to increase over the first few years and then taper off again slowly by the end of mine life. Summer flows are predicted to range between about 570 gpm (at end of mine life) to about 1,030 gpm (around Year 5); whereas winter flows are predicted to range between about 90 to 710 gpm.

SRS water chemistry (Table 3.7-34) is predicted to be neutral pH. Sulfate, ammonia, TDS, WAD cyanide, antimony, arsenic, iron, manganese, molybdenum, selenium, and mercury concentrations are expected to exceed AWQC (Hatch 2015).

*Pit Lake*

Inflow Sources and Gradient

In Year 22 of the mine life, the final limits of the pit would be reached. At this point, all PAG 6 and PAG 7 waste rock mined in the Lewis Pit would be placed as backfill into the ACMA Pit. Rock classified as NAG 1-4 and PAG 5 would also be backfilled into the ACMA Pit as it is mined from the Lewis Pit (SRK 2012e).

After closure, pit dewatering would stop and the pit would be allowed to fill with water from several sources (Lorax 2012a), including:

- Groundwater inflows;
- Highwall precipitation runoff;
- Direct precipitation on the surface of the pit lake;
- Excess tailings water in the impoundment at the end of operations;
- Tailings consolidation water and cover infiltration water;
- Tailings SRS water consisting of natural groundwater and a small component of tailings porewater;
- NAG seepage water from the WRF;
- PAG seepage water from the isolated cells of the WRF; and
- Undisturbed runoff from American Creek watershed and runoff from the WRF reclamation cover.

**Table 3.7-34: Predicted TSF Seepage Recovery System Water Quality**

| Parameter | Units | Most Stringent Applicable Water Quality Criterion | Seepage Recovery System | |
|---|---|---|---|---|
| | | | 50th Percentile | 95th Percentile |
| **Major Constituents** | | | | |
| pH | | 6.5-8.5[1] | 7.2 | 7.8 |
| Calcium | mg/L | -- | 122 | 128 |
| Magnesium | mg/L | -- | 110 | 112 |
| Potassium | mg/L | -- | 13.2 | 15.4 |
| Sodium | mg/L | -- | 121 | 122 |
| Chloride | mg/L | 230[2b] | 3.2 | 3.6 |
| Fluoride | mg/L | 1[2e] | 0.303 | 0.303 |
| Sulfate | mg/L | 250[1] | 471 | 474 |
| Ammonia | as N mg/L | 0.18[2g] | 3.1 | 3.2 |
| Total Dissolved Solids | mg/L | 500[1] | 905 | 919 |
| **Cyanide** | | | | |
| WAD Cyanide | µg/L | 5.2[2b] | 30 | 32 |
| **Metals** | | | | |
| Aluminum | µg/L | 87/750[2a,b] | 19 | 43 |
| Antimony | µg/L | 6[2d] | 120 | 120 |
| Arsenic | µg/L | 10[2d] | 1,610 | 1,610 |
| Barium | µg/L | 2,000[2d] | 60 | 90 |
| Beryllium | µg/L | 4[2d] | 0.4 | 2 |
| Boron | µg/L | 750[2e] | 85 | 110 |
| Cadmium | µg/L | 0.64[2a,b] | 0.3 | 0.52 |
| Chromium, total | µg/L | 100[2d] | 2 | 3 |
| Cobalt | µg/L | 50[2e] | 2.2 | 3.1 |

**Table 3.7-34: Predicted TSF Seepage Recovery System Water Quality**

| Parameter | Units | Most Stringent Applicable Water Quality Criterion | Seepage Recovery System | |
|---|---|---|---|---|
| | | | 50th Percentile | 95th Percentile |
| Copper | µg/L | 29[2a,b] | 2.4 | 2.8 |
| Iron | µg/L | 1,000[2b] | 10,600 | 10,700 |
| Lead | µg/L | 10.9[2a,b] | 0.4 | 0.5 |
| Lithium | µg/L | 2,500[2e] | 5 | 5 |
| Manganese | µg/L | 50[2f] | 230 | 270 |
| Molybdenum | µg/L | 10[2e] | 29 | 34 |
| Nickel | µg/L | 168[2a] | 7.5 | 8.4 |
| Selenium | µg/L | 4.6[2b] | 6.7 | 6.7 |
| Thallium | µg/L | 1.7[2f] | 0.5 | 0.1 |
| Vanadium | µg/L | 100[2e] | 5 | 20 |
| Zinc | µg/L | 379[2a,c] | 6 | 8 |
| Mercury | ng/L | 12[2b] | 1,070[3] | 1,080[3] |

**Notes:**

Values exceeding discharge criteria are highlighted.

1 18 AAC 70. ADEC, Alaska Water Quality Standards. Amended as of April 8, 2012, maximum drinking water levels.
2 Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances. Amended through December 12, 2008. Most stringent criteria used. Criteria are expressed in terms of dissolved metal in the water column, except for aluminum and mercury, which are in terms of total recoverable metal.
2a Aquatic life for fresh water hardness-dependent criteria. A hardness of 400 mg/L was used for all calculations based on modeled values for hardness. For aluminum, if pH≥7.0 and hardness ≥50, then 750 µg/L; otherwise, 87 µg/L.
2b Aquatic life for fresh water (chronic) criteria. Free cyanide measured as weak acid dissociable (WAD) cyanide.
2c Aquatic life for fresh water (acute) criteria.
2d Drinking water primary maximum contaminant levels.
2e Irrigation water criteria.
2f Human health criteria for non-carcinogens (for consumption of water + aquatic organisms).
2g Aquatic life for fresh water (chronic) criteria based on pH and temperature when early life stages of fish are present. The ADEC numeric water quality standard for ammonia depends upon both the temperature and the pH of the matrix water, but not the hardness. Because the measured or predicted temperature and pH of the water may vary over a wide range of values depending on time of year, sample location, and other factors, the most conservative possible numeric standard for ammonia in freshwater (0.179 mg/L; ADEC 2008a) is used as a basis for comparison for all of the waters considered in this section.
3 Mercury concentrations are after Year 18 during late winter with minimal SRS underdrain flow. The maximum WTP feed concentration considered for design 137 ng/L. Reference: Rieser 2015c.

Source: Hatch 2015.

According to the numerical hydrogeologic model developed by BGC (2011d, 2015g), for about 52 years after pit dewatering is stopped, water would flow into the pit from the groundwater at higher elevations and from the pit into the pore space of the waste rock placed as backfill and into the localized bedrock outside of and surrounding the pit from which bedrock water had been removed during mining. Once the pit lake reaches its maximum managed water level, flow out of the pit lake would cease and groundwater would move towards the pit (pit lake) from all directions. The managed final elevation of the pit lake is approximately 30 feet below the designed spillway overflow elevation of 359 feet AMSL (BGC 2015l). Additional description of the temporary localized flow reversal into bedrock as the pit fills is given in Section 3.6, Groundwater Hydrology. The pit outflow may result in an elevated input of sulfate and metals and decreased pH to the bedrock portion of the aquifer during the period that the pit lake is filling. Pit lake levels would be managed in post-closure to maintain an inward groundwater gradient to the pit at all times by pumping from the lake surface and treating it at the WTP for discharge to Crooked Creek (SRK 2012b, f; BGC 2014b, 2015g).

Treatment and discharge of pit lake surface water are predicted to begin approximately 53 years after closure, based on the most likely pit filling rate obtained in the BGC (2015g) hydrogeological model. Hydrogeologic sensitivity runs suggested that the timing of pit lake filling could be as little as 26 years, assuming a future wet climate due to climate change or a higher hydraulic conductivity, or as long as 63 years (BGC 2015i). The uncertainty in the pit filling rate is discussed in more detail in Section 3.6, Groundwater Hydrology.

Most WRF seepage would report to the WRF underdrain, and from there would flow by gravity to the pit rim. Pumping would be required to get TSF and SRS water to the pit rim, where it would be combined with the WRF seepage, then flow via a gravity-fed pipe to the bottom of the pit lake. Groundwater seepage through the pit walls could possibly contain a small fraction of WRF seepage that leaks below the WRF underdrain, but this is expected to be a very minor contribution to the pit lake in comparison to the piped flows and overall groundwater seepage from around the pit. The denser TSF/WRF water piped to the bottom of the pit lake would likely stay below the pycnocline. Groundwater seepage into the pit lake through the walls would likely be less dense than the TSF/WRF water. Section 3.6, Groundwater Hydrology, further describes the inflows and water balance in relation to the pit lake.

#### Pit Lake Modeling

PitMod, a one-dimensional (vertical) model, was developed and used by Lorax (2012a) to investigate the evolution of the post-closure pit lake. The model allowed assessment of the physics and geochemistry of the pit filling process. It provided justification for the assumption that the pit lake would stratify, and predicted the quality of the water that would be discharged from the lake for 100 years following closure (SRK 2012b). A number of sensitivity runs were conducted. The initial modeling and sensitivity runs were done under assumptions of an operations water management plan that allowed no discharge of process or seepage waters. When the AWT option was introduced as part of Alternative 2, a revised model was developed (Lorax 2015).

Detailed discussion of the model is given in Appendix H, Geochemistry (Section 4.4.2, Pit Lake Modeling). It includes discussion of general physical and chemical lake processes, as well as the predicted chemistries of all input waters to the lake.

*Results of Sensitivity Analyses*. Several sensitivity runs were conducted, as shown in Table 3.7-35. They are discussed in some detail in Appendix H, Geochemistry. The results of the sensitivity analyses suggest that the pit lake would develop a density stratification with poor quality, highly saline bottom waters overlain by low TDS (112 to 142 mg/L) surface water under all likely scenarios (Table 3.7-35). For the decreased salinity case, the TDS decreased somewhat from the base case, although the metals and sulfate concentrations remained essentially unchanged. In the base case, as well as the extreme winds and decreased salinity sensitivity cases, aluminum, antimony, arsenic, cadmium, lead, manganese, selenium, and mercury concentrations exceeded AWQC.

One sensitivity run forced the lake to mix completely in Year 55 (Table 3.7-35). In that year, the TDS was calculated to be 2,350 mg/L throughout the water column. By Year 99, stratification had re-established, and the surface water TDS had decreased to 918 mg/L. In this case, even in Year 99, all constituents of interest exceed AWQC, showing the importance to treatment costs of maintaining a permanently stratified pit lake, because this result would likely require reverse osmosis or other comparable water treatment technology to treat the sulfate and TDS.

**Table 3.7-35: Surface Water Quality Estimates for Pit Lake at Closure Year 99 – Sensitivity Analysis (assuming Exhausted PAG Pit-Wall Runoff and No-Discharge Water Management)**

| Parameter | Units | Most Stringent Applicable Water Quality Criterion | Base Case | Groundwater Sensitivity | Complete Mixing[3] | Extreme Winds Sensitivity[4] | Decreased Salinity Sensitivity |
|---|---|---|---|---|---|---|---|
| Sulfate | mg/L | 250[1] | 31 | 48 | 658 | 31 | 30 |
| Total Dissolved Solids | mg/L | 500[1] | 135 | 142 | 918 | 137 | 112 |
| Aluminum | µg/L | 87[2a,b] | 310 | 311 | 12,700 | 316 | 311 |
| Antimony | µg/L | 6[2d] | 67 | 120 | 216 | 68 | 67 |
| Arsenic | µg/L | 10[2d] | 112 | 198 | 1,060 | 116 | 112 |
| Boron | µg/L | 750[2e] | 202 | 356 | 880 | 205 | 199 |
| Cadmium | µg/L | 0.18[a,b] | 0.24 | 0.33 | 0.4 | 0.24 | 0.24 |
| Chromium | µg/L | 100[2d] | 4 | 6.7 | 7.5 | 4 | 4 |
| Copper | µg/L | 6.2[2a,b] | 1.4 | 1.7 | 32 | 1.4 | 1.4 |
| Lead | µg/L | 1.6[2a,b] | 2.3 | 3.8 | 38 | 2.3 | 2.2 |
| Manganese | µg/L | 50[2f] | 128 | 136 | 2,350 | 131 | 128 |
| Nickel | µg/L | 36[2a,b] | 11 | 19 | 70 | 12 | 11 |
| Selenium | µg/L | 4.6[2b] | 20 | 36 | 70 | 21 | 20 |
| Zinc | µg/L | 81[2a,c] | 13 | 21 | 304 | 14 | 13 |

**Table 3.7-35: Surface Water Quality Estimates for Pit Lake at Closure Year 99 – Sensitivity Analysis (assuming Exhausted PAG Pit-Wall Runoff and No-Discharge Water Management)**

| Parameter | Units | Most Stringent Applicable Water Quality Criterion | Base Case | Groundwater Sensitivity | Complete Mixing[3] | Extreme Winds Sensitivity[4] | Decreased Salinity Sensitivity |
|---|---|---|---|---|---|---|---|
| Mercury | ng/L | 12[2b] | 25 | 42 | 100 | 25 | 26 |

**Notes:**

Values are for dissolved metals, and represent depths between 0 and 33 feet in lake. Shaded cells exceed most stringent water quality standard. The pH was not modeled, but estimated to be between 5 and 6, based on input pH values.

1 18 AAC 70. ADEC, Alaska Water Quality Standards. Amended as of April 8, 2012, maximum drinking water levels.
2 Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances. Amended through December 12, 2008. Most stringent criteria used. Criteria are expressed in terms of dissolved metal in the water column, except for aluminum and mercury, which are in terms of total recoverable metal.
2a Aquatic life for fresh water hardness-dependent criteria. A value of 65 mg/L as $CaCO_3$ was used for hardness, based on model predictions for calcium and magnesium (not shown). For aluminum, if pH≥7.0 and hardness ≥50, then 750 µg/L, otherwise, 87 µg/L.
2b Aquatic life for fresh water (chronic) criteria.
2c Aquatic life for fresh water (acute) criteria.
2d Drinking water primary maximum contaminant levels.
2e Irrigation water criteria.
2f Human health criteria for non-carcinogens (for consumption of water + aquatic organisms).
3 Represents Year 56 (complete mixing induced in Year 55).
4 Represents Year 56 (hurricane winds induced in Years 55 and 56).

Source: Lorax 2012a (Table 4-2).

The base case and sensitivity runs used exhausted PAG runoff concentrations for PAG wall rock. However, pit walls are known to undergo periodic sloughing events that expose fresh rock to weathering processes (e.g., Filipek 2004). Accordingly, the PAG runoff is more likely to have concentrations over time that range between those used in the model and those given for peak oxidation rates. (See Appendix H, Geochemistry, Table 11.) To test the effects of using peak PAG concentrations for runoff, Lorax conducted two additional peak-PAG model runs for their decreased salinity case: (1) a conservative case, in which no reactions were allowed but PHREEQC was used to calculate pH of the mixed solutions; and (2) a reactive case allowing precipitation of low-temperature saturated aluminum, iron, and manganese oxyhydroxide minerals (Table 3.7-36).

In both peak PAG, decreased salinity cases, the results were similar to the base case (within a factor of two for most constituents). Lake surface-water concentrations of aluminum, antimony, arsenic, cadmium, lead, molybdenum, selenium, and mercury exceeded AWQC in all three cases. Copper exceeded AWQC in both peak PAG cases, but not in the base case. Manganese concentrations exceeded AWQC when not allowed to precipitate. The predicted pH in both peak-PAG cases was predicted to be outside regulatory limits: The modeled pH was 5.2 for the no-reaction peak PAG case, and 5.1 with mineral precipitation.

The base case and sensitivity runs also used predicted inflow water quality based on a no-discharge water management plan. When the AWT water management option was added to Alternative 2, Lorax (2015) developed another pit lake model using the revised water quality

values from Table H-11 in Appendix H (Geochemistry) for the major inflow sources. Table 3.7-37 shows a comparison of the chemistries used under the AWT assumption and the assumption of the initial no-discharge water management plan (labeled "base case") for sources whose predicted chemistries changed under the different assumptions.

The resulting predicted water quality for the uppermost 33 feet of the pit lake, shown in Table 3.7-36, is similar to those predicted for the original water management plan. Aluminum, antimony, arsenic, cadmium, copper, iron, lead, manganese, molybdenum, selenium, and mercury concentrations exceeded AWQC. Although not modeled, pH was estimated to be between 5.0 and 6.0, less than the lower AWQC limit.

**Table 3.7-36: Surface Water Quality Estimates for Pit Lake at Closure Year 99 – Comparison of Exhausted-PAG (Base Case), Peak-PAG Pit-Wall Runoff (Decreased Salinity Case), and AWT Model**

| Parameter[1] | Units | Most Stringent Applicable Water Quality Criterion | Base Case | Peak-PAG Case | | AWT |
|---|---|---|---|---|---|---|
| | | | No Reaction[2] | No Reaction[3] | Mineral Precipitation[4] | No Reaction[5] |
| pH | Units | 6.5 – 8.5[1] | 6 (est.) | 5.2 | 5.1 | 5.0 – 6.0 |
| Sulfate | mg/L | 250[1] | 31 | 48 | 48 | 41 |
| Total Dissolved Solids | mg/L | 500[1] | 139 | 143 | 97 | 125 |
| Aluminum | µg/L | 87[2a,b] | 310 | 590 | 97 | 1,530 |
| Antimony | µg/L | 6[2d] | 67 | 75 | 76 | 67 |
| Arsenic | µg/L | 10[2d] | 112 | 190 | 190 | 114 |
| Boron | µg/L | 750[2e] | 200 | 230 | 200 | 31 |
| Cadmium | µg/L | 0.18[2a,b] | 0.24 | 0.31 | 0.31 | 0.35 |
| Chromium | µg/L | 100[2d] | 4.0 | 4.3 | 4.3 | 4.6 |
| Cobalt | µg/L | 50[2e] | 3.0 | 5 | 5 | 6.5 |
| Copper | µg/L | 6.2[2a,b] | 1.4 | 7.1 | 6.7 | 10 |
| Iron | µg/L | 1000[2b] | 830 | 960 | 180 | 1,200 |
| Lead | µg/L | 1.6[2a,b] | 2.3 | 2.7 | 2.7 | 2.6 |
| Manganese | µg/L | 50[2f] | 128 | 170 | 15 | 176 |
| Molybdenum | µg/L | 10[2e] | 17 | 19 | 18 | 17 |
| Nickel | µg/L | 36[2a,b] | 11 | 20 | 20 | 19 |
| Selenium | µg/L | 4.6[2b] | 20 | 23 | 23 | 20 |
| Zinc | µg/L | 81[2a,c] | 13 | 45 | 47 | 53 |

**Table 3.7-36: Surface Water Quality Estimates for Pit Lake at Closure Year 99 – Comparison of Exhausted-PAG (Base Case), Peak-PAG Pit-Wall Runoff (Decreased Salinity Case), and AWT Model**

| Parameter[1] | Units | Most Stringent Applicable Water Quality Criterion | Base Case | Peak-PAG Case | | AWT |
|---|---|---|---|---|---|---|
| | | | No Reaction[2] | No Reaction[3] | Mineral Precipitation[4] | No Reaction[5] |
| Mercury | ng/L | 12[2b] | 25 | 28 | 28 | 25 |

**Notes:**

Values are for dissolved metals, and represent depths between 0 and 33 feet in lake. Shaded cells exceed most stringent water quality standard.

1 18 AAC 70. ADEC, Alaska Water Quality Standards. Amended as of April 8, 2012.

2 Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances. Amended through December 12, 2008. Most stringent criteria used. Criteria are expressed in terms of dissolved metal in the water column, except for aluminum and mercury, which are in terms of total recoverable metal.

2a Aquatic life for fresh water hardness-dependent criteria. A hardness of 65 mg/L as $CaCO_3$ was used for hardness, based on model predictions for hardness. For aluminum, if pH≥7.0 and hardness ≥50, then 750 µg/L, otherwise, 87 µg/L.

2b Aquatic life for fresh water (chronic) criteria.

2c Aquatic life for fresh water (acute) criteria.

2d Drinking water primary maximum contaminant levels.

2e Irrigation water criteria.

2f Human health criteria for non-carcinogens (for consumption of water + aquatic organisms).

3 Lorax. 2014b

4 Lorax. 2014c; Aluminum, iron, and manganese low-temperature oxyhydroxide minerals were allowed to precipitate if saturated.

5 Lorax 2015

**Table 3.7-37: Water Quality of Major Inflows to Pit at Closure, Comparison of AWT and Base Case Inputs**

| Parameter | Units | Most Stringent Applicable Water Quality Criterion | PAG Cell Seepage | | Initial Pit Lake Water | | Tailings Pore-water Seepage | |
|---|---|---|---|---|---|---|---|---|
| | | | AWT[3] | Base Case[4] | AWT[5] | Base Case[6] | AWT[7] | Base Case[8] |
| pH | Units | 6.5-8.5[1] | 3.5 | 4.1 | 7.7 | 7.7 | 7.7 | 5.5 |
| Sulfate | mg/L | 250[1] | 180,000 | 42,450 | 3,811 | 10,537 | 4,400 | 15,900 |
| Total Dissolved Solids (est.) | mg/L | 500[1] | 210,000 | 160,000 | 5,500 | 14,000 | 8,300 | 23,000 |
| Aluminum | µg/L | 87/750[2a,b] | 30,000,000 | 30,470,000 | 221 | 18.14 | 5.6 | 1.9 |
| Antimony | µg/L | 6[2d] | 2,800 | 2,800 | 1,630 | 920 | 1,100 | 1,160 |
| Arsenic | µg/L | 10[2d] | 27,000 | 27,000 | 12,600 | 6,600 | 15,000 | 15,700 |
| Cadmium | µg/L | 0.64[2a,b] | 65 | 65 | 1 | 0.7 | 7.3 | 0.93 |
| Copper | µg/L | 29[2a,b] | 33,000 | 35,600 | 22 | 310 | 18 | 674 |
| Chromium | µg/L | 100[2d] | 130 | 130 | 22 | 11 | 12 | 7.23 |
| Lead | µg/L | 10.9[2a,b] | 460 | 99 | 680 | 350 | 3 | 82.5 |
| Manganese | µg/L | 50[2f] | 170,000 | 370,300 | 5,600 | 43,200 | 2,000 | 45,600 |
| Selenium | µg/L | 4.6[2b] | 80,000 | 18,790 | 470 | 330 | 42 | 220 |
| Zinc | µg/L | 379[2a,c] | 190,000 | 3,991,000 | 4,000 | 2,100 | 33 | 79 |
| Mercury | ng/L | 12[2b] | 180 | 150 | 34,900 | 720 | 73,000 | 1,440 |

**Notes:**

Shaded cells exceed most stringent water quality standard.

1 18 AAC 70. ADEC, Alaska Water Quality Standards. Amended as of April 8, 2012, maximum drinking water levels.

2 Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances. Amended through December 12, 2008. Most stringent criteria used. Criteria are expressed in terms of dissolved metal in the water column, except for aluminum and mercury, which are in terms of total recoverable metal.

2a Aquatic life for fresh water hardness-dependent criteria. A hardness of >400 mg/L was used for all calculations based on modeled values for hardness. For aluminum, if pH≥7.0 and hardness ≥50, then 750 µg/L, otherwise, 87 µg/L.

2b Aquatic life for fresh water (chronic) criteria.

2c Aquatic life for fresh water (acute) criteria.

2d Drinking water primary maximum contaminant levels.

2e Irrigation water criteria.

2f Human health criteria for non-carcinogens (for consumption of water + aquatic organisms).

3 75th Percentile chemistry for poorly mixed PAG at year 2050 based on scaling of humidity cell leachate data (SRK 2015c).

4 75th Percentile chemistry for poorly mixed PAG at year 2050 based on scaling of humidity cell leachate data (SRK 2012h).

5 Conservative mixture of 8,920 acre-feet of backfill runoff and 24,000 acre-feet of tailings supernatant water (Lorax 2015).

6 Conservative mixture of 8,920 acre-feet of backfill runoff and 24,000 acre-feet of tailings supernatant water (Lorax 2012a).

7 Predicted concentrations of tailings pore water (SRK 2015a).

8 Predicted concentrations of tailings pore water (Lorax 2012a).

*Temporal Changes in Surface-Water Quality and Pycnocline Depth*. In all modeled cases, pit lake surface-water concentrations appeared to reach steady state soon after the lake reached its maximum allowed elevation, so that the results for all but the Complete Mixing case for Year 53 are essentially identical to those shown in Table 3.7-35 for Year 99. In contrast, in all cases, the depth of the top of the pycnocline was found to decrease over time (Figure 3.7-21). As the

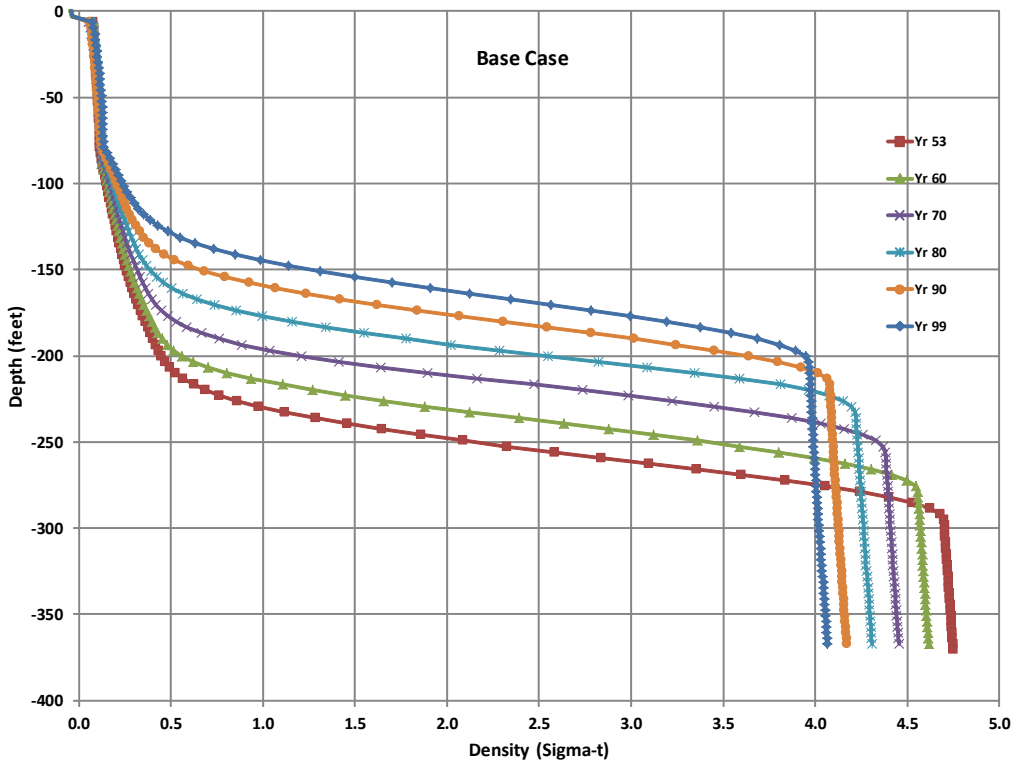
pycnocline depth decreased, so did the concentration difference above and below the pycnocline.

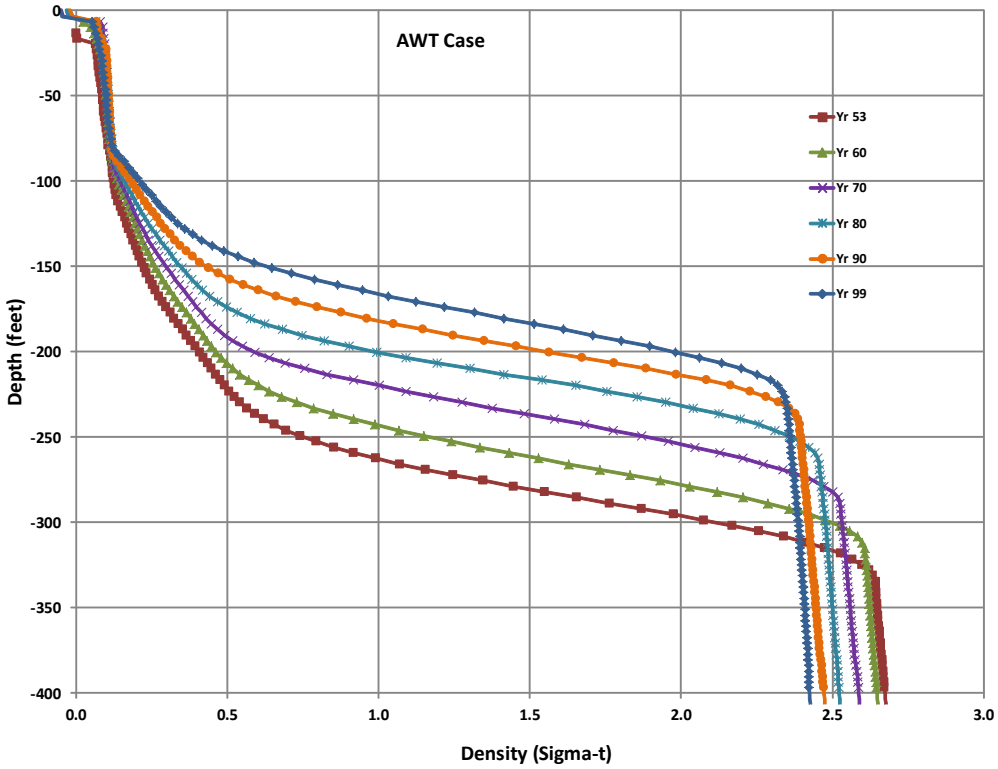
For the three cases given in Table 3.7-36 (the base case; the peak-PAG, decreased salinity case; and the AWT case), the top of the pycnocline was at essentially the same depth in Year 99 after closure (Figure 3.7-23). However, as evidenced by the relative slopes of the pycnocline the strength of the pycnocline varied among the three cases and suggests that the decreased-salinity and AWT systems could be more vulnerable to overturn and mixing than the base case.

The modeled pycnocline moved up through the water column with time in all cases likely because each year additional water was fed through the pipe to the lake bottom and because of ongoing groundwater influx below the pycnocline, increasing the volume of water in the hypolimnion (i.e., below the pycnocline), while water was being removed and treated from above the pycnocline. Therefore, it would be expected that eventually the pycnocline would be close enough to the surface that wind and/or winter overturn would cause water below the pycnocline to mix with the surface water. Based on the complete mixing sensitivity run, after the lake overturns, the pit lake would likely eventually re-establish a pycnocline, but with higher constituent concentrations in the surficial layer, as occurred for the complete mixing case. The actual concentrations at the surface for the AWT case would likely be lower than for the complete mixing case due to the lower concentrations in the hypolimnion for the AWT case than the base case (Figure 3.7-22).

*Summary of Mine Site Geochemical Impacts*

The water quality of drainages from the WRF and the isolated PAG cells, TSF, and SRS is predicted in all cases to exceed AWQC for several constituents, potentially for many tens of decades. The Lower and Upper CWD are also predicted to exceed AWQC for several constituents during operations. Drainage from the SOB may also exceed AWQC during operations. These drainages would be collected and stored in the Lower and Upper CWD for use in process water or for treatment and discharge to Crooked Creek, as needed for water management. In the post-closure period, these drainages would be pumped to deeper layers of the pit lake, where they would be isolated from the surface for more than 100 years. Water from the pit lake would flow into backfill material and also into the surrounding bedrock void space adjacent to the pit during the period that the pit lake is filling towards its peak managed level. After the pit lake fills, groundwater (including the contact water from the pit lake) would flow back into the pit lake from all directions and at all times as long as the managed pit lake level remains below its designed level.




Data Source: Lorax 2015

Note:
Scale change for Density

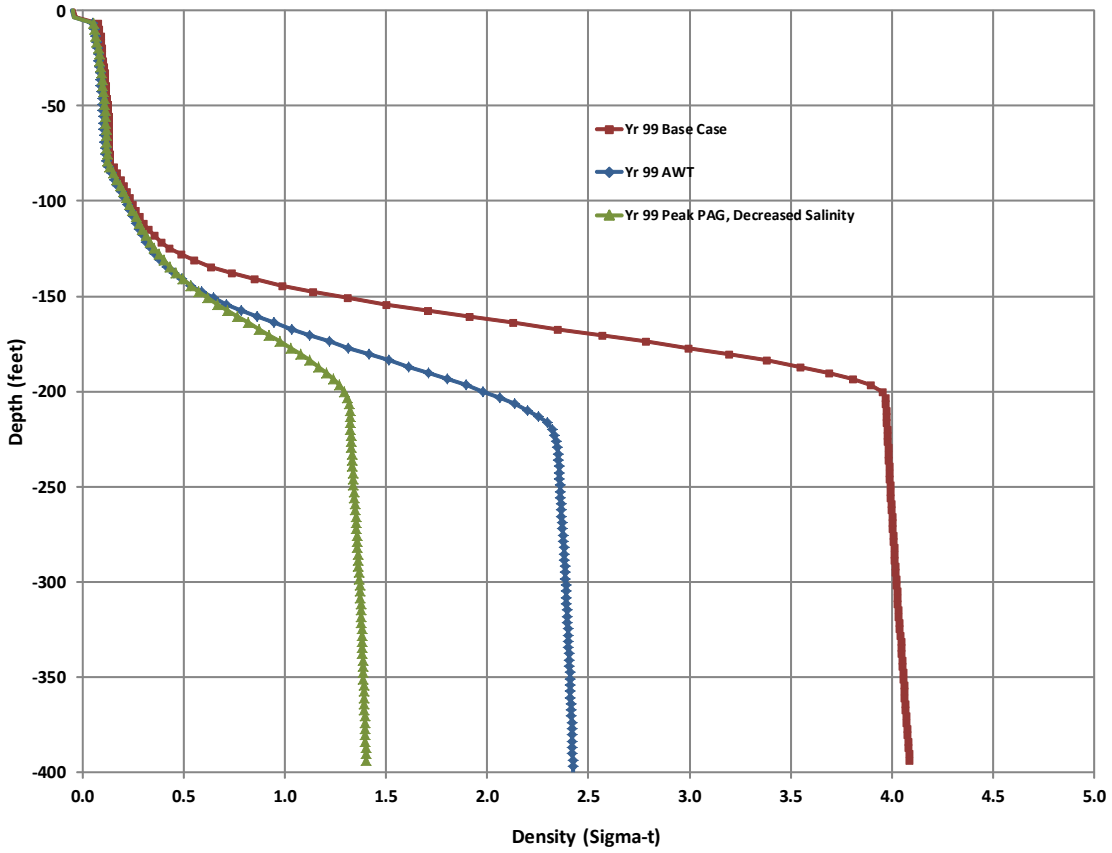
DONLIN GOLD

*DONLIN GOLD PROJECT EIS*

VARIATION OF PYCNOCLINE DEPTH WITH AGE OF PIT LAKE (55 TO 99 YEARS) BASE CASE AND AWT WATER MANAGEMENT PLAN CASE

NOVEMBER 2015

FIGURE 3.7-22




Data Source: Lorax 2015

DONLIN GOLD PROJECT EIS

COMPARISON OF PYCNOCLINE DEPTH AND STRENGTH FOR THE BASE CASE, PEAK-PAG, DECREASED SALINITY CASE, AND AWT CASE (YEAR 99)

NOVEMBER 2015 FIGURE 3.7-23

The surficial pit lake water is also expected to exceed AWQC for several constituents. Once the pit lake reaches its maximum allowable elevation at or about Year 52 post-closure, the surficial water would be treated to meet AWQC and then discharged. The results of the various modeling efforts of the predicted pit lake suggest that (1) the concentrations of several constituents in surface waters would exceed the most stringent AWQC throughout the 100-year modeling period and (2) the pycnocline is predicted to move upward toward the surface and become less intense over time, eventually reaching the surface and allowing complete mixing at some point beyond the modeling period. For these reasons, additional monitoring and adaptive management measures that would help maintain lake stratification as long as possible, manage surface water quality, and assure appropriate water treatment during post-closure are provided in Chapter 5, Impact Avoidance, Minimization, and Mitigation.

Transportation Facilities

The geochemistry of rocks disturbed by mining would not impact water quality in the transportation facilities areas. Potential water quality impacts from rocks disturbed at material sites along the mine access road are described below in Section 3.7.3.2.2.

Natural Gas Pipeline

The geochemistry of rocks disturbed by mining would not impact water quality in the pipeline corridor. Potential water quality impacts from rocks disturbed at material sites along the pipeline are described below in Section 3.7.3.2.2.

#### 3.7.3.2.2 SURFACE WATER QUALITY

The primary source of water quality issues for the Donlin Gold Project are related to rock geochemical processes described in the previous section and Appendix H, Geochemistry. The sections below address additional water quality and saturated sediment quality effects related to the mine site, transportation facilities, and pipeline components of the project.

Mine Site

Water will be produced by pit dewatering wells during both construction and operations. Additionally, under average precipitation conditions, the mine is expected to operate with a water surplus. Based on the geochemistry of the rocks and water at the site, some of this water is expected to exceed Alaska water quality standards. Accordingly, an APDES permit application will be made to treat and discharge excess water to Crooked Creek. Water would be treated using an advanced water treatment (AWT) process developed by Hatch (2015) to meet applicable water quality-based permit limitations associated with the discharge from the following sources:

- Pit dewatering – Groundwater collected in the pit perimeter and in-pit dewatering wells.
- TSF SRS – Water collected from the TSF underdrains at the SRS pond, which includes groundwater flows originating upslope of the areas covered by the TSF liner and a volume of seepage that may leak from the TSF liner (determined using EPA developed assumptions for potential seepage through synthetic liners).
- CWD – Water collected from the Upper and Lower CWDs. Sources of water in the CWDs include open pit drainage (direct precipitation falling on the pit walls and flows

from horizontal pit drains); seepage and runoff from the WRF; seepage and runoff from the SOB; and undiverted runoff from undisturbed areas in the American Creek drainage. This water is predicted to have variable and increasing concentrations over time, with high concentrations of selenium, arsenic, and several metals (Table 3.7-31 and Table 3.7-32).

- TSF Pond Water – Excess precipitation and tailings consolidation water collected in the TSF pond would be treated and discharged as provided in the NPDES New Source Performance Standards for gold mining operations (40 CFR 440.104).

The amounts of these waters that could be treated and discharged were developed based on the site-wide water balance model that considers hydrology, quantities of water produced, and quantities of water required for process plant operations (BGC 2015f).

The intent is to maximize the total amount of water that can be treated and discharged from the project in order to minimize the amount of water that must be stored and managed during operations and at closure, while still supplying water required by the processing facility. This would enable operational flexibility with regard to the mine site's water balance and could potentially prevent problems associated with accumulation of too much water within the mine facilities during periods of heavy precipitation.

*Water Treatment Methods*. The SRS water, in-pit runoff, water from the upper CWD (assumed to be a mixture of pumped water from the lower CWD water and runoff), and TSF pond water that would be discharged are predicted to contain concentrations of some metals and TDS that would be elevated (Table 3.7-38) relative to typical most stringent AWQC (Table 3.7-39). Consequently, additional water treatment measures to actively manage metals and TDS in the water would be required in order to produce effluent that would conform to the water quality-based effluent limitations of an APDES permit (assumed to be AWQC for purposes of this discussion).

Several methods were investigated by Hatch (2015). A conceptual water treatment process was selected based on predicted water chemistries at the mine site and preliminary design work. In this process, the wastewater coming from the four individual water sources (pit dewatering, SRS, Lower and Upper CWD, and TSF pond water) would be collected and blended in a WTP feed tank. This combined water would then be initially treated with iron co-precipitation/adsorption using a high rate clarifier (HRC), followed by a manganese greensand filter and ultrafiltration. When necessary, the treatment would include reverse osmosis (RO) as the final polishing step (Hatch 2015). If required in later years, an ion exchange step would be included to reduce selenium concentrations. The predicted treated water quality is given in Table 3.7-39, along with AWQC and baseline water quality for Category 2 sites, which represent the background water quality in waters draining areas of defined mineralized zones with no placer mining activities. The proposed treatment process is also applicable for the treatment of any of the water sources individually. However, polishing treatment using an ion exchange resin may be needed after an initial operations period to treat increasing concentrations of selenium (in the Upper CWD) and mercury (in the TSF) over the mine life (Hatch 2015).

**Table 3.7-38: Estimated WTP Influent Water Quality**

| | | Wells | | SRS | | Upper CWD | | TSF | WTP Blended Feed | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Unit** | **50th Percentile** | **95th Percentile** | **50th Percentile** | **95th Percentile** | **50th Percentile** | **95th Percentile** | **Steady State** | **50th Percentile** | **95th Percentile** |
| Aluminum | mg/L | 0.081 | 2.67 | 0.019 | 0.043 | 0.078 | 0.121 | 0.013 | 0.061 | 1.309 |
| Ammonia | mg/L | 0.315 | 1.1 | 3.1 | 3.2 | 0.541 | 0.551 | 29 | 2.341 | 2.741 |
| Antimony | mg/L | <0.0005 | <0.001 | 0.12 | 0.12 | 0.423 | 0.483 | 0.022 | 0.135 | 0.149 |
| Arsenic | mg/L | 0.1 | 2.13 | 1.61 | 1.61 | 2.444 | 2.871 | 3.3 | 1.164 | 2.228 |
| Barium | mg/L | 0.151 | 1.45 | 0.06 | 0.09 | 0.122 | 0.176 | 0.011 | 0.115 | 0.753 |
| Beryllium | mg/L | <0.0004 | <0.0004 | 0.0004 | 0.002 | 0.00048 | 0.00053 | <0.00006 | 0.00022 | 0.00063 |
| Boron | mg/L | 0.03 | 0.19 | 0.085 | 0.11 | 0.110 | 0.114 | 0.594 | 0.073 | 0.081 |
| Cadmium | mg/L | <0.00025 | <0.0005 | 0.0003 | 0.0052 | 0.0008 | 0.0008 | 0.00073 | 0.00041 | 0.00059 |
| Calcium | mg/L | 33.35 | 62.79 | 122 | 128 | 111 | 123 | 610 | 116.6 | 135.0 |
| Chloride | mg/L | 1.21 | 3.4 | 3.2 | 3.6 | 1.0 | 1.3 | 26 | 2.7 | 3.9 |
| Chromium, total | mg/L | <0.001 | 0.0043 | 0.002 | 0.003 | 0.013 | 0.014 | 0.012 | 0.005 | 0.005 |
| Cobalt | mg/L | <0.002 | <0.004 | 0.0022 | 0.0031 | 0.032 | 0.032 | 0.019 | 0.010 | 0.011 |
| Copper | mg/L | 0.0015 | 0.0098 | 0.0024 | 0.0028 | 0.005 | 0.005 | 0.018 | 0.003 | 0.007 |
| Fluoride | mg/L | 0.4 | 0.52 | 0.303 | 0.303 | 0.153 | 0.159 | 2 | 0.390 | 0.449 |
| Iron | mg/L | 1.76 | 5.5 | 10.6 | 10.7 | 0.30 | 0.47 | 0.0044 | 3.6 | 5.4 |
| Lead | mg/L | <0.0001 | <0.0027 | 0.0004 | 0.0005 | 0.0424 | 0.0485 | 0.003 | 0.0102 | 0.0128 |
| Lithium | mg/L | 0.011 | 0.014 | 0.005 | 0.005 | 0.062 | 0.072 | <0.006 | 0.030 | 0.034 |
| Magnesium | mg/L | 10.35 | 26.33 | 110 | 112 | 14.4 | 18.1 | 1,734 | 11.32 | 122.1 |
| Manganese | mg/L | 0.22 | 1.41 | 0.23 | 0.27 | 0.95 | 1.26 | 2 | 0.5 | 1.1 |
| Mercury[1] | mg/L | 0.0000022 | 0.000014 | 0.00107 | 0.00108 | 0.000099 | 0.000108 | 0.010 | 0.00074 | 0.0075 |
| Molybdenum | mg/L | <0.005 | <0.01 | 0.029 | 0.034 | 0.101 | 0.123 | 0.23 | 0.044 | 0.052 |
| Nickel | mg/L | <0.001 | 0.005 | 0.0075 | 0.0084 | 0.187 | 0.189 | 0.062 | 0.049 | 0.051 |

**Table 3.7-38: Estimated WTP Influent Water Quality**

| | | Wells | | SRS | | Upper CWD | | TSF | WTP Blended Feed | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Unit** | **50th Percentile** | **95th Percentile** | **50th Percentile** | **95th Percentile** | **50th Percentile** | **95th Percentile** | **Steady State** | **50th Percentile** | **95th Percentile** |
| pH | -- | 7.34 | 8.8 | 7.2 | 7.8 | 7.93 | 8.06 | 7.7 | 7.46 | 8.33 |
| Potassium | mg/L | 1.1 | 3.93 | 13.2 | 15.4 | 13.0 | 16.7 | 120 | 12.2 | 14.9 |
| Selenium | mg/L | <0.0025 | <0.005 | 0.0067 | 0.0067 | 0.125 | 0.136 | 0.042 | 0.034 | 0.038 |
| Silica | mg/L | 5.49 | 10.58 | N/A | N/A | 16.0 | 16.9 | 7 | 7.89 | 10.52 |
| Sodium | mg/L | 38.6 | 132.2 | 120.7 | 122.1 | 12.3 | 21.7 | 1,100 | 100.3 | 147.3 |
| Strontium | mg/L | 0.35 | 1.01 | n/a | n/a | 1.65 | 2.05 | 7.9 | 1.08 | 1.48 |
| Sulphate | mg/L | 9.1 | 81.9 | 471 | 474 | 279 | 333 | 8,612 | 572 | 620 |
| TDS | mg/L | 178 | 545 | 905 | 919 | 519 | 614 | 11,550 | 966 | 1,166 |
| Thallium | mg/L | <0.0005 | <0.0005 | 0.0005 | 0.001 | 0.001 | 0.001 | 0.00041 | 0.0006 | 0.0007 |
| TSS | mg/L | 6.29 | 61.8 | N/A | N/A | N/A | N/A | 21 | 3.9 | 30.3 |
| Vanadium | mg/L | <0.01 | <0.02 | 0.005 | 0.02 | 0.013 | 0.018 | 0.0048 | 0.0092 | 0.0188 |
| WAD Cyanide[2] | mg/L | <0.0025 | <0.0025 | 0.016 | 0.018 | 0.005 | 0.005 | 0.13 | 0.015 | 0.017 |
| WAD Cyanide[3] | mg/L | <0.0025 | <0.0025 | 0.030 | 0.032 | 0.005 | 0.005 | 0.26 | 0.021 | 0.023 |
| Zinc | mg/L | <0.0025 | 0.03 | 0.006 | 0.008 | 0.267 | 0.281 | 0.033 | 0.066 | 0.083 |

**Notes:**

1 Mercury concentrations are after Year 18 during late winter with minimal SRS underdrain flow. The maximum WTP feed concentration considered for design is 0.000288 mg/L.
2 Summer values. 50% natural degradation assumed in the TSF.
3 Winter values. Assumes no natural degradation in the TSF.

Highlighted parameters exceed the most stringent water quality objectives.
N/A = Not Available

Source: Hatch 2015, Table 4-3.

**Table 3.7-39: Predicted Treated Water Quality**

| Parameter | Units | Treated Water | Baseline Category 2 (averages[3]) | Most Stringent Applicable Water Quality Criterion |
|---|---|---|---|---|
| Aluminum | µg/L | < 6 | 288 | 87[2ab] |
| Ammonia | mg/L | 0.6 | 0.062 | 0.18[2h] |
| Antimony | µg/L | <4 | 0.57 | 6[2d] |
| Arsenic | µg/L | <4 | 7.21 | 10[2d] |
| Barium | µg/L | <20 | 60.9 | 2,000[2d] |
| Boron | µg/L | <40 | 18.4 | 750[2e] |
| Cadmium | µg/L | 0.036 | 0.28 | 0.25[2a] |
| Chloride | mg/L | <0.120 | 1.66 | 230[2b] |
| Chromium, total | µg/L | <0.5 | 1.13 | 100[2d] |
| Cobalt | µg/L | <0. 3 | 2.01 | 50[2e] |
| Iron | µg/L | <5 | 662 | 1,000[2b] |
| Lead | µg/L | 0.4 | 0.28 | 2.79[2a] |
| Manganese | µg/L | <2 | 107 | 50[2f] |
| Mercury[4] | ng/L | 11 | 5.77 | 12[2b] |
| Molybdenum | µg/L | <5 | 4.76 | 10[2e] |
| pH | units | 7-8 | 7.23 | 6.5-8.5 |
| Selenium | µg/L | <4 | 2.48 | 5[2b] |
| Sulfate | mg/L | <22 | 21.5 | 250[1] |
| TDS | mg/L | <38 | 142 | 500[1] |
| WAD Cyanide[5] | µg/L | <4.5 | 2.45 | 5.2[2g] |
| Zinc | µg/L | <3 | 4.29 | 109.8[2a] |

**Notes:**

1 18 AAC 70. ADEC, Alaska Water Quality Standards. Amended as of April 8, 2012, maximum drinking water levels.

2 Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances. Amended through December 12, 2008. Most stringent criteria used. Criteria are expressed in terms of dissolved metal in the water column.

2a Aquatic life for fresh water hardness-dependent criteria. Acute and chronic aquatic life numeric criteria for some metals (Cd, Cr, Cu, Pb, Ni, Zn) are hardness dependent. Values contained in this table were calculated using a hardness value of 90.18 mg/L as $CaCO_3$. For Al, if pH≥7.0 and hardness ≥50, then 750 µg/L.

2b Aquatic life for fresh water (chronic) criteria.

2c Aquatic life for fresh water (acute) criteria.

2d Drinking water primary maximum contaminant levels.

2e Irrigation water criteria.

2f Human health criteria for non-carcinogens (for consumption of water + aquatic organisms).

2g Aquatic life criteria (chronic)for free cyanide, measured as weak acid dissociable (WAD) cyanide.

2h Aquatic life for fresh water (chronic) criteria based on pH and temperature when early life stages of fish are present. The ADEC numeric water quality standard for ammonia depends upon both the temperature and the pH of the matrix water, but not the hardness. Because the measured or predicted temperature and pH of the water may vary over a wide range of values depending on time of year, sample location, and other factors, the most conservative possible numeric standard for ammonia in freshwater (0.179 mg/L; ADEC 2008a) is used as a basis for comparison for all of the waters considered in this section.

3 Calculated for all observations using detected values and ½ of the reporting limit value when analyte not detected.

4 Mercury removal performance is based on 30 $m^3$/h TSF flow, 5 ppb mercury in the TSF, 1.3% TSF seepage contribution to SRS flow, and 96% reverse osmosis (RO) removal.

5 WAD cyanide removal performance is based on 30 30 $m^3$/h TSF flow, 0.26 mg/L cyanide in the TSF and 80% RO removal.

Source: Hatch 2015, Table 4-10.

In the iron-coprecipitation/adsorption treatment method, ferric sulfate ($Fe_2(SO_4)_3$, would be added to the water to be treated in order to capture anionic forms of antimony, arsenic, molybdenum, and selenium. The efficiency of treatment is pH dependent. The optimal pH for most species is in the range of 4 to 6, so sulfuric acid would be added as needed. Removal of a particular element is also dependent on its oxidation state. Selenium is only removed if it is in the selenite state (Se IV). Selenate (Se VI) is not readily adsorbed by the iron, so is not removed in this process. Arsenic is better removed as arsenate (As V) than as arsenite (As III). Thus, an oxidation step may need to be added in order to remove selenium and arsenic to levels specified by the most stringent applicable water quality criteria.

The iron-coprecipitation/adsorption treatment method produces a relatively large quantity of low-solids content sludge and can have a substantial footprint. The process requires a stirred reactor followed by solid/liquid separation to remove the sludge. HRCs can reduce the space requirements for this process by combining the reaction and settling steps within a single unit and would be used at Donlin. Both coprecipitation/adsorption and HRC are proven technologies widely used in industry (Hatch 2015).

The manganese greensand filter is designed to reduce iron and manganese levels down to 0.05 mg/L. Some arsenic many also be removed with the iron. The water coming from the HRC may have a pH as low as 5. In that case, sodium hydroxide (NaOH) would be added in-line to raise the pH to 7. The filter uses a special medium covered with manganese oxide groups and requires either continuous or intermittent addition of an oxidant such as potassium permanganate. Continuous addition of the oxidant is preferred for waters with high iron and manganese concentration, making it ideal as a treatment step following initial solids removal by iron co-precipitation. Ultra- or microfiltration would follow greensand filtration to remove remaining fine suspended solids.

The effluent water from the previous step may have TDS and some other constituents at concentrations above AWQC. In that case, RO will be used as the final polishing step. RO uses high pressure to allow clean water to flow across a special membrane, while concentrating dissolved constituents in a reject brine stream. Water recoveries vary with TDS concentration and the method is limited to feed streams with TDS concentrations below about 45,000 mg/L. When the water to be treated has a TDS less than 5,000 mg/L, water recoveries of 50 to 75 percent are possible, depending on the scaling potential of the feed water (Hatch 2015).

During later years of operation, selenium concentrations may increase in the Upper CWD, SRS, or waste stream water to levels that may need additional treatment. In this case, selenium would be treated using ion exchange as a polishing step.

Each of the steps of the water treatment process produces a waste stream that would need to be disposed (Hatch 2015). The sludge from the HRC would be sent to the TSF. The greensand filter would be backwashed intermittently and the wastewater sent to the TSF. The brine from the RO process would then be returned to the process plant as a source of reclaim water, except during construction, when the volume of brine is expected to be less. During that period, it would report to the Lower CWD (Table 3.7-40).

**Table 3.7-40: AWT Waste Streams**

| Waste Stream | Type | Flow or Volume | Main Characteristics | Destination |
|---|---|---|---|---|
| HRC sludge | Continuous | 32 $m^3$/h | · TSS: 1,902 mg/L<br>· pH: 5-6<br>· Other parameters: similar quality to feed water | TSF |
| Greensand media filter backwash wastewater | Intermittent | 504 $m^3$/day | · TSS: 327 mg/L<br>· pH: 7-8<br>· Other parameters: similar quality to RO concentrate | TSF |
| RO brine | Continuous | 138 $m^3$/h | · TDS < 5,070 mg/L | Reclaim Water Tank |
| RO CIP waste | Intermittent | 100 $m^3$/cleaning cycle/ RO train | · pH: 1-12 | TSF |

Source: Hatch 2015, Table 4-11.

A flow diagram of the conceptual WTP is given in Figure 3.7-24. The Water Treatment Plant (WTP) would typically operate from April (start of snowmelt) through November. However, it would have the ability to operate and discharge year-round, if required. The design capacity of 4,672 gpm is based on the predicted maximum flow to the WTP during Year 12. However, if required, the WTP capacity can be expanded to 6,600 gpm (Hatch 2015). The RO plant is expected to produce an estimated brine of 25 percent during operations, but only about 2.5 percent during construction. The lower estimated brine production during construction is due to the predicted better water quality of the pit dewatering well water.

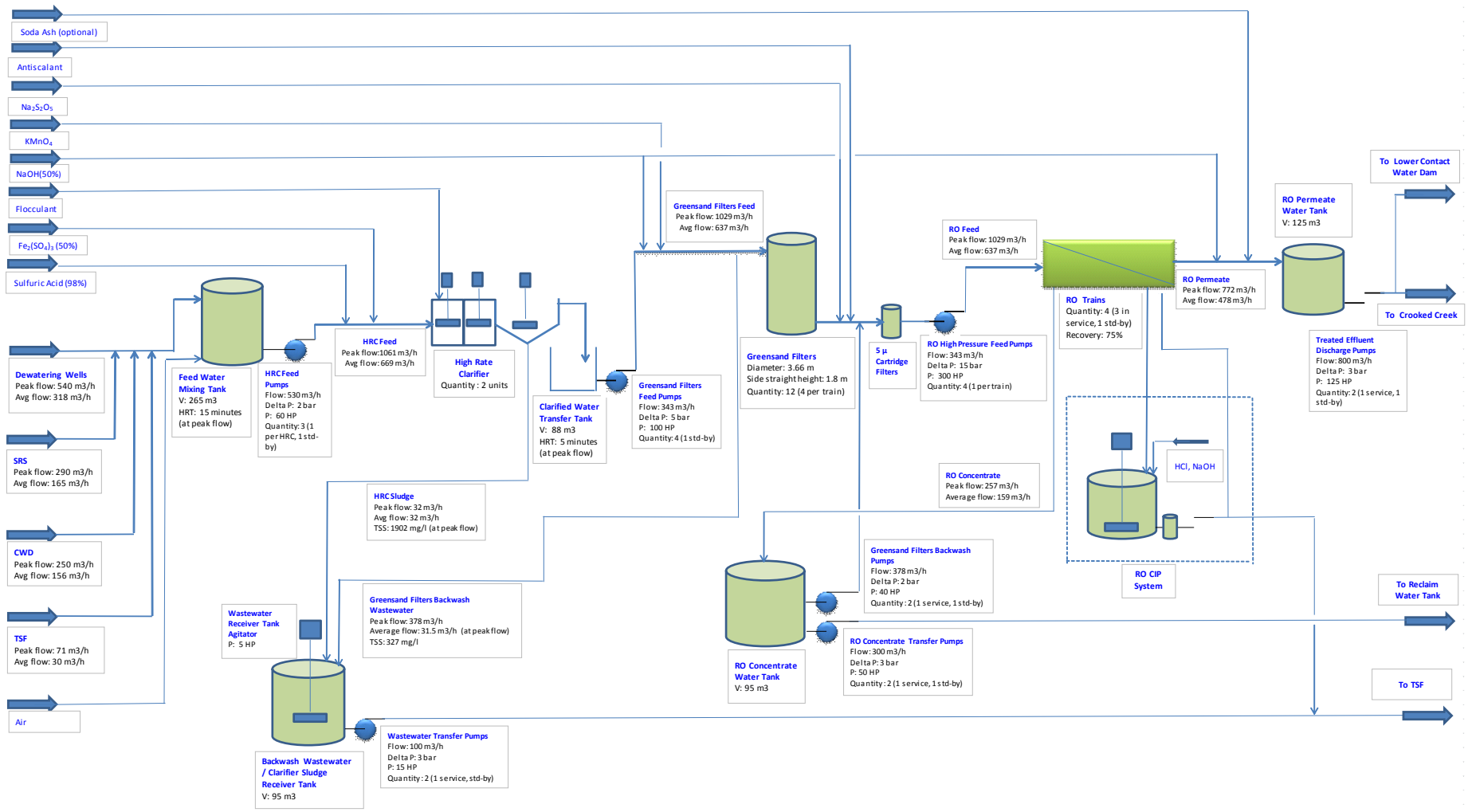
*Construction*

Under Alternative 2, construction at the mine site would take place over a 3-year period. The American Creek drainage into the CWDs, pit dewatering, overburden stockpiles, construction camp potable water wells, Snow Gulch FWD, and TSF (Anaconda Creek runoff) are the primary components of the mine site that could potentially impact surface water quality during the construction phase. In order to address potential impacts to surface water quality, water management objectives during construction include:

- Treat all pit dewatering groundwater prior to discharge into Crooked Creek;
- Minimize build-up of contact water in the lower CWD during construction; and
- Eliminate the need to store water in the TSF facility until immediately before mine start-up.

Besides geochemical processes, three primary mechanisms would be responsible for potential impacts to surface water quality at the mine site during construction. Those three mechanisms would be:

- Discharges of treated water to Crooked Creek,
- Runoff from construction materials, and
- Erosion and sedimentation.




Data Sources: Hatch 2015b

DONLIN GOLD

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# FLOW DIAGRAM OF THE CONCEPTUAL WATER TREATMENT PLANT

NOVEMBER 2015

FIGURE 3.7-24

### Discharges of Treated Water to Crooked Creek

Under Alternative 2, contact water would likely not be discharged during construction, and therefore, impacts to surface water quality attributable to contact water would be limited in geographic extent to the areas used for contact water storage. Water collected at the Lower CWD is not expected to meet Applicable Water Quality Criteria (AWQC) for discharge and would not be released to the environment unless it is first treated; the contact water would be stored throughout the construction period, then treated as necessary during operations (BGC 2011d, 2015f). Any excess non-contact water captured by the American Creek FWDD located upstream of the Lower CWD would be expected to meet AWQC for discharge, and would be pumped to Crooked Creek (SRK 2012b).

The main source of water that would be treated and discharged to Crooked Creek during construction would be from pit dewatering (up to about 1,700 gpm) (SRK 2012b). Concentrations of dissolved antimony, arsenic, iron, and manganese, and total concentrations of aluminum, antimony, arsenic, copper, iron, lead, and manganese in the pit dewatering water would be expected to be greater than the concentrations specified in the most stringent AWQC (BGC 2014b). In order to meet effluent limitations for discharge, groundwater from the pit perimeter wells would be treated to meet water-quality -based effluent limitations of an APDES permit (which would be based on AWQC) prior to discharge to Crooked Creek using the treatment system discussed in the previous section. The proposed treatment process is expected to provide effective treatment for all parameters of concern, and the effluent would be compliant with the most stringent effluent limitations. The water quality of the dewatering well water is estimated to be substantially better than SRS, CWD, or TSF pond water, so it is assumed that 90 percent of the dewatering well water can bypass the RO (BGC 2015f), producing only about 2.5 percent brine solution during construction. The brine would be stored in the Lower CWD during this period (BGC 2015f). It is not anticipated that in-pit dewatering wells would be required during the construction period (SRK 2012b).

Based on available data, stream temperature downstream of the mine site is anticipated to remain relatively constant during construction (ARCADIS 2013a). Although the treated groundwater discharged to Crooked Creek during construction could have a temperature higher than that of the surface water in Crooked Creek, the larger contribution of surface water inputs relative to treated groundwater inputs would be expected to attenuate changes to water temperature within Crooked Creek during construction. Existing surface water temperatures downstream of the mine site vary between 0° and 9.16°C depending on the time of year, and construction activities are not expected to have any substantial impacts on surface water temperatures (ARCADIS 2013a).

There would be no discharge of power plant cooling water at the mine site, as the cooling system would be closed-circuit. Boiler replacement water would be pumped to the mill (Weglinski 2015f).

As a result of the effective water management and treatment processes proposed under Alternative 2, impacts to water quality in Crooked Creek resulting from discharges of treated pit dewatering water would be low in magnitude because the effects would be below, or treated to be below, AWQC. The wintertime treatment of water is not planned; however, the capability for wintertime operations is present. Any impacts to temperature in Crooked Creek resulting from discharge of treated water would likely be greatest during the winter when the discharged treated groundwater would be warmer than the ambient water in Crooked Creek and the

discharged water would represent a greater proportion of the overall water in Crooked Creek. Conservatively assuming that the discharged treated water represents 10 percent of the total flow in Crooked Creek, if the temperature of the discharged water is 9°C and the temperature of the receiving water is 0.5°C, the effect would be an increase of 0.9°C, and the final water temperature would be 1.4°C.

Impacts would extend over the construction period on a discontinuous basis, and would therefore be considered temporary. The impacts would affect a common to important resource within a discrete portion of the project area.

#### Runoff from Construction Materials

Non-acid generating (NAG) rock, including waste rock and material from borrow sites, would be used for construction of various facilities associated with the mine site including roads, berms, and dams. There is potential for impacts to surface water quality to occur as a result of metal leaching from NAG rock used for construction. In order to minimize potential impacts, the materials collected from borrow sites for the construction of roads and other mine infrastructure would be tested for metal leaching before use (URS 2013a) (Table 5.2-1, Design Features). To determine metal leaching in WR samples, rock material would be subjected to three tests: 1) bulk geochemical analysis; 2) meteoric water mobility procedure (MWMP); and 3) acid-base accounting (ABA). If sample materials from a particular borrow site show potential for metal leaching or acid generation, then those materials would not be used for applications where surface water quality could be adversely impacted.

NAG waste rock with metal leaching potential could be used for construction of the Lower CWD. Under Alternative 2, there would be potential for the generation of seepage and runoff with elevated metals concentrations derived from metal leaching from the NAG used for construction of the lower CWD. Runoff and seepage from the Lower CWD would be collected either in the ACMA pit dewatering system, or at a proposed ore stockpile berm designed to minimize surface runoff to the pit. The ACMA pit would intersect American Creek downstream of the dam during construction, so that runoff and seepage from the lower CWD would not migrate off site and would only have a localized effect on surface water in the American Creek watershed.

#### Erosion and Sedimentation

Construction of the mine site facilities would result in increased erosion and potential increases in concentrations of suspended sediment in surface waters in the vicinity of the mine site. Clearing, grading, and excavation work during the construction of the mine's processing and support facilities would expose large areas to erosion. Use of heavy construction equipment would cause disturbance of near-surface soils that could locally result in increased runoff and subsequent increased sedimentation at downstream locations (see Section 3.2, Soils). In order to minimize such impacts to water quality from erosion, runoff and sedimentation, an important part of the water management strategy for construction involves diversion structures that would direct surface water and runoff from precipitation around and away from the exposed areas (see Section 3.2, Soils). By minimizing the rates of flow over the cleared areas, impacts from erosion and sedimentation would be controlled so that surface water quality would be expected to comply with all AWQC during the construction phase. Stormwater collected in diversion ditches and areas not in contact with waste rock, mine pit, or process solutions (non-contact water) would be suitable to discharge to the environment without treatment. Energy

dissipating and erosion control features would be installed or modified as required to meet APDES Multisector General Permit (MSGP) discharge requirements. BMPs detailing sediment and erosion control measures would be developed and implemented as part of the SWPPP (Section 3.2, Soils).

As described in Section 3.7.3.2.1, several overburden stockpiles would be required to store material that would ultimately be used to reclaim the TSF and WRFs. These stockpiles would lay downgradient of areas that drain into proposed dams and, therefore, would require sediment control structures to prevent sediment-laden runoff from affecting surface water quality. Runoff from these overburden stockpiles would be managed by intercepting and directing surface runoff toward settling ponds sized to contain a 10-year return period, 24-hour duration storm (SRK 2012b). Upslope diversions would limit runoff to the stockpiles, while channels on the downslope sides would direct surface runoff to the settling ponds. The runoff from the SOB stockpile, which could have acid and/or leached metals, would report to the Lower CWD. The effects of potential arsenic leaching and ARD from the SOB stockpile are described in Section 3.7.3.2.1, and Appendix H, and recommended mitigation for reducing these effects are provided in Chapter 5, Impact Avoidance, Minimization, and Mitigation. Runoff from the NOB and other overburden stockpiles is considered suitable for discharge without treatment, other than stormwater and sediment runoff control (SRK 2012b).

The greatest potential impacts to surface water quality at the mine site during construction would likely result from suspension of sediment caused by in-stream construction and erosion of cleared stream banks in the American Creek and Anaconda Creek watersheds. In-stream construction could cause dislodging and transport of channel bed sediment and the alteration of stream bottom contours, resulting in increased suspended sediment concentrations in surface water. Changes in the bottom contours could alter stream dynamics and increase downstream erosion or deposition (SRK 2012b). Surface discharges to the local drainages during construction would potentially result in increased erosion and sedimentation, which could adversely affect surface water quality. Treated water from the pit dewatering system would be discharged to Crooked Creek below Omega Gulch. The outfall structural design would include energy dissipators and erosion control measures to reduce downstream impacts from erosion and sedimentation, and to meet AWQC.

*Operations and Maintenance*

Alternative 2 would involve operation of mine site facilities in the American Creek and Anaconda Creek drainages, including the mine pit, WRF, TSF and associated SRS. A dam would also operate in Snow Gulch to serve as a source of freshwater for the mine process circuit and other applications. The American and Anaconda Creek FWDDs would be removed early in operations following construction of the lower CWD, initial lifts of the WRF, and TSF starter dam.

Five primary mechanisms would be responsible for potential impacts to surface water quality at the mine site during the operational phase:

- Discharges of treated water to Crooked Creek;
- Reduced flows in Crooked Creek due to diversion of water to support mine operations;
- Impacts to water quality resulting from wetlands alteration;

- Inputs of mercury to surface water from runoff and atmospheric sources; and
- Water quality at facilities containing contact water (i.e., TSF and CWD ponds).

Diversion structures to limit the amount of freshwater entering the mine site are an important part of the water management strategy. Synthetic liners, runoff collection systems, and seepage collection and pump back facilities would prevent the discharge of untreated contact water.

In order to manage impacts to surface water resources and to minimize build-up of water in the TSF, pit dewatering groundwater and TSF SRS runoff will be treated and discharged to Crooked Creek. Contact water collected in the Lower and Upper CWD, a well as some water from the TSF pond, may also be treated and discharged to Crooked Creek in order to build flexibility into the overall water management system. Because the CWD and TSF pond water have higher concentrations of several constituents than the pit dewatering groundwater, they would be treated at maximum rates of 1,101 gpm and 313 gpm, respectively (BGC 2015f).

Although the water within the mine facilities would not be considered waters of the State of Alaska or waters of the U.S., and are not subject to regulation under the Clean Water Act or the APDES permitting program, potential receiving waters downstream of the mine are subject to Clean Water Act regulations. Thus, their expected water quality is discussed in this section for comparison to baseline water quality conditions.

#### Discharges to Crooked Creek

Water that would be discharged under Alternative 2 would be treated prior to discharge to meet applicable water quality criteria and permit limitations associated with the discharge. The intent of Alterative 2 is to maximize the total amount of water that can be treated and discharged from the project in order to minimize the amount of water that must be stored and managed during operations and at closure, while still supplying water required by the processing facility. This would enable operational flexibility with regard to the mine site's water balance and could potentially prevent problems associated with accumulation of too much water within the mine facilities during periods of heavy precipitation.

The SRS water, in-pit runoff, water from the Upper and Lower CWDs, and TSF pond water that would be discharged under Alternative 2 are predicted to contain concentrations of some metals and total dissolved solids (TDS) that would be elevated relative to the most stringent AWQC. Consequently, additional water treatment measures to actively manage metals and TDS in the water would be required in order to produce effluent that would conform with the AWQC, as discussed previously.

*Dewatering Well Water*. Treatment and discharge of pit dewatering water to Crooked Creek would occur mostly during spring, summer, and fall, when excess water in the Upper and Lower CWDs would be sufficient to meet the freshwater demand for the process plant. In contrast, during the winter months, CWD pond volumes would be low and the pit dewatering water would be used in the process plant rather than discharged to Crooked Creek. The average estimated discharge flow from the treated pit dewatering well water over the operational phase of the mine is 844 gpm, although there would be periods of no discharge when all pit dewatering water is used in the process (BGC 2015f). The volumes of pit dewatering water that would be treated and discharged and the temporal dynamics of the discharges under Alternative 2 are discussed in Section 3.5, Surface Water Hydrology.

Based on 95th percentile concentrations of dissolved and total constituents in water from wells completed in the mineralized zone, groundwater derived from the pit perimeter dewatering wells would be expected to require treatment prior to discharge (Table 3.7-38) (BGC 2014b; Hatch 2015). The monitoring wells summarized in Table 3.7-38 were completed within the mineralized zone and are therefore considered to represent a reasonable characterization of baseline groundwater quality in the vicinity of the pit (BGC 2014b).

#### Reduced Flows to Crooked Creek

As described in Section 3.5, Surface Water Hydrology, and Section 3.6, Groundwater Hydrology, water management and requirements for process water during operations would result in the disruption of the natural flows of water in Snow Gulch and in the American Creek and Anaconda Creek drainages. These drainages are tributaries to Crooked Creek, and the disruptions would result in reduced flows that could potentially influence the water quality in Crooked Creek. Additionally, pit dewatering would result in direct streamflow losses from Crooked Creek into groundwater and then into the pit dewatering system, which could also influence the quality of water in Crooked Creek.

During mining operations, surface water runoff and groundwater seepage in some parts of the Crooked Creek watershed would be diverted and captured for use in milling processes and power plant operations. For example, precipitation that falls on the WRF and does not evaporate or infiltrate into the ground would be captured in the lower CWD and then used in the milling process; the water would be deposited in the TSF as tailings slurry, then the water would be recycled through the process circuit. Because the facilities have been designed to minimize discharge of water affected by the mining operations, most contact water would be managed so it is not released to surface water streams. Regardless of their final use or consumption, the diversion and storage of waters in the Crooked Creek watershed would result in reduced rates of runoff and base flow that would normally reach surface waters in the proposed project area. During the operational phase of the mine, surface water would be removed from the American Creek and Snow Gulch drainages and diverted to the process facilities. This would result in reduced discharge in Crooked Creek relative to baseline conditions.

Correlation analysis performed as part of a water quality loading study for the Donlin Gold Project indicates that relatively strong relationships exist between levels of flow and the concentrations of chemical constituents in Crooked Creek (Tetra Tech 2013). Concentrations of total aluminum, total iron, and total manganese generally increase with increasing stream flow because these metals are primarily associated with sediments which consist of naturally occurring minerals and organic material. Higher stream discharge is usually associated with higher flow velocity which entrains sediments from the substrate, increasing the total concentrations of the metals in the water column. In contrast, concentrations of sulfate in Crooked Creek generally decrease with increasing rates of flow as a result of dilution (Tetra Tech 2013).

Inversely, the lower flow rates in Crooked Creek that would occur as a result of surface water diversion and reduced base flows associated with Alternative 2 may be expected to result in decreased total concentrations of aluminum, iron, and manganese in the water, and increased concentrations of sulfate. However, considering the relatively small portion of the Crooked Creek drainage area in Anaconda and American creeks that would be affected by operations, it is unlikely that reduced flows would measurably affect water quality in Crooked Creek. During

high runoff periods, sediments would continue to be mobilized to Crooked Creek from undisturbed areas outside the mining area, and concentrations of aluminum, iron, and manganese in the water would remain similar to those observed during baseline studies. Likewise, overall inputs of sulfate would decrease in proportion to the fraction of the Crooked Creek drainage area that would be affected by operations, thereby offsetting any effect of decreased dilution; as a result, concentrations of sulfate in the water would be expected to remain similar to those observed during baseline studies.

#### Wetlands Impacts on Water Quality

Another factor that could affect surface water quality during mine operation involves the in-filling, and removal of wetlands in the American Creek, Omega Gulch, Anaconda Creek, Snow Gulch, and Crooked Creek watersheds. Wetlands naturally serve to maintain water quality through a variety of mechanisms; debris and suspended solids may be removed by physical processes such as filtering and sedimentation. Nutrients and dissolved solids may be removed or degraded by biological processes, or incorporated into biomass. Similarly, microbial activity occurring in anoxic wetland environments may result in the chemical reduction of certain iron and sulfate species facilitating their removal from the water as insoluble precipitates. Many dissolved metals are removed by wetlands; for example, arsenic (in association with iron) has been shown to accumulate in wetlands in areas influenced by mining activities (SRK 2012b). Wetlands can reduce the solubility and mobility of iron, manganese, and zinc by retaining these metals within the sediment. Wetlands systems in regions of permafrost generally have elevated DOC, organic nitrogen, and relatively low concentrations of dissolved minerals (SRK 2012b).

As a result of the wetlands removal that would occur under Alternative 2 (see Section 3.11, Wetlands), elements that are associated primarily with the particulate fraction, such as arsenic, mercury, lead, and zinc, could increase within the proposed project area, specifically at Category 3 sample locations that drain the proposed project area (see Section 3.7.2.1.1). Increased particulate loading in watersheds draining the operational area would not necessarily translate into an increase in dissolved concentrations of these elements, although there may be a slight increase in dissolved arsenic, mercury, lead, and zinc due to desorption and dissolution from sediments (SRK 2012b). However, it is likely that any effects of wetlands removal on water quality would be offset by the capture of the water that comes into contact with the disturbed areas.

*Estimated Changes in Mercury Methylation Rates in Wetland Systems*. In freshwater aquatic ecosystems, shallow sediment catchments and the anoxic bottom waters of stratified lakes are important zones of net methylation. Methylation is less prevalent in environments with higher flow and low hydraulic retention (St. Louis et al. 1994). In-river methylation is typically a negligible component of the methylmercury budget for creeks, and wetlands are frequently the most important contributor of methylmercury to downstream aquatic ecosystems (St. Louis et al. 1994, Berndt and Bavin 2012).

Wetlands can be either a sink or a source of methylmercury. Any changes to rates of mercury methylation in wetland systems as a result of the activities proposed under Alternative 2 would depend upon several variables, including: presence of anoxic environments requisite for mercury methylation; presence of sulfate-reducing or iron-reducing bacteria to facilitate the methylation process, availability of mercury to participate in methylation reactions, the nutrient status of the wetland systems (organic carbon and inorganic nitrogen and sulfur), and the pH of the sediments or soils. The data collected during the 2013 field program were used to evaluate

methylation potential, and consequent potential project-related changes in mercury concentrations and methylation rates (ARCADIS 2014).

The 2013 field program samples show that the total mercury concentration in the upland soil (average of 260 µg/kg) is slightly lower than in the wetland soil (average of 320 µg/kg), although the variance in the soil concentration data was high in both cases. The relative differences suggest that the wetlands in the study area presently act as a sink for total mercury relative to upland areas (ARCADIS 2014).

Measured differences in methylmercury concentrations between upland soils and wetland soils were very small, suggesting that the wetland systems in the study area do not have a large methylation potential relative to uplands (ARCADIS 2014). The 2013 field program results show that the percentage of total mercury that is methylmercury in soils currently comprises between 0.23 percent and 2.59 percent in upland systems and 0.09 percent to 1.83 percent in wetland systems, with an overall average of less than 1 percent in each system (only detected values were included in these calculations). These ratios of total mercury to methylmercury are typical of boreal wetland and upland soils (ARCADIS 2014). Similar fractions (approximately 1 percent methylmercury) were detected in a similar system evaluated in northern Minnesota (a boreal system dominated by spruce/moss/shrub wetlands), which was characterized as having low methylmercury production (Hines et al. 2004).

Recent studies suggest that the nutrient status of the sediments and soils (organic carbon and inorganic nitrogen and sulfur), and the pH of the sediments or soils may play key roles in determining mercury methylation potential in the environment (e.g., Tjerngren et al. 2012; Braaten et al. 2014). In a study of mercury methylation processes in subarctic and boreal lakes, Braaten et al. (2014) found that concentrations of both total organic carbon (TOC) and total nitrogen had strong positive correlations with the fraction of mercury present as methylmercury in the subarctic and boreal lake systems. The authors concluded that total nitrogen was in fact the variable with the strongest influence on methylmercury fractions (a proxy for methylation potential), and suggest that nitrogen availability exerts a positive contribution on concentrations of methylmercury and the fraction of mercury present as MeHg (Braaten et al. 2014). Tjengren et al. (2012) found that maximum MeHg yield was obtained in wetlands with an intermediate soil acidity (pH ~5.0) and C/N ratio (~20). The geochemical data from the proposed mine site suggest low rates of mercury methylation in project area wetlands. The average C:N ratio of the upland and wetland soils is high (41 and 36 in uplands and wetlands, respectively), and the average pH is acidic (4.7 and 4.5 in uplands and wetlands, respectively) (ARCADIS 2014). Wetland systems studied elsewhere that have similar C:N ratios and lower soil pH also show relatively low methylmercury production rates. For example, Tjerngren et al. (2012) showed that systems with a C:N ratio of approximately 35 to 38, and soil pH approximately 4.5, were characterized as "nutrient poor" and were less productive in terms of methylation activity relative to systems with lower C/N ratios.

Sulfate concentrations in soils were very low in all of the samples. At relatively low sulfate concentrations (approximately 50 mg/kg and lower), mercury methylation is limited by the rate of sulfate reduction, while at high sulfate concentrations (greater than 100 mg/kg) sulfide buildup from sulfate reduction results in decreased methylation of mercury (Fitzgerald and Lamborg 2014). Sulfate levels in the wetland systems in the study area are insufficient to support high activity of sulfate reducing bacteria (SRB), the microorganisms predominantly responsible for mercury methylation (ARCADIS 2014).

These results suggest that current rates of mercury methylation in wetlands and uplands in the vicinity of the proposed mine facilities are low. Methylation rates are not expected to increase as a result of the activities proposed under Alternative 2 because low nutrient availability and low levels of sulfate reducing bacteria activity currently limit the mercury methylation potential in project area wetlands, and these drivers would not be altered as a result of the activities proposed under Alternative 2.

Mercury methylation rates in project area wetlands are not expected to increase as a result of the activities proposed under Alternative 2, and the amounts of mercury converted to methylmercury in these systems would not be expected to increase in proportion to increases in mercury deposition. Mercury methylation rates in project area wetlands are currently limited by low levels of nutrients and low activity of sulfate reducing bacteria in the anoxic environments requisite for mercury methylation. Because these limiting factors are not expected to increase as a result of activities proposed under Alternative 2, this likely indicates that rates of mercury methylation in wetland systems would be the same during operations as they are currently.

#### Inputs of Mercury from Runoff and Atmospheric Sources

*Predicted Total Mercury in Surface Water*. Elevated concentrations of mercury are a natural feature of surface water in the vicinity of the proposed mine site. As described in Section 3.7.2.1.1, concentrations of total mercury detected in 465 water samples collected between June 2005 and June 2013 ranged from 0.518 to 260 nanograms per liter (ng/L); mean = 8.2 ng/L (Enos 2013b). The applicable numeric criteria for mercury for CWA purposes are the EPA-approved aquatic life criteria: 2,400 ng/L acute and 12 ng/L chronic, both as total recoverable mercury (EPA 2013k). Total mercury concentrations did not exceed the acute criterion in any of the samples; however, 81 samples had total mercury concentrations in excess of the chronic criterion. Samples with total mercury concentrations greater than 12 ng/L were distributed relatively evenly between all three categories of sites defined by the Donlin Gold water quality characterization program, with 29 of the samples (36 percent) collected from Category 1 sites (waters draining undisturbed areas and areas outside of the mineralized area of interest), 18 of the samples (22 percent) from Category 2 sites (waters draining area of defined mineralized zone only with no placer mining activities), and 34 of the samples (42 percent) from Category 3 sites (waters draining from areas of both placer mining and the mineralized zone of the proposed Donlin Gold Project). These data suggest that existing concentrations of total mercury in surface water are sometimes elevated above the applicable chronic numeric criterion for the protection of aquatic life at locations throughout the mine site area. The activities proposed under Alternative 2 would result in additional inputs of mercury to surface water from both atmospheric and aqueous sources, which would likely cause exceedances of the 12 ng/L chronic criterion at additional sites.

Predicting changes in mercury concentrations in aquatic systems is challenging because a portion of mercury that is deposited to surface waters will be transported downstream, such that estimates of mercury deposition by watershed do not necessarily correspond to direct increases in mercury content in surface waters (ARCADIS 2014). Additionally, the importance of atmospheric deposition relative to runoff inputs to streams is another source of uncertainty. The relative bioavailability of pre-existing mercury in the area versus the bio-availability of newly deposited mercury from the mine activities associated with Alternative 2 is also an important consideration that could influence mercury methylation rates. Typically only a small

fraction of inorganic mercury is available for methylation (Marvin-Dipasquale et al. 2009). New inputs of mercury of atmospheric origin may be more or less bio-available than older or geologic sources of mercury; thus, the new inputs of mercury from the mining activities may be more or less available for mercury methylation processes relative to older mercury within the area (whether of geologic or atmospheric origin).

Studies of mercury mass balances in forest-dominated catchments have shown that mercury inputs to aquatic systems are more heavily dominated by contribution from wetland runoff (St. Louis et al. 1996; Selvendiran et al. 2008; Berndt and Bavin 2012) than by atmospheric deposition. Current estimates indicate that rates of methylmercury production in project area wetlands are low, and are not expected to increase substantially due to the project. For this reason, methylmercury concentrations in aquatic systems may change very little if mercury inputs to streams are dominated by wetland runoff rather than atmospheric deposition (ARCADIS 2014).

A conservative estimate of the potential changes in mercury concentrations in surface water due to atmospheric deposition resulting from activities proposed under Alternative 2 was developed (ARCADIS 2014). The study area for the model included the Hydrologic Unit Code (HUC) 12 watershed in which the mine site would be located, as well as the surrounding watersheds in the area where potential for deposition would occur. The proposed mine site lies within the Crooked Creek HUC 12 watershed, and is surrounded by the following HUC 12 watersheds: Donlin Creek, Flat Creek, Grouse Creek, West Juningguira Mountain, Getmuna Creek, and Bell Creek. Within these watersheds there are a number of drainages, including the Crooked Creek drainage, which is located along the west side of the mine site. The current rate of mercury deposition within the Crooked Creek and Donlin Creek HUC 12 watersheds study area is estimated to be 8.4 micrograms per square meter per year (µg/m2/y) (Environ 2014a). The baseline mercury deposition is estimated to be 8.4 µg/m2/yr at Camp and 7.8 µg/m2/yr at Crooked Creek Village (Environ 2014a). Mercury deposition rates are projected to increase in these watersheds by 2.3 to 4.8 µg/m2/y, with an average increase of 3.55 µg/m2/y, an increase of 42 percent as a result of the activities proposed under Alternative 2. Because the rates of mercury transformation and transport in upland/wetland systems and aquatic sediments are not expected to change as a result of the project activities, a linear response between atmospheric deposition rates and mercury concentration in surface water is assumed (ARCADIS 2014). This assumption is conservative because it precludes consideration of the phase partitioning of the mercury deposited from atmospheric sources, and the possibility that a large fraction of the mercury deposited from atmospheric sources would partition into soils and sediments in the project area and would not be present in surface water. The model simply assumes a linear relationship between atmospheric deposition rates of mercury and concentrations of mercury in surface water. Following this model and associated assumptions, the activities proposed under Alternative 2 could cause an increase in the average concentration of total mercury in surface water to 11.6 ng/L (ARCADIS 2014), which is at or below EPA-approved aquatic life criteria of 2,400 ng/L (acute) and 12 ng/L (chronic) (EPA 2013k), and the Alaska water quality standard of 50 ng/L for total recoverable mercury.

The average and 95th percentile baseline mercury concentrations and the range of estimated potential increases resulting from the project are shown in Table 3.7-41. With the projected changes applied to current concentrations, the resulting surface water concentrations of total mercury would, in some instances, exceed the applicable chronic criterion of 12 ng/L. However, as described in Section 3.7.2.1.1, existing concentrations of total mercury in surface water

measured as part of the Donlin Gold water quality characterization program exceeded the 12 ng/L chronic criterion in 81 of the 465 samples collected between June 2005 and June 2013, indicating that concentrations of mercury above the applicable chronic criterion are a widespread natural feature of surface water in the vicinity of the proposed mine site. Atmospheric deposition of mercury to surface water resulting from the activities proposed under Alternative 2 could result in increases in the concentrations of total mercury in surface water, which may be sufficient to exceed AWQC at some locations.

Conservative estimates predict that the chronic mercury surface water quality criteria could be exceeded. Therefore, the magnitude of impacts to surface water quality resulting from project-related atmospheric deposition of mercury could range from low to high, depending on sample location, season, and existing natural concentrations. It is worth noting that the high level of impact is predicated upon several conservative assumptions with regard to phase partitioning and environmental transport of mercury; it is likely that a large fraction of the mercury deposited from atmospheric sources would associate with soils and sediments in the project area and only a small fraction of that mercury would be present as aqueous mercury in surface water. More realistic constraints on the environmental transport and fate of mercury deposited from atmospheric sources within the project area would enable more precise predictions of impacts to surface water quality. The duration of such impacts to mercury concentrations in surface water would be long-term, as concentrations would be expected to return to pre-activity levels at some time after the completion of the project. Impacts to surface water quality resulting from atmospheric deposition of mercury due to Donlin stack and fugitive sources would be greatest in the Crooked Creek watershed, and would generally decrease with distance from the mine site. As shown in Figure 3.8-5, Section 3.8, Air Quality, such impacts are expected to decrease to below detectable levels within about 15 miles of the mine site. Thus, the geographic extent of impacts to water quality resulting from increased rates of mercury deposition under Alternative 2 would be considered local to regional, due to the potential for impacts both inside and outside of the immediate project area, and the resources impacted would be considered common to important in context.

**Table 3.7-41: Baseline and Predicted Mercury Concentrations in Surface Water in the Mine Site Study Area**

| Statistic | Baseline Total Mercury (ng/L) | Estimated Total Mercury in Operations (ng/L) |
|---|---|---|
| Average | 8.2 | 11.6 |
| 95% Upper Confidence Limit | 23.5 | 33.4 |

**Notes:**

State of Alaska most stringent water quality criterion: 50 ng/L. EPA-approved State of Alaska aquatic life criteria: 2,400 ng/L acute, 12 ng/L chronic.

Statistics generated from data collected 2005-2011 (ARCADIS 2014).

The evaluation of the estimated impacts to concentrations of total mercury in surface water shown in Table 3.7-41 above is considered conservative because the majority of mercury potentially deposited as a result of the activities proposed under Alternative 2 would be particulate mercury, which would tend to rapidly settle out of the water and become buried in stream sediments (ARCADIS 2014). The above evaluation is intended to identify an upper limit

of potential changes in mercury concentrations in surface water resulting from the activities proposed under Alternative 2.

*Predicted Methylmercury in Surface Water*. In addition to total mercury, a model was developed to predict mercury and methylmercury concentrations in surface water based on concentrations of dissolved organic carbon (DOC) in the water, suspended sediments, flow and velocity, and watershed size (ARCADIS 2014). The model is based upon a study by Brigham et al. (2009) in which the study authors derived an equation to predict mercury and methylmercury concentrations in surface water based on correlations between these parameters and existing mercury content of stream surface water. Using a DOC concentration of 20 mg/L, the modeled concentration of total mercury in surface water is 8.6 ng/L, very close (within approximately 5 percent) to the measured average concentration of total mercury in surface water of 8.16 ng/L within the Crooked Creek and Donlin Creek watersheds (ARCADIS 2014). Based upon the similarity between measured and predicted concentrations of mercury using this model, the existing methylmercury concentration was estimated to be 0.280 ng/L within the Crooked Creek and Donlin Creek watersheds (ARCADIS 2014). For comparison, the USGS has published a comprehensive study of stream methylmercury concentrations (n=337) throughout the US (Scudder et al. 2009). In this report the average methylmercury in stream sites is 0.19 ng/L, and there was no significant difference in methylmercury concentrations in mined basins relative to unmined basins.

It is important to note that the regression equation described by Brigham et al. (2009) had an $r^2$ value of 0.48. This indicates that more than half of the variability in the stream methylmercury concentrations cannot be explained by the equation parameters: DOC in the water, suspended sediments, flow and velocity, and watershed size. This is important to keep in mind when interpreting the predicted methylmercury concentrations.

The measured concentration of methylmercury in pore water from sediment recovered from Crooked Creek is 0.495 ng/L, which is considered consistent with the model result, given the expectation that sediment concentrations of methylmercury would be higher than the concentrations in the water column because methylmercury would be retained by organic matter in sediments and limited by diffusion out of sediments (ARCADIS 2014). Using the same approach used to estimate the increase in the average concentration of total mercury in the water column based on increases in average highest mercury deposition rates over the confluence of the Crooked Creek and Donlin Creek watersheds (3.55 $\mu g/m^2/y$), average methylmercury concentrations in surface water are estimated to increase from 0.280 ng/L to 0.398 ng/L, an increase of 42 percent over baseline as a result of the activities proposed under Alternative 2 (ARCADIS 2014). The duration of such impacts to methylmercury concentrations in surface water would be long-term, as concentrations would be expected to return to pre-activity levels at some time after the completion of the project. The geographic extent of such impacts would be considered regional due to the potential for impacts outside of the immediate project area due to mercury deposition from atmospheric sources, and the resources impacted would be considered common to important in context. Because the applicable numeric water quality criterion for methylmercury is expressed as a fish and shellfish tissue concentration, not as a surface water concentration (EPA 2010a), the methylmercury concentrations in surface water predicted to occur as a result of activities proposed under Alternative 2 cannot be compared to regulatory limits. Potential impacts to fish and other aquatic organisms are described in Section 3.13, Fish and Aquatic Resources.

Site-specific bioaccumulation factors (BAFs) can be used to explain and predict the relationships between methylmercury concentrations in primary media, such as surface water or sediment, and the concentrations present in fish tissue. Recommendations are provided in Chapter 5 (Impact Avoidance, Minimization, and Mitigation) to conduct fish tissue monitoring to develop site-specific BAFs.

#### Water Quality at Water Management Facilities

The Donlin Gold Project includes numerous structures and operating rules designed to ensure availability of sufficient freshwater for ore processing while minimizing the accumulation of excess water in the system (SRK 2012b).

During the operations phase of the mine, water from the process plant would be recycled through the TSF. The Upper and Lower CWDs, the pit dewatering system, and the Snow Gulch Freshwater Reservoir would also supply water to the process circuit under certain conditions. The water balance model and operating rules for water management are discussed in Section 3.5, Surface Water Hydrology.

The TSF and upper and lower CWDs included under Alternative 2 are not considered waters of the State of Alaska or waters of the U.S. These facilities are not subject to regulation under the Clean Water Act or the APDES permitting program; the quality of water in the TSF and CWDs is discussed in this section in order to provide a means for comparison with the baseline water quality conditions that presently exist in the American Creek, Anaconda Creek, and Snow Gulch watersheds.

##### TSF

Tailings deposited to the TSF during the operations phase would consist of flotation tailings, wash thickener overflow, and the tailings from the carbon-in-leach (CIL) circuit.

The configuration and chemistry of the TSF, and the resulting impacts to the quality of water contained in the TSF, would evolve over the operational period of the mine. The tailings would be comprised initially of about 64 percent water (36 percent solids) by weight. Predicted concentrations of constituents in the liquor component of the tailings generated through metallurgical pilot testing (Appendix H, Geochemistry, Table H-4) suggest that the final plant tailings liquor would be elevated relative to the most stringent water quality criteria for a number of constituents. The concentrations of constituents in the TSF pond and pore water could increase beyond the results summarized above by as much as a factor of three, as discussed in Appendix H, Geochemistry, due to recirculation of tailings water through the process circuit (SRK 2015a). Assuming the three-fold concentration, the predicted concentrations are as follows: sulfate (5,800 mg / L), arsenic (3,300 µg / L), mercury (10,00 ng / L), manganese (2,000 µg / L), molybdenum (230 µg / L), antimony (22 µg / L), and selenium (42 µg / L) (SRK 2015a). The water quality criteria are mentioned in this section to provide the reader with a frame of reference for interpreting the predicted concentrations of constituents in the TSF water, however, surface water in the TSF is not subject to regulation under the CWA or the APDES permitting program.

Under Alternative 2, fugitive dust would be generated from drilling, blasting, material handling, ore loading and unloading, waste loading and unloading, ore and waste hauling, maintenance equipment (dozers, graders, water trucks), and wind erosion of exposed surfaces including the TSF tailings beach, haul roads, access roads, waste dumps, and stockpiles. As

described in Section 3.8, Air Quality, during operations, 90 percent fugitive dust control efficiency would be expected for dust generated from unpaved roads (haul roads and access roads), material handling (ore and waste), maintenance equipment (dozers, graders, water trucks). No dust controls would be applied to the fugitive emissions resulting from drilling, blasting, or wind erosion of the TSF tailings beach. Additional best practical methods to suppress dust from other dust generating sources within the mine site would minimize the potential for water quality impacts associated with dust from the TSF and other mine site components.

Contact Water Dam (CWD) Ponds

The lower and upper CWDs would be located in the American Creek watershed, adjacent to the WRF, with the objective of managing contact water and runoff from the WRF and pit. The dams would contain water that would be used throughout the year as a source of water for the process plant (SRK 2012b).

As discussed in Section 3.7.3.2.1, Geochemistry, and described in Appendix H (Section H-3.4 and Table H-6), the Lower CWD would receive runoff from a variety of sources:

- Surface and seepage runoff from the WRF (bare and reclaimed);
- Runoff from undisturbed ground upgradient of the WRF;
- Surface runoff within the open pit footprint;
- In-pit dewatering well and horizontal drains from the open pit;
- Runoff collected within the ore stockpile berm; and
- Runoff from the SOB stockpile.

The Upper CWD would receive runoff from undisturbed areas and would also serve to provide additional capacity for contact water storage.

There would be considerable variability in the quality of the water that would be contained behind the lower and upper CWDs, as shown in Table H-6, Appendix H. As the volumes of water stored behind the CWDs increase, the waste rock would become progressively inundated. Subsequent use of the CWD water in the process circuit would decrease the volumes of water stored behind the CWDs, allowing the waste rock to dry. Intermittent drying and inundation of the waste rock could result in increased rates of oxidation and dissolution of sulfide minerals, leading to ARD and potential for leaching of metals and metalloids (e.g., arsenic) and salts (e.g., sulfate), which could degrade the quality of water stored behind the CWDs. Water quality issues in the CWD reservoirs would be managed during operations by limiting storage volumes in the lower CWD not to exceed 405 acre-feet more than 5 percent of the time (SRK 2012b).

The objective of treating water from the CWDs at a maximum rate of 1,101 gpm (250 $m^3/h$) is to build flexibility into the water management system such that TSF pond volumes are minimized to the extent practical during operations (BGC 2015f). Water from the upper and lower CWDs would be managed as mine contact water and would not be discharged to the environment. The operation of the lower CWD as described under Alternative 2 would cause acute and obvious adverse changes to the quality of water in the CWDs' portion of the American Creek watershed

relative to baseline conditions, but the lower CWD would prevent the contact water from reaching the lower part of the American Creek watershed and Crooked Creek.

### *Closure, Reclamation, and Monitoring*

#### Pit Lake and Post-Closure WTP Effluent

The pit lake would serve an important water management function during closure. As described in Appendix H, Geochemistry, water from the TSF and seepage from the WRF would be directed to the bottom of the pit lake. Pumping would be required to get TSF and SRS water to the pit rim, where it would be combined with WRF seepage, then flow by gravity-fed pipe to the bottom of the pit lake. Runoff would be directed to the surface of the pit lake. The difference in densities of these waters and their vertical delivery locations would result in a stratified lake with lower quality waters at the bottom and higher quality waters at the surface. As the pit fills, water level and quality (at different depths) would be monitored, and the pit lake model would be re-calibrated as data become available. Treatment and discharge of lake water would be required as the pit nears complete filling. A post-closure WTP would be constructed 5 years prior to the pit completely filling, and treatment would begin 2 to 3 years before filling is complete and discharge commences to allow adequate freeboard (SRK 2012b).

The parameters of concern predicted in pit lake water requiring treatment prior to release are discussed in Section 3.7.3.2.1 and Appendix H, Geochemistry. Pit lake modeling results (Lorax 2012) indicated that the chemistry of the pit lake surface water would not likely change substantially from the time when water treatment begins (approximately 52 years following closure) through the final model year (99 years after closure). However, as discussed in Section 3.7.3.2.1, assumptions regarding the weathering of highwall rock do produce substantial differences in metals concentrations. These model results, along with predicted pit lake water treatment effluent and the most stringent AWQC, are summarized in Table 3.7-42.

**Table 3.7-42: Predicted Pit Lake Surface Water Quality Estimates at Closure Year 99 and Predicted Base Case Post-Treatment WTP Effluent Water Quality**

| Parameter[1] | Units | Most Stringent Applicable Water Quality Criteria | Predicted Effluent Water Quality (Base Case) | Base Case | Peak-PAG Case | |
|---|---|---|---|---|---|---|
| | | | | No Reaction[2] | No Reaction[3] | Mineral Precipitation[4] |
| pH | units | 6.5 - 9.0 | 6.5-9.0 | 6.4 | 5.2 | 5.1 |
| Sulfate | mg/L | 250 | 31 | 31 | 48 | 48 |
| Total Dissolved Solids | mg/L | 500 | 139 | 139 | 143 | 97 |
| Aluminum | µg/L | 87[a,c] | 1.3 | 310 | 590 | 97 |
| Antimony | µg/L | 6 | 0.040 | 67 | 75 | 76 |
| Arsenic | µg/L | 10 | 0.18 | 112 | 190 | 190 |
| Boron | µg/L | 750 | 194 | 200 | 230 | 200 |
| Cadmium | µg/L | 0.18[a,b] | 0.030 | 0.24 | 0.31 | 0.31 |

**Table 3.7-42: Predicted Pit Lake Surface Water Quality Estimates at Closure Year 99 and Predicted Base Case Post-Treatment WTP Effluent Water Quality**

| Parameter[1] | Units | Most Stringent Applicable Water Quality Criteria | Predicted Effluent Water Quality (Base Case) | Base Case | Peak-PAG Case | |
|---|---|---|---|---|---|---|
| | | | | No Reaction[2] | No Reaction[3] | Mineral Precipitation[4] |
| Chromium | µg/L | 100 | 4.2 | 4.0 | 4.3 | 4.3 |
| Cobalt | µg/L | 50 | <3 | 3.0 | 5 | 5 |
| Copper | µg/L | 7.6 | 0.0235 | 1.4 | 7.1 | 6.7 |
| Iron | µg/L | 1,000 | <1,000 | NR[5] | 960 | 180 |
| Lead | µg/L | 1.6[a,b] | 2.0 | 2.3 | 2.7 | 2.7 |
| Manganese | µg/L | 50 | 0.397 | 128 | 170 | 15 |
| Molybdenum | µg/L | 10 | <0.473 | 17 | 19 | 18 |
| Nickel | µg/L | 36[a,b] | 0.40 | 11 | 20 | 20 |
| Selenium | µg/L | 5 | 1.41 | 20 | 23 | 23 |
| Zinc | µg/L | 82[a,b] | 7 | 13 | 45 | 47 |
| Mercury | ng/L | 12 | 11[6] | 25 | 28 | 28 |

**Notes:**

1 Values are for dissolved metals, and represent depths between 0 and 33 feet in lake. Shaded cells exceed most stringent water quality standard.
2 Lorax Environmental, 2012a,b. Donlin Creek Gold Project Pit Lake Modeling Assessment in Support of Project Permitting, October; PitMod_base case 1012. xls
3 Lorax. 2014b.
4 Lorax. 2014c. Aluminum, iron, and manganese low-temperature oxyhydroxide minerals were allowed to precipitate if saturated.
5 NR = Not Reported
6 Hatch 2015.
a Value shown corresponds to the chronic standard
b Acute and chronic aquatic life numeric criteria for some metals (Cd, Cr, Cu, Pb, Ni, Zn) are hardness dependent. Values may be slightly different than those in other tables due to differences in the way hardness-dependent standards were calculated.
c Where the pH is greater than or equal to 7.0 and the hardness is greater than or equal to 50 ppm as CaCO3, the chronic aluminum standard will then be equal to the acute aluminum standard, 750 µg/L as total recoverable aluminum.

### TSF and SRS Water Quality

At closure, the tailings pond water would be pumped to the open pit. In addition, tailings water from the beach runoff and tailings consolidation would be pumped to the open pit as reclamation of the TSF begins. As the TSF is drained, it would be reclaimed with an engineered cover overlain by a peat/mineral growth media mix. The engineered cover would promote runoff and reduce the potential for runoff or precipitation to contact the consolidated tailings. The reclaimed TSF would be covered and revegetated, with any intercepted precipitation draining to a lined settling pond. Once this water meets AWQC (expected in approximately Year 11 of closure), it would be directed to Crevice Creek through a spillway (SRK 2012b).

Closure of the proposed TSF is expected to take approximately 4 years, with an overall goal of minimizing meteoric water that comes into contact with the tailings. The underlying tailings would continue to drain and consolidate over a period of approximately 52 years, with water

from the consolidation process and any infiltrated water through the cap being captured and directed to the pit, along with water that flows to the seepage recovery system (SRS). It is assumed that by approximately Year 52 post-closure, the flow would be essentially all infiltrated precipitation, and SRS water quality would be consistent with natural conditions and suitable for discharge (BGC 2014b). Quarterly monitoring to demonstrate seepage water quality would continue for both the SRS pond and collection wells until analytical results indicate acceptable chemistry for discharge. If the seepage water is not suitable for discharge, it would continue to be pumped to the pit lake. The SRS would be operated for the required compliance period during closure (BGC 2014b).

Based on plans to capture, pump and ultimately treat all contaminated surface and porewater from the TSF, the impacts to surface water quality resulting from the reclaimed tailings facility on surface water quality would be negligible.

Avoidance of impacts to surface water quality under Alternative 2 would depend upon the reliability of the pumps used to convey captured seepage to the pit lake during the approximately 52-year period during which the covered tailings would drain and consolidate. If the SRS pumping system were to fail before the covered tailings are fully drained and consolidated, it is estimated that it would take approximately 2 weeks for SRS water to enter Anaconda Creek downstream of the SRS and subsequently enter Crooked Creek. Unlike the WRF, the TSF would not naturally drain to the pit lake, and impacts to surface water quality could occur in the event of an SRS pump failure greater than 2 weeks in duration (see Section 3.6, Groundwater Hydrology). The SRS water would be comprised of seepage from the TSF and groundwater flow to the SRS. The ratio of seepage to groundwater flow in the SRS water would vary over time. Based on estimated rates of seepage from the TSF and estimated rates of groundwater flow reporting to the TSF SRS during the post closure period, approximately 96 percent (431 gpm) of the SRS water would be natural groundwater, and only 4 percent (18 gpm) of the SRS water would be seepage from the TSF (BGC 2014b, see Figure 3.5-25: Schematic Water Balance During Closure, in Section 3.5, Surface Water Hydrology). Thus the TSF seepage would be diluted by a factor of about 24:1 with groundwater before reporting to the TSF SRS. Several constituents in the SRS water are predicted to exceed AWQC in spite of the dilution factor, including TDS, sulfate, antimony, arsenic, cadmium, cobalt, copper, iron, manganese, selenium, and mercury (see Table 3.7-43). However, the release of SRS water to the environment during the approximately 52-year period during which the covered tailings would drain and consolidate would only occur in the event of a pump failure greater than 2 weeks in duration, and such an event is considered unlikely under Alternative 2.

Table 3.7-43 shows the 95th percentile concentrations of selected constituents in natural groundwater samples from the mineralized area, the concentrations of constituents in the tailings pore water, and the potential concentrations in the SRS water, which would be comprised of approximately 96 percent groundwater and 4 percent tailings pore water. Actual concentrations of constituents in SRS water may be lower than shown in Table 3.7-43 because the groundwater in the vicinity of the TSF may not be as contaminated as water in the mineralized area and actual seepage through the liner may be below predicted amounts 52 years after closure.

**Table 3.7-43: Potential SRS Water Quality**

| Parameter | Units | 95th percentile concentrations in groundwater | Tailings Pore Water | SRS water (estimated based on 431 gpm groundwater and 18 gpm tailings pore water) | Most Stringent Applicable Water Quality Criteria |
|---|---|---|---|---|---|
| Aluminum | µg/L | 160 | 1.9 | 154 | 87[2a] |
| Antimony | µg/L | 33 | 1,300 | 83.8 | 6[2d] |
| Arsenic | µg/L | 1,950 | 17,000 | 2,550 | 10[2d] |
| Barium | µg/L | 1300 | 10 | 1,250.0 | 2,000[2d] |
| Boron | µg/L | 19 | | 18.2 | 750[2e] |
| Cadmium | µg/L | 0.5 | 0.91 | 0.5 | 0.25[2a] |
| Chromium | µg/L | 3 | 7.1 | 3.2 | 100[2d] |
| Cobalt | µg/L | 4 | 710 | 32.3 | 50[2e] |
| Copper | µg/L | 3 | 680 | 30.1 | 8.54[2a] |
| Iron | µg/L | 5,500 | 120,000 | 10,090 | 1,000[2b] |
| Lead | µg/L | 2 | 2.3 | 2.0 | 2.79[2a] |
| Manganese | µg/L | 1,440 | 450,00 | 3,186 | 50[2f] |
| Mercury | ng/L | 19 | 1,400 | 74.4 | 12[2b] |
| Nickel | µg/L | 19 | 320 | 31.1 | 47.8[2a] |
| Selenium | µg/L | 5 | 220 | 13.6 | 5[2b] |
| Sulfate | mg/L | 83.1 | 19,000 | 841 | 250[1] |
| Thallium | µg/L | 1 | 2.5 | 1.1 | 1.7[2f] |
| TDS | mg/L | 577 | 19,000 | 1,316 | 500[1] |
| Zinc | µg/L | 30 | 78 | 31.9 | 109.8[2a] |

**Notes:**

1 18 AAC 70. ADEC, Alaska Water Quality Standards. Amended as of April 8, 2012.

2 Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances. Amended through December 12, 2008. Most stringent criteria used. Criteria are expressed in terms of dissolved metal in the water column.

2a Aquatic life for fresh water hardness-dependent criteria. Acute and chronic aquatic life numeric criteria for some metals (Cd, Cr, Cu, Pb, Ni, Zn) are hardness dependent. Values contained in this table were calculated using a hardness value of 90.18 mg/L as CaCO 3 For Al, if pH≥7.0 and hardness ≥50, then 750 µg/L.

2b Aquatic life for fresh water (chronic) criteria.

2c Aquatic life for fresh water (acute) criteria.

2d Drinking water primary maximum contaminant levels.

2e Irrigation water criteria.

2f Human health criteria for non-carcinogens (for consumption of water + aquatic organisms).

2g Aquatic life criteria (chronic)for free cyanide, measured as weak acid dissociable (WAD) cyanide.

2h Aquatic life for fresh water (chronic) criteria based on pH and temperature when early life stages of fish are present. The ADEC numeric water quality standard for ammonia depends upon both the temperature and the pH of the matrix water, but not the hardness. Because the measured or predicted temperature and pH of the water may vary over a wide range of values depending on time of year, sample location, and other factors, the most conservative possible numeric standard for ammonia in freshwater (0.179 mg/L; ADEC 2008a) is used as a basis for comparison for all of the waters considered in this section.

3 Calculated for all observations using detected values and ½ of the reporting limit value when analyte not detected

4 Mercury removal performance is based on 30 m3/h TSF flow, 5 ppb mercury in the TSF, 1.3% TSF seepage contribution to SRS flow, and 96% reverse osmosis (RO) removal.

5 WAD cyanide removal performance is based on 30 30 m3/h TSF flow, 0.26 mg/L cyanide in the TSF and 80% RO removal.

Source: Hatch 2015, Table 4-10.

Because water treatment and discharge would continue after mine closure, in-stream constituent concentrations in Crooked Creek would be expected to be essentially the same as those occurring during mine operations. A small reduction in the dilution effect that occurs during low stream flows could be expected because the predicted annual discharge requirements are slightly less after closure (1,350 Mgal/yr) than during active operations (1,527 Mgal/yr).

*Summary of Mine Site Impacts*

Surface water in the American and Anaconda Creek watersheds would be influenced by the creation and perpetual maintenance of the pit lake and TSF impoundment; however, due to planned water treatment and water management practices, water from the TSF and pit lake would not leave these watersheds, and would be restricted to facilities within discrete portions of the project area. Effects from pit dewatering discharge to Crooked Creek during construction - from pit dewatering, CWD water, and TSF pond water during operations; and from pit lake and SRS discharge during post-closure - would be of low intensity, as all water would be treated to meet the most stringent AWQC prior to discharge. There is a low risk that high intensity impacts to Anaconda and Crooked creeks could result in the event of SRS pump failure and overflow in post-closure. Because there are many relatively similar watersheds in the region, and because water quality is governed by regulation, the context for impacts to surface water quality resulting from Alternative 2 is considered common to important.

The magnitude of impacts to surface water quality resulting from atmospheric deposition of mercury would be both low and high. High intensity impacts to surface water quality would be likely to occur at some locations within the Crooked Creek and Donlin Creek watersheds, where the inputs of mercury to the water are expected to be the greatest. Water quality is likely to be within regulatory limits on average, but could exceed baseline conditions and EPA chronic criteria in some areas (based on 95 percent upper confidence limit values). The duration of such impacts to mercury concentrations in surface water would be long-term, as concentrations would be expected to return to pre-activity levels at some time after the completion of the project. The geographic extent of such impacts would be considered local to regional due to the potential for impacts inside and outside of the immediate project area due to mercury deposition from atmospheric sources.

## Transportation Facilities

### *Construction*

#### Roads

Material sites are proposed along the mine access road to supply appropriately-sized and crushed gravel for road construction and continuing maintenance. As each site is no longer needed, it would be reclaimed. Stockpiles of non-acid generating (NAG) rock used for road construction could act as sources of arsenic, selenium, antimony, and possibly other constituents of concern, to area surface water resources, including Jungjuk Creek (see Appendix H, Geochemistry). Eight material sites have been identified along the lower mine access road corridor. Six material sites have been identified along the central mine access road corridor. In order to mitigate potential impacts to surface water resources that could result from materials stockpiles, Donlin Gold would test materials for the potential to act as sources of constituents of

concern prior to stockpiling materials. Materials that could act as sources of contamination would not be used for road construction, and other material sources would be identified (URS 2013a).

#### Runoff and Sedimentation from Construction Activities

Runoff and sedimentation associated with the construction of transportation facilities (mine access road, airstrip, ports, and tank farms) would potentially impact the quality of surface water resources. The intensity of impacts resulting from runoff of sediment-laden waters would be low, because BMPs and erosion and sedimentation control (ESC) measures would mitigate effects (described in Section 3.2, Soils) so that receiving waters would comply with ADEC water quality criteria. (Turbidity levels in freshwater streams may not exceed 5 NTU above natural conditions when the natural turbidity is 50 NTU or less, and may not have more than 10 percent increase in turbidity when the natural turbidity is more than 50 NTU, not to exceed a maximum increase of 15 NTU.) The impacts would be temporary, and turbidity levels and concentrations of suspended sediment in the water would be expected to return to pre-activity levels immediately following the cessation of the construction activities. The impacts would be local to discrete sections of the project area and would affect common to important resources.

#### Ports and Tank Farms

The Angyaruaq (Jungjuk) Port would serve as the node between barge transport from Bethel and road transport to the mine. A dock would also be constructed at the Bethel port, and fuel storage facilities at Dutch Harbor would be expanded as a result of the proposed action. The Jungjuk dock facility would be constructed both above and below the high water line and would include barge berths and a barge ramp. An access road would be constructed against the front of the bluff to allow access from the berth area to a terrace storage yard. Hazardous materials and fuel storage facilities would be constructed in concrete- and geosynthetic-lined and bermed containment structures at the back of the gravel pad, furthest from the river, and would be fully covered under required spill contingency and response plans. BMPs and ESC structures would be constructed and maintained at the dock and tank farm facilities as needed to prevent degradation to adjacent wetlands or waters of the U.S. (see Section 3.2, Soils). The potential for impacts to water quality from fuel spills at ports and tank farms is described in Section 3.24, Spill Risk, and Section 3.7.3.8.

### *Operations and Maintenance; and Closure, Reclamation, and Monitoring*

Barge operations on the Kuskokwim River would add roughly twice as many barge trips as are currently operated on the Kuskokwim (Section 3.23, Transportation), and would be restricted to an ice-free season of approximately 120 days per year. Barge operations are expected to have negligible impacts on surface water quality in the Kuskokwim River. Although concentrations of suspended sediments may increase in some shallow locations at low water levels as a result of increased barge traffic (see Section 3.5, Surface Water Hydrology), these impacts would be low in magnitude and local in extent, in that the disturbed sediments are expected to settle within a short distance, and are unlikely to exceed natural levels of suspended sediment in this river (Table 3.7-7) (Wang 1999). The duration of any changes to surface water quality resulting from increased barge traffic would be intermittent (low water conditions only) and temporary, and water quality would be expected to return to pre-activity levels within hours of a barge passing.

During reclamation of the Angyaruaq (Jungjuk) Port, all support facilities (buildings, tanks, fencing, and equipment) would be removed. Reclamation activities could result in temporary, localized impacts to surface water quality in the areas immediately adjacent to the reclamation activities. It is possible that levels of turbidity and concentrations of suspended solids would increase as a result of closure and reclamation activities. BMPs and stormwater pollution controls would limit the intensity of such impacts, and water quality would be expected to return to pre-activity levels at the completion of the activities.

*Summary of Transportation Facilities Impacts*

Under Alternative 2, effects to surface water quality would be considered low intensity (e.g., occasional barge–induced suspended sediment, or erosion effects at construction sites), due to high natural conditions (Section 3.7.2.1.2) and/or planned mitigation measures designed to limit erosion effects. Potential impacts resulting from runoff of water from NAG rock used for road construction could include inputs of arsenic, selenium, antimony, and possibly other constituents of concern, to area surface water resources, including Jungjuk Creek. The geographic distribution of such impacts would be limited to areas in the immediate vicinity of roads and road construction material stockpiles, and could be mitigated through implementation of a materials testing program prior to the beginning of road construction activities. Such impacts would be considered local in geographic extent due to the discrete areas of the project area that would impacted. The duration of such impacts would be considered long-term because the impacts would be likely to persist for the duration of the project, and water quality would return to baseline levels at some time following the completion of mining activities. The impacts would affect a common to important resource.

Natural Gas Pipeline

*Construction*

The primary impacts to surface water quality would be associated with installation of the natural gas pipeline at river and stream crossings and use of local water sources for hydrostatic testing. Impacts at material sites would be the same as those described above under Transportation Facilities.

The majority of rivers and streams on the pipeline route would be crossed by open cutting in the winter months when flows are lowest and disturbance of the river and streambanks can be held to a minimum. Select rivers and streams would be crossed using HDD technology. In all cases, pipe would be buried to a depth that is below the scour potential of the particular river or stream, and long-term effects to the river or stream at the location would be negligible. Potential effects on the overlying river and recommended mitigation related to HDD frac-out are described in Section 3.3, Geohazards and Seismic Conditions and Chapter 5, Mitigation.

At river and stream crossings where the open-cut (trench) method is employed, the dredged or excavated material would be kept to a minimum, and the work would be conducted in a manner to minimize turbidity of the water in the work area and downstream to ensure compliance with applicable water quality standards. Excavation of the pipeline trench would not result in the relocation of any existing stream or river channel or restrict stream flow.

ADEC water quality standards for fresh water streams specify that turbidity levels may not exceed 5 NTU above natural conditions when the natural turbidity is 50 NTU or less, and may

not have more than 10 percent increase in turbidity when the natural turbidity is more than 50 NTU, not to exceed a maximum increase of 15 NTU (Section 3.7.2.1.3). Surface water quality at stream crossings along the pipeline corridor during construction would be expected to comply with this water quality standard. Isolated occurrences of high intensity impacts (above this standard) could occur (e.g., during periods of high precipitation along summer construction segments), but are expected to be reduced within a short timeframe due to planned redundancies in BMPs, ESC measures, and reclamation/cleanup crew functions.

The extent of potential impacts resulting from hydrostatic testing (for pipeline pressure testing, Section 3.2.2.3.1, Soils) would be limited because the amounts of water required for hydrostatic testing would be small compared to potential sources from rivers and small lakes along the route (see Chapter 2, Alternatives, Table 2.3-16, Susitna Valley Winter Access Potential Water Extraction Sites for Ice Road Construction, and Table 2.3-17, Potential Water Extraction Sites for Pipeline Construction). Impacts to surface water quality would likely be negligible, provided that freeze depressants or other contaminants of potential concern are not present in discharged hydrostatic test water. Discharges of hydrostatic test water would meet the requirements of the applicable APDES General Permit.

Clearing of riparian areas during pipeline construction activities could result in additional impacts to surface water quality. If vegetative cover is disturbed and bare soil is exposed, the potential for introduction of fine-grained sediments (silts and clays) to surface water is greatly enhanced. Surface water impacts during pipeline construction resulting from increased amounts of sediment in the water would be mitigated by using HDD to install the pipeline under selected crossings, using BMPs and ESC measures (Section 3.2, Soils), restoring banks at stream crossing sites, and initiating reclamation of disturbed areas as soon as practicable.

Thus, most impacts from pipeline construction on surface water quality would be low in magnitude, because they would be mitigated to be within ranges specified by regulatory limits, with isolated occurrences of high intensity effects. The effects would be local, as water quality would only be affected at discrete locations (e.g., stream crossings) within the project area. Sediment control measures specified in the ESC Plan (SRK 2013b, Appendix H), would minimize the potential for erosion impacts to move downgradient from disturbed sites to waterbodies.

*Operations and Maintenance; and Closure, Reclamation, and Monitoring*

Impacts to surface water quality during the operational phase of the pipeline are expected to be negligible. The Erosion and Sedimentation Control Plan would be implemented to control erosion and storm water runoff. Continued ground surveillance and monitoring and corrective erosion control and vegetation maintenance would be employed throughout the life of the project. Existing drainage patterns would be maintained where practical.

If the pipe is abandoned in place, then any impacts caused by removal of the pipe would be avoided. Reclamation of the ROW would include methods to recontour and revegetate disturbed areas with native vegetation to maintain surface drainage patterns.

The proposed project would use the following mitigation measures to prevent or minimize adverse effects on surface and ground waters resulting from the natural gas pipeline:

- Minimizing the number of river and stream crossings;

- Using temporary bridge placement to facilitate construction traffic across the river and stream channels when possible;
- Using HDD to install the pipeline under selected crossings;
- Maintaining, to maximum extent practicable, the existing surface hydrology at all water body crossings;
- Restoring banks at stream crossing sites - use an excavator to grab entire riparian vegetation for stockpiling keeping it intact and use it again in the same area to restore the bank where feasible;
- Preventing discharges that have the potential to adversely affect water bodies;
- Stabilizing cut slopes immediately when the designed grade is obtained;
- Initiating reclamation of disturbed areas as soon as practicable;
- Verifying that water withdrawals for hydrostatic testing meet permit requirements;
- Keeping construction activities within the footprint of the ROW and the disturbed area of the adjacent construction zone to the maximum extent practicable;
- Implementing dewatering practices that prevent adverse impacts to existing quality of surface waters;
- Locating fuel storage, equipment refueling, and equipment maintenance operations at least 100 feet from surface waters;
- Minimizing construction of new, permanent-access roads by emphasizing winter construction using snow-ice roads;
- Verifying that any water discharges from hydrostatic testing meet discharge permit requirements; and
- Sampling all material sites to check the potential for acid generating rock.

*Summary of Natural Gas Pipeline Impacts*

The primary impacts to surface water quality resulting from the installation, operations, and closure of the natural gas pipeline as proposed under Alternative 2 would be associated with erosion and the introduction of fine-grained sediments (silts and clays) to surface water. These impacts would be temporary in duration and water quality would return to baseline levels following the completion of the activity responsible for the erosion and subsequent stream bank stabilization activities. Wetlands disturbed during construction would be restored shortly after installation of the pipeline. Following restoration and revegetation, few long-term effects on water quality would be expected to result from wetlands disturbance associated with construction, operation, and closure of the pipeline facilities. (Impacts to wetlands and their associated functions are described in Section 3.11, Wetlands). The intensity of the impacts to surface water quality resulting from the construction, operation, and closure of the natural gas pipeline would be considered low, because water quality would meet applicable regulatory standards due to planned BMPs and ESC measures designed to limit effects on water quality. The geographic distribution of impacts would be considered local because only discrete

portions of the pipeline corridor would be impacted. The impacted resources would be considered common to important in context.

#### 3.7.3.2.3 GROUNDWATER QUALITY

Mine Site

*Construction*

During construction, non-acid generating (NAG) waste rock with potential for metal leaching would be used for construction of the Lower CWD. The generation of seepage and runoff with elevated metals concentrations derived from metal leaching from the Lower CWD construction material could potentially infiltrate shallow (alluvial) groundwater resources in the immediate vicinity of the Lower CWD. However, detailed groundwater modeling (e.g., BGC 2014c) (Section 3.6, Groundwater Hydrology) indicates that any groundwater affected by metal leaching from the construction materials would flow towards the pit, where it would be captured by the pit dewatering system, and subsequently treated before discharge to Crooked Creek. Therefore, the groundwater quality would be affected only within a discrete portion of the mine site. Because concentrations of arsenic, antimony, and selenium are likely to exceed regulatory criteria in the solutions generated by interactions between meteoric water and NAG waste rock, the intensity of direct impacts to groundwater resources during the construction period would be high, and the impacts would be likely to persist throughout the construction and operations periods and beyond. The impacts would affect a common to important resource and would be limited to a discrete portion of the project area.

To achieve targets for depressurization of pit walls for slope stability, pumping from pit perimeter dewatering wells would begin 6 months before the start of pre-stripping, approximately 1.75 years prior to the start of operations (SRK 2012b). A description of bedrock aquifer depths affected by dewatering and their hydraulic connectivity to Crooked Creek is provided in Section 3.6, Groundwater Hydrology. Groundwater pumping during the construction period would result in localized depletion of groundwater resources within the project area, but would not be expected to affect groundwater quality. With the exception of localized inputs of metals and TDS from the use of waste rock in the construction of the Lower CWD, the quality (composition) of the groundwater would be expected to remain unchanged relative to background conditions during the construction period.

*Operations and Maintenance*

WRF and Pit Area

During mine operations, the primary mechanism for impacts to groundwater quality would involve infiltration of meteoric water contacting the WRF to the local groundwater system. Seepage from the WRF is planned to be collected in a rock underdrain and directed to the lower contact water pond for use as process water during operations. However, the WRF and underdrain would not be lined and some water from these facilities would leak into the underlying groundwater system (Section 3.6.2.3, Groundwater Hydrology). Water from the WRF would have concentrations of several constituents that are predicted to exceed the most stringent AWQC, and therefore adverse impacts to groundwater quality would occur in areas underneath and immediately adjacent to the WRF. Arsenic, antimony, and selenium are

constituents of particular concern in the seepage from the WRF, because these metals are soluble in the neutral to basic solutions likely to be generated by interactions between meteoric water and the NAG waste rock (Section 3.7.2.2.1).

Because concentrations of several constituents in the WRF seepage are expected to exceed water quality regulatory limits, the magnitude of these direct adverse impacts would be high. The duration of the effects would be long-term because the impacts would last throughout the operational period. Detailed groundwater modeling indicates that the spatial extent of impacts to groundwater quality resulting from infiltration of WRF seepage would be limited to areas immediately adjacent to the WRF and a small area between the WRF and the pit because the affected groundwater would be intercepted by the pit and the pit dewatering system (BGC 2014c).

As described in Section 3.6 (Groundwater Hydrology), pit dewatering wells would lower the water table in the vicinity of the mine pit, resulting in a cone of depression designed to direct groundwater flows towards the pit from alluvial deposits and bedrock underlying the project area (see Section 3.6.2.3). Groundwater from the pit perimeter wells and water from the in-pit dewatering wells would be treated to meet the most stringent applicable criteria prior to discharge to Crooked Creek (BGC 2014b). Thus, direct impacts to bedrock and alluvial groundwater quality resulting from infiltration of WRF seepage would be contained and would affect only a discrete portion of the project area due to the hydraulic control that would be exerted to prevent the flow of water out of the mined area of the pit (BGC 2014c).

Surface water infiltration to the WRF would be controlled through concurrent reclamation of portions of the WRF during operations. A layer designed to minimize infiltration would be placed over portions of the WRF as the placement of waste rock in those areas is completed, and the surface of this layer would be contoured to direct precipitation to the lower CWD (BGC 2011b). In addition, surface waters from the American Creek drainage would be directed around the WRF through diversion ditches. These design elements would reduce impacts to groundwater quality during operations.

#### TSF

The TSF would be designed to reduce potential impacts to the quality of groundwater. Diversion structures and ditches would be constructed upgradient to reduce surface water deposition to the TSF. The TSF would be constructed with a synthetic liner, and a seepage recovery system would be constructed downgradient from the TSF dam. The liner would substantially reduce connectivity between the TSF and groundwater resources. Any leakage through the liner would be captured by the seepage recovery system and pumped to the process plant as part of the process freshwater requirement, effectively isolating the TSF from groundwater resources during operations. Therefore, operation of the TSF would not be expected to result in impacts to groundwater quality.

#### Other Effects

Disruption, in-filling, and removal of wetlands in the American Creek, Snow Gulch, Omega Gulch, Anaconda Creek, and Crooked Creek watersheds would influence groundwater recharge and discharge patterns, which could affect groundwater quality in the vicinity of the mine site. Currently the alluvial groundwater environment is reducing, and concentrations of total and dissolved aluminum, iron, manganese, and arsenic are elevated as compared to EPA maximum contaminant levels and applicable ADEC water quality criteria for aluminum, iron,

and manganese, as discussed in Section 3.7.1.2. Reducing conditions are prevalent due partly to deposition of organic carbon from wetlands and infiltration of organic carbon during spring thaw. The redox state of the alluvium is not expected to change during mine operations; however, concentrations of metals in shallow groundwater may increase due to disruption of wetlands and increased sedimentation (SRK 2012b).

*Closure, Reclamation, and Monitoring*

Concurrent and final reclamation of WRF, TSF, remaining overburden stockpiles, and associated disturbed areas are designed to manage stormwater runoff and reduce infiltration. At mine closure, contact water would be managed and low permeability covers installed so that release of leachate from the waste rock and tailing facilities is controlled, although some infiltration and seepage through the unlined WRF and then to the pit lake is expected to continue in post-closure.

When pit dewatering is stopped, water would flow from the pit into the bedrock depressurized by dewatering wells underlying the proposed project area; this would result in inputs of sulfate and metals, and decreased pH, to the deep bedrock portions of the aquifer (SRK 2012b; see also Section 3.6, Groundwater Hydrology). Groundwater flow model analysis indicates that the period during which contaminated groundwater flows from the pit to the depressurized bedrock aquifer would last for the full period of time that it takes for the pit lake to fill; however, flow rates would be highest during the approximately 8 years following the cessation of pit dewatering. After the pit lake fills to its highest managed level, groundwater would flow back into the pit lake during the remainder of the period of closure and throughout the post-closure period, provided that pit lake levels are properly managed to maintain a net inward groundwater gradient to the pit (BGC 2014c; SRK 2012b).

*Summary of Mine Site Impacts*

Due to effective water management during the construction, operations, and closure phases, impacts to groundwater quality would be limited to discrete portions of the project area. The principal mechanisms responsible for effects to groundwater quality at the mine site would be inputs of seepage from the WRF to shallow groundwater resources underneath and immediately adjacent to the WRF, and the discharge of water from the pit to the surrounding deep bedrock groundwater. Groundwater that would be contaminated by inputs of WRF seepage would flow towards the pit, and the spatial extent of the impacts would be limited because the contaminated groundwater would be intercepted by the pit and the pit dewatering system. The magnitude of impacts to local groundwater resources would be considered high, and the duration of the impacts would be long-term; however, the magnitude of groundwater impacts outside of the cone of depression would be low, as groundwater outside of the cone of depression would be unaffected by mine contact water. The magnitude of the impacts resulting from inputs of contaminated water from the pit to the deep bedrock groundwater following the cessation of pit depressurization would be high in that the concentrations of sulfate, antimony, arsenic and selenium would be expected to increase in the deep bedrock groundwater surrounding the pit during the 52-year period following cessation of pit depressurization. However, following that period, flow modeling indicates that groundwater would flow towards the pit lake radially from all directions (BGC 2014c), thereby limiting the extent of migration of the contaminated groundwater and restricting the geographic extent of the impact.

Overall, the duration of direct impacts to groundwater resulting from Alternative 2 at the mine site would be long-term to permanent. Groundwater quality would be reduced during the life of the project, and is expected to improve following reclamation of the WRF, but some seepage from this unlined facility would continue into post-closure and would be captured by the pit, provided that the pit lake would be managed during the post-closure period to ensure that the direction of groundwater flow is towards the pit from all directions. The magnitude of local impacts to groundwater resources would be high, as the quality of groundwater would not meet regulatory criteria at certain discrete locations within the mine site (e.g., in groundwater underlying the WRF during the operations period, and in deep bedrock groundwater in the vicinity of the pit during the period following the cessation of pit depressurization activities). However, impacts to groundwater quality outside the mine facilities area are expected to be of low intensity. Groundwater resources are considered common to important in context, as there is an abundance of groundwater in the Project Area, the groundwater impacted by mine site facilities are not sources of drinking water, the impacted groundwater is not expected to be released to the environment outside of the pit lake, and the resource is governed by regulation.

#### Transportation Facilities

##### *Construction*

The construction of transportation facilities at Dutch Harbor, Bethel, and Angyaruaq (Jungjuk) ports proposed under Alternative 2 are not expected to have measurable effects on groundwater quality. It is possible that placement of sheet pile associated with the construction of transportation terminals at Bethel and Angyaruaq (Jungjuk) ports would have localized impacts on the rates of exchange between surface water and shallow groundwater deposits along the banks of the Kuskokwim River (see Section 3.7.2.2.2). These impacts would be limited to the areas immediately adjacent to the terminal facilities, and the effects on the composition of the groundwater and availability for beneficial uses would be negligible. The use of groundwater for drinking water supplies at the Angyaruaq (Jungjuk) Port would not adversely affect groundwater quality.

##### *Operations and Maintenance; and Closure, Reclamation, and Monitoring*

Operations of the transportation facilities proposed under Alternative 2 are not expected to have measurable effects on groundwater quality. Closure of the transportation facilities would not be expected to result in any additional impacts.

##### *Summary of Transportation Facilities Impacts*

Impacts to groundwater quality resulting from changes in the rates of surface water-groundwater interactions during the construction, operations, and closure phases would be low in intensity, temporary, localized, and impact common to important resources.

#### Natural Gas Pipeline

##### *Construction; and Operations and Maintenance*

Potential impacts to groundwater quality during construction and operation of the natural gas pipeline are expected to be minimal (SRK 2013b). The primary impacts would be associated with installation of the pipeline which could result in alterations to groundwater flow patterns

and small changes in the composition of the groundwater. Such impacts would be low intensity because groundwater quality would not be expected to exceed applicable regulatory criteria. The impacts would be temporary in duration, as the period of impacts would be focused on the construction phase and ground water flow (drainage and recharge) patterns should reestablish after site reclamation has been completed (SRK 2012b). The geographic extent would be local and limited to particular areas, primarily in the vicinity of river and stream crossings (SRK 2013b).

*Closure, Reclamation, and Monitoring*

Groundwater drainage patterns should reestablish after site reclamation has been completed (SRK 2013b). Under Alternative 2, the pipeline would be abandoned in place; therefore, no additional impacts to groundwater quality are expected to be associated with the termination phase, except perhaps for the production and mobilization of minor corrosion products from the steel pipe sections. This effect is expected to be relatively low intensity and limited in extent.

*Summary of Natural Gas Pipeline Impacts*

Natural gas pipeline construction activities described under Alternative 2 would result in low intensity, localized impacts to groundwater quality at discrete locations. The duration of these impacts would be temporary, as groundwater quality would rapidly return to pre-activity levels following reclamation. Because groundwater resources are abundant in the area proposed for pipeline construction, but are governed by regulation, the affected resources are considered common to important.

#### 3.7.3.2.4 SEDIMENT QUALITY

<u>Mine Site</u>

*Construction*

Under Alternative 2, construction of the mine site and associated facilities could result in increased erosion that could produce increased sediment deposition in Crooked Creek and tributaries if uncontrolled. Extensive sediment control measures would be identified in the SWPPP that are required to be developed and implemented as part of the mine permitting process. Active sediment controls used during construction would include silt fences, hay bales, sediment control basins, cross bars and ditches, revegetation, and BMPs to reduce the intensity of surface runoff and sediment loading (see Section 3.2, Soils). Specific ESC design features at the overburden stockpiles would include diversion channels, berms, and sedimentation ponds. Thus, impacts to sediment quality during construction are expected to be minor.

*Operations and Maintenance*

The primary sources of impacts to sediment quality at the mine site during operations would involve increased mercury concentrations in sediments as a result of atmospheric deposition. In order to understand the effect of additional mercury deposition from atmospheric sources on sediment quality in the vicinity of the mine site, a conceptual site model was developed that identified the sources, potential exposure routes, and transport mechanisms of mercury in the environment (ARCADIS 2014). Based on the conceptual site model, baseline data, and results of

deposition modeling, the incremental increases in sediment concentrations as a result of project air emissions were estimated. These estimates were developed for Year 27 of the mine life, since this represents the maximum deposition and potential impact (SRK 2014a). If it is assumed that all of the mercury deposited from the atmosphere immediately adheres to stream sediment at the sediment surface (a conservative assumption, especially in areas of highest deposition), then estimated sediment mercury increases would be as shown in Table 3.7-44. The greatest estimated increase of mercury in sediment occurs in the Crooked Creek watershed, and the lowest estimated increase occurs in the Village Creek watershed (ARCADIS 2014). The model results demonstrate an estimated 2.5 percent increase in sediment mercury concentrations closest to the Donlin Camp and 0.2 percent increase at the Bell Creek watershed (SRK 2014a). While these increases are small, the increased concentrations of mercury in sediment may result in increases in the mercury content of fish, wildlife, and plants. However, the impacts to sediment quality would be minor.

**Table 3.7-44: Estimated Changes in Sediment Concentrations as a Result of Changes in Mercury Deposition Rates**

| Watershed | Modeled Total Hg deposition[1] (µg/m²-y) | Current Sediment Average Total Hg Concentration (µg/kg) | Modeled Total Hg deposition rate (µg/kg/year) | Average Total Hg concentration at 27 years (µg/kg) | % Increase at 27 years |
|---|---|---|---|---|---|
| Crooked Creek HUC 12 | 4.8 | N/A | 0.16 | N/A | N/A |
| Donlin Creek HUC 12 | 2.3 | 173 | 0.08 | 175 | 1.2% |
| Grouse Creek HUC 12 | 1.7 | 236 | 0.06 | 238 | 0.6% |
| Flat Creek HUC 12 | 1.0 | 238 | 0.03 | 238 | 0.4% |
| Bell Creek HUC 12 | 0.5 | 205 | 0.02 | 206 | 0.2% |
| Village Creek HUC 12 | 0.4 | 43 | 0.01 | 43 | 0.8% |

**Notes:**

1 Modeled deposition rates from stack and fugitive sources associated with the project (Environ 2013).

The threshold effects level (TEL) and probable effects level (PEL) for mercury in sediment are 174 µg/kg and 486 µg/kg respectively. Values that exceed the 174 µg/kg PEL are shaded in the table.

N/A means not available

Source: ARCADIS 2014.

Although methylmercury generally represents a very small fraction of the total mercury content in sediments, it is of interest due to its ability to cross membranes in living organisms, high lipid solubility, and relatively high toxicity compared to other forms of mercury. For example, essentially all mercury in freshwater fish tissues is in the form of methylmercury, even though methylmercury typically accounts for less than 1 percent of the total mercury pool in a lake (ATSDR 1999). Therefore, methylation of mercury is a key step in the entrance of mercury into food chains (EPA 2010a).

In-river methylation is typically a negligible component of the methylmercury budget for creeks, whereas mercury methylation in wetlands may be an important contributor of methylmercury to downstream aquatic ecosystems (St. Louis et al. 1994; Berndt and Bavin 2012). The geochemical data collected in the aquatic systems in the study area generally indicate that stream sediments in the study area are neither a sink for mercury nor a source of

methylmercury production (ARCADIS 2014). The potential for mercury methylation in these environments is low and is generally limited by the availability of bioavailable carbon and other nutrients, which are required to sustain heterotrophic microbiological activity that drives the methylation of mercury in anoxic environments (ARCADIS 2014). In sediments in the vicinity of the proposed mine site, the average TOC concentration is low (1.7 percent), the pH is neutral (7.1), and average sulfate and sulfide concentrations are relatively low (13,000 and less than 5,000 μg/kg, respectively) (ARCADIS 2014). It should be noted that a study by Wang (1999) reported sediment TOC concentrations ranging from 3.6 percent to 5.4 percent in samples collected from a single location in Crooked Creek near its confluence with the Kuskokwim River, suggesting that concentrations of TOC in Crooked Creek sediment may be higher at locations near the confluence with the Kuskokwim River relative to upgradient locations in the vicinity of the proposed mine site.

Even if sulfate concentrations were to increase in some stream sections as a result of water treatment plant discharge, the low concentrations of nutrients would likely continue to limit methylation potential in stream sediments (ARCADIS 2014). As described in Section 3.6, Groundwater Hydrology, pit de-watering as part of the mine operations would result in a large area around the pit becoming dryer. As these areas dry out, the breakdown of organic material could increase due to oxidation of organic material within the cone of depression. After mine closure, the water table would rise again, and previously dry soils would become rewetted. This could result in a pulse of bioavailable carbon into the system which could stimulate mercury methylation. However, due to the relatively low organic content of soils within the cone of depression, the resulting pulse of bioavailable carbon is likely to be small. Methylation of mercury requires the simultaneous occurrence of several conditions including anoxia, availability of carbon and other nutrients, presence of mercury-methylating bacteria, and pH values amenable for mercury methylation. An increase in any one of the factors necessary for mercury methylation would not necessarily result in increased methylation rates in sediments.

The potential for mercury methylation and bioaccumulation in the FWDD and CWD reservoirs would be insubstantial due to the low concentrations of dissolved organic carbon to support heterotrophic bacterial activity in these reservoirs, and the lack of higher trophic level biota, which would be requisite for bioaccumulation.

Thus, aquatic systems in the study area have a low rate of methylmercury production, and this rate is not expected to change as a result of the activities proposed under Alternative 2 (ARCADIS 2014).

Additional impacts to sediment quality in the Crooked Creek watershed could result from stream flow alteration and changes in the surface water chemistry in Crooked Creek as a result of the activities associated with Alternative 2. However, such impacts would be low intensity because changes in sediment quality would be unlikely to exceed Sediment Quality Guidelines (SQGs) recommended by ADEC (Buchman 2008).

*Closure, Reclamation, and Monitoring*

After mine closure, the majority of the facilities including the WRF, the SOB stockpile, and TSF would be reclaimed. Surface runoff from the top of the WRF, as well as water that seeps through the reclamation cover, would be conveyed to the then-closed pit. Runoff from the SOB stockpile would be directed to control basins to allow sediment in the runoff to settle out, and then would be discharged directly to Crooked Creek. As a result of careful water management

during closure and post closure activities, direct impacts to sediment quality at the mine site are expected to be negligible during the closure and reclamation period.

Impacts to sediment quality from mercury and effects on mercury methylation would gradually decline during the post-closure period. Mercury methylation rates in stream sediments would likely continue to be limited by the availability of nutrients and organic carbon in aquatic systems in the vicinity of the mine site, and would not necessarily be expected to result in substantial impacts to concentrations of mercury and methyl mercury in sediments.

*Summary of Mine Site Impacts*

Impacts to sediment quality would be local and would affect only discrete portions of the mine site. Although effects to sediment quality may result from altered stream flows and water chemistry in Crooked Creek and project-related atmospheric deposition of mercury, these effects would be low in intensity, as concentrations of mercury and methylmercury are predicted to remain within the range of naturally occurring values presently found in the study area. Also, snow removal from roads may also impact sediment quality. Sediment is considered common to important in context; although sediment can be considered an abundant resource in most drainages, impacts to sediment may also influence other resource types (e.g., fish and other biological resources). While sediment in the Donlin Gold Project area is governed by neither ADEC nor EPA regulations, it is the subject of Sediment Quality Guidelines (SQGs) recommended by these agencies.

Transportation Facilities

The primary project-related mechanisms of impact to sediment quality in the transportation corridor under Alternative 2 would be associated with the construction of shoreside facilities at the Bethel and Angyaruaq (Jungjuk) ports, and occasional sediment disturbance by propeller wash during low water periods in the Kuskokwim River. In-stream construction has the potential to contribute to increased sediment loads at downstream locations.

*Construction*

As discussed in Section 3.2.2.2.1, Soils, there is potential for erosion and resuspension of fine-grained sediments during barging and construction of both the Bethel and the Angyaruaq (Jungjuk) ports. Construction of the Bethel Port would involve placement of approximately 1,150 linear feet of sheet pile at an average depth of approximately 20 feet below MLLW along approximately 850 feet of the Kuskokwim River shoreline. Similarly, construction of the Angyaruaq (Jungjuk) Port would involve placement of sheet pile bulkhead in the Kuskokwim River. The sheet pile cells would be backfilled to create a dock with an area of approximately 5 acres. There is also the potential for localized sediment erosion at certain critical sections of the river during low water periods (see Section 3.5, Surface Water Hydrology). Under Alternative 2, fine-grained sediments eroded or resuspended as a result of construction activities and barging could contribute to increased sediment loads and deposition.

The eroded sediments deposited would be similar in composition to the naturally extant sediments. Due to the natural dynamics of sediment transport in the Kuskokwim River, the duration of any effects to sediment quality resulting from the redistribution of sediments would be temporary. Effects would be limited to the time period of construction of the port facilities, and sediment quality would be expected to return to pre-activity conditions at the completion

of the construction activity. The effects would be limited to a discrete portion of the project area and the affected sediments would be considered common in context. Temporary bank stabilization and/or mitigation measures would be required along or near construction areas bordering the Kuskokwim River shoreline for SWPPP compliance during terminal construction. Permanent erosion control at the port sites would include the installation of sheet pile and construction of sheet pile bulkheads at both the Angyaruaq (Jungjuk) and Bethel ports.

In general, the mine access road and airstrip would be constructed using conventional cut-and-fill techniques. At intervals not appropriate for cut-and-fill construction, for example, where snow-drifting and permafrost are a concern, an elevated fill section would typically be employed. The currently defined routes can be constructed with conventional equipment and methods. No excessively large cuts or fills would be required. A final surfacing layer would be applied, consisting of crushed and/or screened material that is suitable as a surface maintenance and wear course. Stormwater BMPs would be implemented according to a SWPPP (Section 3.2, Soils) to mitigate potential erosion effects on downgradient sediment quality.

*Operations and Maintenance; and Closure, Reclamation, and Monitoring*

Impacts to sediment quality during operations would be less than those during construction at the ports, road, and airstrip, because BMPs and ESC measures employed to control erosion and sedimentation effects are expected to stabilize in operations (Section 3.2, Soils). The potential for barge-induced resuspension of bottom sediment in operations would be the same as described above for construction.

The mine access road, Angyaruaq (Jungjuk) Port, and airstrip are required for post-mining reclamation and closure activities, and would remain as long-term assets after the end of mining. Therefore the impacts to sediment quality associated with transportation facilities during the post-closure period would be similar to those during operations.

*Summary of Transportation Facilities Impacts*

Effects on sediment quality resulting from the construction, operations, and closure of the transportation facilities are expected to be of low intensity (e.g., resettled sediment would be of similar composition to the existing natural deposit). The duration of effects would be temporary and localized within the immediate vicinity of the road, ports, and critical sections of the river. Sediment is considered common to important in context.

Natural Gas Pipeline

*Construction*

Under Alternative 2, the primary mechanisms of impact to sediment quality resulting from construction of the natural gas pipeline would involve soil erosion associated with installation of the pipeline at river and stream crossings, and clearing of riparian habitat along the pipeline ROW. Streambank alterations at pipeline crossings could result in increased water velocity, increased erosion both upstream and at the location of the pipeline crossing, and increased deposition of sediment at downstream locations. Along the pipeline ROW, reduced permeability and infiltration associated with vegetation removal and compaction of near-surface soils would result in increased surface runoff and sediment input compared to natural conditions. Additionally, removal of vegetation from streambanks could result in changes to

streambank stability, runoff patterns, and temperature regimes, potentially resulting in effects to sediment quality.

The majority of rivers and streams along the pipeline route would be crossed by open cutting in the winter when flows are lowest and disturbance of the river and streambanks can be held to a minimum (SRK 2013b). In general, the open-cut method would be used for three different types of water bodies:

- Intermittent streams, ditches, and non-sensitive water bodies where sedimentation is not a key consideration;
- Frozen rivers or streams in winter that have no surface flow; and
- Streams and rivers so large that no isolation method can be used.

Cuts would be excavated using chain trenchers, wheel trenchers, or backhoes, and crews would be equipped with both backhoes and trenchers to provide the technique best suited for each soil type (SRK 2013b). Trench width would vary, depending on what piece of equipment is used for excavation, but generally, trench width would be approximately 18 to 30 inches wide to allow for placement of pipe and backfill without excavating more material than necessary. At river and stream crossings, trench width at the ground surface may be wider to accommodate the sloughing action of soils in high groundwater tables (SRK 2013b). If necessary, sedimentation at stream crossing locations would be controlled during trench dewatering with the use of sedimentation basins, geofabrics, and silt fences, which would limit the magnitude of impacts to sediment quality at downstream locations. For larger rivers, the trench would be excavated through the water body using backhoes operating from the banks or within the water body (SRK 2013b). Equipment operating within active stream channels would compact substrate and resuspend sediment, resulting in increased sedimentation and changes to sediment quality at downstream locations. For wide, braided rivers, backhoe operators would utilize channel diversion techniques to create places from which equipment could operate outside of active stream channels (SRK 2013b). Resulting impacts to sediment quality would be of low intensity because concentrations of constituents of concern in sediments would be unlikely to exceed chemical SQGs recommended by ADEC, and sediment grain size in depositional areas downstream of the ROW are likely to be similar to that of the construction area.

BMPs and ESC measures that would minimize inputs of silt and suspended sediment to active stream channels are described in SRK (2013b) and Section 3.2 (Soils–Erosion). Excavated material from intermittent streams, trenches, and non-sensitive water bodies would be placed at least 10 feet from the water's edge on the construction ROW and would be contained as necessary using silt fencing. For water bodies other than non-flowing streams or drainage ditches, trench plugs would be placed between the upland trench and the in-stream activities to prevent diversion of water into upland portions of the pipeline trench and to keep sediment-laden trench water out of the water body. In order to control potential impacts to sediment quality resulting from trenching and excavation activities during pipeline construction, excavated mineral soils would be stored separately from windrowed, organic spoil piles. Subsoils would not be stored in flowing water bodies, dry drainages, or washes that cross the ROW. Subsoil would be placed on the banks of the drainage in such a manner as to prevent sedimentation from occurring. Temporary erosion control measures including stormwater control measures, such as rolled erosion control product sediment barriers (e.g., brush barriers or silt fences) and water interception or diversion ditches, would be installed as needed to

contain disturbed soils on the construction ROW and to minimize the potential for sediment to enter wetlands or water bodies. After installation, erosion control measures would be regularly inspected and maintained in effective operating condition throughout the duration of construction, until soil sediment stabilization is achieved and reclamation is complete.

Select rivers and streams would be crossed using Horizontal Directional Drilling (HDD) technology (SRK 2013b). A Drilling Mud Disposal Plan would be prepared as part of the overall *HDD Practices, Contingency, and Resource Protection Plan* prior to work taking place on any stream crossing where HDD would be used. For the purposes of this analysis, it is assumed that the plan would prohibit discharges of HDD drilling fluids to the environment, and would include appropriate provisions for the disposal of drilling wastes. With the exception of a potential frac-out into the overlying river (see Section 3.3, Geohazards and Seismic Conditions), HDD techniques are expected to result in negligible disturbance to stream beds and active stream channels. Stream crossings using HDD practices are not expected to experience measureable direct impacts to sediment quality.

One of the most important erosion and sedimentation control considerations is the timing of construction activities. The time between initial disturbances and post construction stabilization is a critical element in minimizing adverse impacts to sediment quality (Corps 2014b). Under Alternative 2, pipeline construction would occur in two spreads, which would be subdivided into various sections. Each section would be completed during one construction season (either summer or winter depending on the location of the specific spread). In order to control the potential for impacts to sediment quality, ground disturbances would be reclaimed concurrent with construction or as soon as conditions allow after construction is completed. In the interim, the areas would be cleaned and stabilized, and any necessary erosion control measures would be implemented (SRK 2013b). The short timeframes between initial disturbance and final stabilization would limit both the duration and the magnitude of impacts to sediment quality associated with pipeline construction.

#### Summary of Construction Effects

Sediment quality would be adversely affected by pipeline construction as a result of increased sedimentation at stream crossing sites. The proposed pipeline corridor crosses more than 400 individual streams ranging in size from small, intermittent channels to large glacially fed river systems (CH2M Hill 2011b). Sedimentation can occur from trenching to lay pipeline beneath the stream channel, runoff at construction sites, and erosion resulting from construction of culverts, roads, bridges, or fords associated with the pipeline ROW. Silt or sand resuspended as a result of construction activities could fill interstices in gravel and reduce water flow through substrate. In addition, resuspension of sediments could result in localized increases in biological oxygen demand, and increased bioavailability of nutrients. The duration of such impacts would be temporary, and in most cases, sediment quality would return to pre-activity levels upon completion of the construction activities at a given site. The magnitude of impacts during construction would be low, because although measureable increases in runoff and sedimentation could occur as a result of pipeline construction activities, the resulting impacts to sediment quality would not exceed regulatory limits, and would be minimized through winter construction and the use of BMPs and ESC measures. The impacts would be local because they would affect only discrete portions of the project area, and are expected to remain within the immediate vicinity of the ROW. Sediment quality is considered a common to important resource.

*Operations and Maintenance; and Closure, Reclamation, and Monitoring*

Expected impacts to sediment quality resulting from the normal operation of the pipeline under Alternative 2 would be negligible. In all cases, the pipe would be buried to a depth that is below the scour potential of the particular river or stream (Section 3.5, Surface Water Hydrology), such that operation of the pipeline would not result in measureable impacts to sediment quality (SRK 2013b). Increased runoff from cleared riparian areas could result in inputs of sediment that would affect sediment quality in streams and rivers along the pipeline route. However, timely reclamation of the ROW would involve methods to recontour and revegetate disturbed areas with native vegetation to maintain surface drainage patterns. The Surveillance and Monitoring Plan and the Erosion and Sedimentation Control Plan would address maintenance of surface drainage patterns and monitoring. BMPs, mitigation measures, and the requirements of the SWPPP would also be used to mitigate impacts to sediment quality within the project area.

If the pipe is abandoned in place at project closure, as may be authorized by the Pipeline Abandonment Plan, any new impacts to sediment quality that could be caused by removal of the pipe would be avoided.

*Summary of Natural Gas Pipeline Impacts*

Under Alternative 2, some temporary measureable impacts to sediment quality would occur as a result of increased sediment loads to area streams during construction of the natural gas pipeline. The magnitude of the impacts would be low, assuming adherence to construction practices, design features, and BMPs specified in the Pipeline Plan of Development (SRK 2013b). The impacts would be local because they would affect only discrete portions of the project area, and would affect common to important resources.

#### 3.7.3.2.5 CLIMATE CHANGE

Predicted overall changes in precipitation and patterns of runoff have the potential to influence the projected effects of the Donlin Gold Project on water quality. These effects are tied to changes in water resources as discussed in Section 3.26.4.2.2, Climate Change.

#### 3.7.3.2.6 SUMMARY OF IMPACTS FOR ALTERNATIVE 2

Direct impacts to geochemistry, surface water quality, groundwater quality, and sediment quality at the mine site would range from low intensity (e.g., water that meets AWQC and is eventually discharged) to high intensity (e.g., water from the WRF and the isolated PAG cells, TSF, TSF cover, and possibly the overburden stockpiles that does not meet AWQC). Although potential impacts may increase with increased rock disturbance, real impacts to downgradient water quality may be reduced by mitigation efforts and material handling. Surface water from the pit lake would eventually be treated to meet AWQC (i.e., reduced to low intensity) and discharged. Additional mitigation measures are provided in Chapter 5 that could help manage pit lake water quality efforts in post-closure and reduce potential impacts from the overburden stockpiles. Permanent changes to surface water quality in the American Creek watershed would result from the creation and perpetual maintenance of the pit lake; however, due to water treatment and water management practices, contaminated water from the pit lake would not leave the American Creek watershed, and would therefore be restricted to a discrete portion of the project area. Localized high intensity impacts to groundwater quality at the mine site would

occur as a result of activities conducted during the operations and closure periods; specifically, seepage from the WRF and flow of water from the pit lake into backfill and dewatered bedrock void spaces in the immediate vicinity of the pit lake would contaminate the local groundwater system; however, this water would subsequently flow back into the pit lake for eventual treatment and discharge after meeting AWQC standards. Impacts to groundwater quality outside of the mine facilities area would be mostly of low intensity. There is a low risk that high intensity impacts to surface and/or groundwater could result in the event of SRS pump failure in post-closure.

The impacts to sediment quality of greatest concern would be associated with increased concentrations of mercury and methylmercury in sediments in the Crooked Creek watershed resulting from atmospheric deposition of mercury released by mine site facilities. However, detailed modeling has demonstrated that concentrations of mercury in sediments would increase by a maximum of 2.5 percent over existing levels (SRK 2014a). Therefore, the increased concentrations of mercury in sediment, while measurable, would be consistent with regional background concentrations and would be unlikely to exceed regulatory guidelines for mercury concentrations in sediments. The magnitude of such impacts would therefore be considered low, and would generally decrease with increasing distance from the mine facilities; their geographic extent would be considered local.

The duration of impacts to surface water quality would be considered long-term (e.g., elevated mercury concentrations in surface water and sediments potentially lasting through operations) to permanent (e.g., pit lake). It is anticipated that mercury concentration levels would slowly return to pre-activity levels following completion of the project. The geographic extent of most water quality impacts would be local, in that impacts are expected to be limited to the immediate vicinity of specific project components. Impacts to surface water quality could also be regional in extent due to the potential for mercury deposition from atmospheric sources to occur inside and outside of the immediate project area. Water quality impacts are considered common (e.g., abundance of groundwater resources in the project area) to important (e.g., quality of water that is released into the environment is governed by regulation) in context. Overall impacts to water quality associated with the mine site are considered minor to moderate (see Table 3.7-45).

For the transportation facilities associated with Alternative 2, effects to surface water quality would be considered low intensity (e.g., occasional barge–induced suspended sediment, or erosion effects at construction sites), due to high natural conditions and/or planned mitigation measures designed to limit erosion effects. The geochemistry of rocks disturbed by mining would not impact water quality in the transportation facilities areas. Potential impacts resulting from runoff of water from NAG rock used for road construction could include inputs of arsenic, selenium, antimony, and possibly other constituents of concern, to area surface water resources, including Jungjuk Creek. The geographic distribution of such impacts would be limited to areas in the immediate vicinity of roads and road construction material stockpiles, and could be mitigated through implementation of a materials testing program prior to the beginning of road construction activities (Section 3.7.3.8). The duration of such impacts would be considered long-term because the impacts would be likely to persist for the duration of the project, and water quality would return to baseline levels at some time following the cessation of mining operations. Impacts to groundwater quality resulting from changes in the rates of surface water-groundwater interactions would be temporary and low in intensity. Any effects on sediment quality resulting from the transportation facilities would be low intensity (e.g., resettled

sediment would be of similar composition to the existing natural deposit). The duration of effects would be temporary and localized within the immediate vicinity of the road, ports, and critical sections of the river. Surface water quality, groundwater quality, and sediment quality are considered common to important resources. Overall impacts to water quality associated with the transportation facilities of Alternative 2 are considered minor.

The primary impacts to surface water quality resulting from the natural gas pipeline as proposed under Alternative 2 would be associated with erosion and the introduction of fine-grained sediments (silts and clays) to surface water. The intensity of these impacts would be considered low, because surface water quality would meet applicable regulatory standards due to planned BMPs and ESC measures. Some temporary measureable sediment quality impacts would also occur as a result of increased sediment loads to area streams during construction of the pipeline. The intensity of the impacts would be also be low, assuming adherence to construction practices, design features, and BMPs. Surface water quality and sediment quality would return to baseline levels following the completion of the activity responsible for the erosion and subsequent stream bank stabilization activities, so impacts would be considered temporary in duration. Wetlands disturbed during construction would be restored shortly after installation of the pipeline. Following restoration and revegetation, few long-term effects on water quality would be expected to result from wetlands disturbance associated with the pipeline facilities. The geochemistry of rocks disturbed by mining would not impact water quality in the pipeline corridor. The geographic distribution of impacts would be considered local because only discrete portions along the pipeline corridor would be impacted. Because surface water, groundwater, and sediment resources are abundant in the project area, but are governed by regulation, the affected resources are considered common to important. Overall impacts to water quality associated with the pipeline under Alternative 2 are considered minor.

**Table 3.7-45: Summary of Impacts to Water Quality for Alternative 2**

| Impacts | Impact Level | | | | |
|---|---|---|---|---|---|
| | Magnitude or Intensity | Duration | Geographic Extent | Context | Summary Impact Rating[1] |
| **Mine Site** | | | | | |
| Surface Water Quality | Low (e.g., treated water discharge to Crooked Creek meets AWQC) and High (mercury deposition could cause AWQC exceedance) | Temporary to Long-term (mercury deposition effects) to Permanent (treated pit water discharge) | Local to Regional | Common to Important | Minor to Moderate |
| Groundwater Quality | Low (outside cone of depression) and High (locations within the mine site) | Long-term to Permanent | Local | Common to Important | |
| Sediment Quality | Low (potential increases consistent with regional background) | Temporary to Long-term | Local | Common to Important | |

**Table 3.7-45: Summary of Impacts to Water Quality for Alternative 2**

| Impacts | Impact Level | | | | |
|---|---|---|---|---|---|
| | Magnitude or Intensity | Duration | Geographic Extent | Context | Summary Impact Rating[1] |
| **Transportation Facilities** | | | | | |
| Surface Water Quality | Low (e.g., barge-induced suspended sediment similar to high natural conditions) | Temporary to Long-term | Local | Common to Important | Minor |
| Groundwater Quality | Low (e.g., localized groundwater interaction at port construction sites) | Temporary | Local | Common to Important | |
| Sediment Quality | Low (sediment deposition similar to natural material) | Temporary | Local | Common to Important | |
| **Pipeline** | | | | | |
| Surface Water Quality | Low (increased turbidity controlled by BMPs) | Temporary to Long-term | Local | Common to Important | Minor |
| Groundwater Quality | Low (e.g., from minor pipe corrosion) | Temporary | Local | Common to Important | |
| Sediment Quality | Low (increased sedimentation controlled by BMPs) | Temporary | Local | Common to Important | |

**Notes:**

1 The summary impact rating accounts for impact reducing design features proposed by Donlin Gold and Standard Permit Conditions and BMPs that would be required. It does not account for additional mitigation measures the Corps is considering.

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

Design features that are most important for reducing impacts to water quality include the following:

- Material sites at the mine site, mine access road, and pipeline would be evaluated prior to use for metals leaching and acid rock drainage potential in final design using bulk geochemistry analysis, meteoric water mobility procedure, and acid-base accounting methods. Alternative sites would be selected if results indicate the potential for impacts to downgradient water resources.
- The TSF will include a relatively flexible, textured geomembrane liner (60 mil or 1.5 mm) that is expected to withstand freezing temperatures, sharp rocks, and anticipated settlement scenarios with an appropriate factor of safety and to minimize impacts from porewater seepage on groundwater quality;

- The layout of major mine facilities is intentionally compact to minimize wetland impacts and limit effects on water quality to the American and Anaconda Creek watersheds. The 404(b)(1) analysis will document the steps taken to minimize wetlands impacts;
- All mine contact water would be collected and reused or treated and discharged; and
- The project design includes use of BMPs at pipeline stream crossings to minimize alterations of the stream bed and bank erosion. It also includes design of pipeline depth of burial at stream crossings to avoid scour exposure of the pipe.

Standard Permit Conditions and BMPs related to water quality include:

- Implementation of SWPPPs and / or Erosion and Sediment Control Plans;
- Preparation and implementation of a Stabilization, Rehabilitation, and Reclamation Plan; and
- Use of BMPs such as watering and use of dust suppressants to control fugitive dust.

#### 3.7.3.2.7 ADDITIONAL MITIGATION AND MONITORING FOR ALTERNATIVE 2

The Corps is considering additional mitigation (Table 5.5-1 in Chapter, Impact Avoidance, Minimization, and Mitigation) to reduce the effects presented above. Additional mitigation measures related to water quality include the following:

- ESC measures specified for snow stockpiles along the ROW include water diversion ditches leading to energy dissipators. Additional measures such as settling ponds, silt fences, or sediment barriers should be considered to minimize the amount of sedimentation from snowmelt; and
- The South Overburden Stockpile (SOB) is composed of materials that are potentially metal leaching. The proposed diversion channels and sediment pond may not be adequate to capture groundwater beneath the SOB that could become contaminated from seepage / leachate and flow towards Crooked Creek. One of the following options should be considered for this facility:
    1. Hydraulic containment (deep sump as part of sediment pond) and downgradient monitoring wells. The feasibility of digging a deep sump should be evaluated further during design work;
    2. Physical containment (liner beneath SOB and sediment pond); or
    3. Additional studies during design work (fate and transport groundwater modeling) to demonstrate a lack of substantial groundwater volume that would result in no major impact on the creek, as a result of natural attenuation of a small temporary slug of contaminated groundwater.

    In all cases, the sediment pond should be equipped with redundant and freeze-protected pumping systems, and the sediment excavated and properly disposed of at closure.

The Corps is considering additional monitoring and adaptive management (Table 5.7-1 in Section 5.7, Impact Avoidance, Minimization, and Mitigation) to reduce effects on water quality. These include the following:

- Recommend adding the upstream monitoring site DCBO as control point for monitoring water quality and discharge;
- The potential exists for arsenic and/or other metals leaching and ARD formation from overburden taken from the pit and TSF areas and stored in stockpiles near Crooked Creek. Water quality monitoring should be conducted during operations in the sedimentation ponds downgradient of the North and South overburden stockpiles, as well as in Lewis Gulch for the North overburden pile. Monitoring results would form the basis for additional adaptive management measures (such as increased pumping or pond size) to reduce potential water quality effects;
- Additional alluvial and/or bedrock groundwater monitoring wells should be considered at locations downgradient of mine facilities not already covered by the existing monitoring network (e.g., overburden stockpiles), where sufficient alluvial aquifer material is present that could represent a pathway to Crooked Creek, and bedrock groundwater is not captured by the pit cone of depression;
- The pond collecting the flow from the drain layer of the TSF cover is planned to be monitored quarterly during Years 6 through 10 post-closure. It is recommended that drainages from the NAG WRF and the isolated PAG cells also be monitored on a quarterly basis to allow evaluation of seasonal variability and the effects that variability may have on the pit lake stratification when these waters are pumped to the deep layers of the pit lake;
- According to the Water Resources Management Plan (SRK 2012b), surface and groundwater monitoring systems in closure would remain in place "up to and possibly beyond 30 years, depending on compliance history" until each facility has stabilized, physically and chemically, to the satisfaction of regulatory agencies. The PAG 5 rock in the WRF is not predicted to produce ARD for several decades (SRK 2007). Therefore, ARD may not develop in the NAG portion of the WRF until after the 30 years of suggested monitoring. Accordingly, it is recommended that long term, semi-annual (after spring melt and in late summer) monitoring and sampling of the NAG WRF seepage continue long term; and
- Collection of additional groundwater quality data in Anaconda valley upgradient of the TSF should be considered prior to construction in order to establish site-specific background conditions that are pertinent to future monitoring and decommissioning of the SRS. This might involve installation of 1 to 2 additional monitoring wells east and southeast of the TSF.

If these mitigation and monitoring measures were adopted and required, the summary impact ratings would be reduced for surface water quality, groundwater quality, and sediment quality, but would remain minor to moderate for the mine site. The summary impact for the transportation facilities and the natural gas pipeline could also be somewhat reduced with mitigation, but overall would remain minor.

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

#### 3.7.3.3.1 GEOCHEMISTRY

Geochemical direct and indirect cumulative impacts under Alternative 3A would be the same as discussed for Alternative 2, as the mine site and associated facility footprints would be the same.

Surface Water Quality

*Mine Site*

Alternative 3A would involve the construction of an LNG plant, LNG tanks, and LNG-fueling infrastructure for haul trucks at the mine site. These facilities would be located within the same facilities footprint proposed under Alternative 2, and are not expected to result in any changes in impacts to surface water quality at the mine site during construction, operations, or closure relative to Alternative 2. Potential impacts resulting from metals leaching from NAG used for construction of mine facilities would also be the same as those described under Alternative 2. The same design features and mitigation measures would apply to Alternative 3A as were discussed under Alternative 2.

*Transportation Facilities*

Alternative 3A would involve a decreased number of barge trips relative to Alternative 2. The number of trips would decrease by 32 percent or about one-third, resulting in about one fewer barge pass per day. The decrease in barging activity would presumably reduce the risk for impacts to surface water quality resulting from spills. In addition, potential impacts to water quality in the Kuskokwim River resulting from increases in suspended sediment concentrations and turbidity at some shallow water locations would decrease by approximately 32 percent under Alternative 3A relative to Alternative 2, assuming a linear relationship between the number of barge trips and the potential impacts to water quality resulting from barging. Under Alternative 3A, the impacts to surface water quality in the Kuskokwim River resulting from normal barging operations would be minor; the impacts would be low in magnitude and local in geographic extent; the duration of such impacts would be temporary, and the impacts would affect a common resource. Closure and reclamation activities related to transportation facilities would be the same under both Alternative 3A and Alternative 2.

*Natural Gas Pipeline*

Impacts to surface water quality associated with the pipeline component of Alternative 3A would be the same as discussed under Alternative 2. The primary impacts to surface water quality resulting from the installation, operations, and closure of the natural gas pipeline would be associated with erosion and the introduction of fine-grained sediments (silts and clays) to surface water. These impacts would be temporary in duration. The intensity of the impacts would be considered low, because water quality is expected to meet applicable regulatory standards due to planned BMPs and ESC measures designed to limit erosion effects on surface water quality. The geographic distribution of impacts would be considered local because only discrete portions of the pipeline corridor would be impacted. The impacted resources would be considered common to important in context. Overall effects to surface water quality resulting

from the construction, operations, and closure of the pipeline as described under Alternative 3A would be considered minor.

Groundwater Quality

Impacts to groundwater quality associated with the mine site, transportation facilities, and pipeline components of Alternative 3A would be the same as discussed under Alternative 2. The reduced barging and operation of LNG-powered rock trucks at the mine site associated with Alternative 3A would not result in changes to any of the principal mechanisms of impact to groundwater quality at the mine site that were described under Alternative 2. The use of LNG-powered rock trucks instead of diesel-powered rock trucks would decrease the potential for spills associated with diesel fuel handling. However, under Alternative 3A, the WRF and pit lake, which are the facilities responsible for the principal mechanisms of impact to groundwater quality, would be constructed, operated, and closed in a manner identical to that described under Alternative 2. Overall impacts to groundwater quality resulting from the activities associated with Alternative 3A would be minor to moderate.

Sediment Quality

The types of sediment quality impacts and mitigative measures under Alternative 3A are expected to be the same as those described under Alternative 2 for the mine site, transportation facilities, and pipeline. While less upland soils and riverbank areas would be subject to erosion at the transportation facilities under Alternative 3A, these areas are small compared to the project as a whole. Intensity levels for sediment quality at remaining project components would be the same and, like Alternative 2, the extent of impacts would be localized within the immediate vicinity of the remaining component footprints. Overall impacts to sediment quality associated with Alternative 3A would be minor.

#### 3.7.3.3.2 SUMMARY OF IMPACTS FOR ALTERNATIVE 3A

Alternative 3A would involve the construction of an LNG plant, LNG tanks, and LNG-fueling infrastructure for haul trucks at the mine site. These mine site and the natural gas pipeline components would be located within the same facilities footprint proposed under Alternative 2, and are not expected to result in any changes in impacts to water quality relative to Alternative 2. The WRF and pit lake, which are the facilities responsible for the principal mechanisms of impact to groundwater quality, would be constructed, operated, and closed in a manner identical to that described under Alternative 2. Overall, impacts to water quality associated with the mine site and natural gas pipeline would be the same as discussed under Alternative 2, and would be considered minor to moderate for the mine site and minor for the pipeline.

Effects on surface water quality, groundwater quality, and sediment quality under Alternative 3A associated with the transportation facilities would also be the same as those described for Alternative 2. The reduced barging and operation of LNG-powered haul trucks at the mine site associated with Alternative 3A would not result in changes to any of the principal mechanisms of impact to groundwater quality at the mine site that were described under Alternative 2. The use of LNG-powered haul trucks instead of diesel-powered trucks would decrease the potential for spills associated with diesel fuel handling. While less upland soils and riverbank areas would be subject to erosion at the transportation facilities under Alternative 3A, these areas are small compared to the project as a whole. In addition, potential impacts to water quality in the

Kuskokwim River resulting from increases in suspended sediment concentrations and turbidity at some shallow water locations would decrease by approximately one-third relative to Alternative 2. Impacts associated with climate change would be the same as those discussed for Alternative 2. Overall, impacts to water quality associated with the transportation facilities would be the same as discussed under Alternative 2, and would be considered minor.

Design features, Standard Permit Conditions, and BMPs related to water quality are described under Alternative 2. Additional mitigation and monitoring measures are also described under Alternative 2. If these mitigation measures were adopted and required for Alternative 3A, the summary impact rating would similar to Alternative 2, minor to moderate for the mine site, and minor for the transportation facilities and pipeline.

### 3.7.3.4 ALTERNATIVE 3B – REDUCED DIESEL BARGING: DIESEL PIPELINE

#### 3.7.3.4.1 GEOCHEMISTRY

Geochemical direct, indirect, and cumulative impacts under Alternative 3B would be the same as discussed for Alternative 2, as the mine site and associated facility footprints would be the same.

<u>Surface Water Quality</u>

*Mine Site*

Under Alternative 3B, the mine site infrastructure would be essentially the same as required under Alternative 2, with the exception of decreased capacity of diesel fuel storage tanks. Under Alternative 3B, approximately 10 Mgal of diesel would be stored at the mine site, compared to approximately 37.5 Mgal of diesel fuel storage capacity proposed under Alternative 2. The decreased requirement for diesel storage at the mine site is not expected to affect any changes to surface water quality at the mine site during the construction period relative to Alternative 2.

During mine operations, approximately 120 Mgal of diesel would be consumed at the mine site annually, compared to approximately 42.3 Mgal of diesel and 11.2 $Bft^3$ of natural gas consumed annually under Alternative 2. The additional use of diesel proposed under Alternative 3B would result in increased potential of adverse impacts to surface water resources resulting from diesel fuel spills; however, under normal operating conditions (i.e., no spills) the impacts to surface water quality at the mine site would be the same as those proposed under Alternative 2. Thus, overall impacts to surface water quality resulting from the construction, operations, and closure of the mine facilities, as well as perpetual monitoring and maintenance of the pit lake would be minor to moderate.

*Transportation Facilities*

Under Alternative 3B, the existing dock at the Tyonek North Foreland Facility would need to be extended approximately 1,500 feet from shore in order to accommodate diesel tank vessels. Construction of the extended dock would presumably require some in-water construction and/or pile driving activities in Cook Inlet, which could potentially result in the resuspension of sediments and increased turbidity in the immediate vicinity of the in-water construction and/or pile driving activities. The magnitude of impacts to surface water quality in upper Cook

Inlet resulting from the construction of transportation facilities proposed under Alternative 3B would be low, as marine water quality standards are likely to be met. The most stringent applicable water quality criterion for turbidity in marine waters specifies that turbidity may not exceed 5 NTU above natural conditions when the natural turbidity is 50 NTU or less, and may not have more than 10 percent increase in turbidity when the natural turbidity is more than 50 NTU, not to exceed a maximum increase of 25 NTU. Any impacts resulting from resuspension of sediments and increased turbidity near in-water construction and/or pile driving activities would be temporary, as the impacts to surface water quality would cease immediately following the completion of the construction activities. High tidal current velocities and efficient water replacement in Cook Inlet due to tidal exchange would ensure rapid dissipation of local impacts to surface water quality resulting from the construction of transportation facilities in Cook Inlet. Because the activities would impact less than one percent of the water volume of Cook Inlet, yet marine water quality is governed by ADEC regulations, the resources impacted are considered to range from common to important in context.

Increased operations at the Tyonek North Foreland Facility would increase the risk of spills associated with fuel handling. However, this increased potential for impacts to surface water quality in upper Cook Inlet would be offset by a decrease in potential impacts resulting from fuel handling activity at Dutch Harbor, Bethel, and the Angyaruaq (Jungjuk) ports. Under normal operations, the impacts to surface water quality that would result from the operations and termination of transportation facilities under Alternative 3B would be essentially the same as those associated with Alternative 2. As a result of decreased barging activities on the Kuskokwim River under Alternative 3B, impacts to surface water quality resulting from localized sediment resuspension in critical shallow sections of the river would decrease. Overall impacts to surface water quality resulting from activities associated with transportation facilities would be minor under Alternative 3B.

*Diesel Pipeline*

The alignment of the diesel pipeline proposed under Alternative 3B, and its associated construction practices, schedule, and stream crossing techniques would be the same as those proposed for the natural gas pipeline discussed under Alternative 2. Impacts to surface water quality resulting from the construction of the diesel pipeline under Alternative 3B would be the same as those described under Alternative 2; surface water quality at stream crossings would be expected to comply with applicable water quality standards throughout the construction phase, and impacts to surface water resources from hydrostatic testing would be limited because amounts of water required for hydrostatic testing would be small compared to potential sources from rivers and small lakes along the route (SRK 2013b).

Impacts to surface water quality resulting from operations and termination of the diesel pipeline under Alternative 3B would be negligible. Relative to the natural gas pipeline proposed under Alternative 2, operations and termination of a diesel pipeline would result in increased potential for impacts to surface water quality as a result of spills or pipeline rupture. However, under normal operating conditions, erosion control measures including vegetation maintenance, BMPs, and mitigation measures would minimize impacts to surface water quality resulting from the operation of the pipeline. If the pipeline is cleaned effectively and abandoned in place, then any impacts to surface water quality caused by removal of the pipeline would be avoided.

## Groundwater Quality

### *Mine Site*

The reduced diesel barging and construction of a diesel pipeline under Alternative 3B would not result in changes to any of the principal mechanisms of impact to groundwater quality at the mine site from those described under Alternative 2. Increased use of diesel at the mine site under Alternative 3B would result in greater potential for impacts to groundwater quality to result from spills associated with diesel fuel handling. However, this mechanism of impact would be offset by the decreased capacity for fuel storage at the mine site. Under Alternative 3B, approximately 10 Mgal of diesel would be stored at the mine site, compared to approximately 37.5 Mgal of diesel fuel storage capacity proposed under Alternative 2. The decreased requirement for diesel storage at the mine site is not expected to affect any changes to groundwater quality at the mine site relative to Alternative 2. Under Alternative 3B, the WRF and pit lake, which are the facilities responsible for the principal mechanisms of impact to groundwater quality, would be constructed, operated, and closed in a manner identical to that described under Alternative 2.

### *Transportation Facilities*

Construction of transportation facilities proposed under Alternative 3B would be substantially similar to that described under Alternative 2, with the exception of extension of the dock at the Tyonek North Foreland Facility. The extension of the dock is not expected to result in any measureable impacts to groundwater quality, and therefore the impacts resulting from the construction of transportation facilities under Alternative 3B would be the same as those described under Alternative 2.

Operations and closure activities associated with the transportation facilities proposed under Alternative 3B are not expected to have measurable effects on groundwater quality.

### *Diesel Pipeline*

#### Construction

Under Alternative 3B, a diesel pipeline would be constructed instead of the natural gas pipeline proposed under Alternative 2. The alignment of the diesel pipeline, construction practices, schedule, and stream crossing techniques would be the same as those proposed for the natural gas pipeline under Alternative 2. Impacts to groundwater quality resulting from the construction of the diesel pipeline under Alternative 3B would be the same as those described under Alternative 2.

#### Operations and Maintenance; and Closure, Reclamation, and Monitoring

Like Alternative 2, impacts to groundwater quality resulting from operations and closure of the diesel pipeline are assumed to be negligible. Relative to the natural gas pipeline proposed under Alternative 2, operation and closure activities associated with a diesel pipeline would result in increased potential for impacts to groundwater quality as a result of spills or pipeline rupture. However, under normal operating conditions, erosion control measures including vegetation maintenance, BMPs, and mitigation measures would minimize impacts to groundwater quality resulting from the operation of the pipeline. If the pipeline is cleaned effectively and abandoned

in place, then any impacts to groundwater quality caused by removal of the pipeline would be avoided.

## Sediment Quality

### *Mine Site*

Under Alternative 3B, increased use of diesel at the mine site would result in increased risks to sediment quality relative to Alternative 2 as a result of diesel spills, which could occur during fuel handling. However, this potential for increased adverse impacts to sediment quality would be offset by the decreased capacity for diesel storage at the mine site under Alternative 3B relative to Alternative 2, which would theoretically decrease the intensity of potential adverse impacts to sediment quality at the mine site in the event of an undetected leak from a diesel storage tank. Under normal operational conditions, the expected impacts to sediment quality at the mine site under Alternative 3B would be the same as those described under Alternative 2.

### *Transportation Facilities*

#### Construction

Under Alternative 3B, the existing dock at the Tyonek North Foreland Facility in upper Cook Inlet would need to be extended approximately 1,500 feet from shore in order to accommodate tank vessels of the size required to supply the diesel pipeline. As described above under Surface Water Quality, construction of the extended dock in Upper Cook Inlet would require some in-water construction and/or pile driving activities, which would potentially result in the resuspension of sediments in the immediate vicinity of the in-water construction and/or pile driving activities. The construction activity associated with the Tyonek Dock would not require dredging. The magnitude of impacts to sediment quality in upper Cook Inlet resulting from the construction of transportation facilities proposed under Alternative 3B would be low, as they may or may not be measurable, and the overall impacts to sediment quality resulting from the construction of transportation facilities described under Alternative 3B would be the same as those described under Alternative 2.

#### Operations and Maintenance; and Closure, Reclamation, and Monitoring

The reduction in barging under Alternative 3B would reduce the level of impact to sediment quality during barging operations compared to those described under Alternative 2. Alternative 3B would eliminate the barging of diesel fuel, eliminating the 58 fuel barge tow round trips per year required under Alternative 2. This would result in a 48 percent reduction in total river barge traffic. Impacts to sediment quality in the Kuskokwim River resulting from the normal operation of barges are expected to be of low intensity, as the decrease in number of barge trips under Alternative 3B would reduce the amount of low water river travel through critical sections by approximately 48 percent, resulting in comparatively fewer situations in which bottom sediment erosion would occur.

### *Diesel Pipeline*

#### Construction

The alignment of the diesel pipeline, construction practices, schedule, and stream crossing techniques would be the same as those proposed for the natural gas pipeline under Alternative

2. Impacts to sediment quality resulting from the construction of the diesel pipeline under Alternative 3B would be the same as those described for the natural gas pipeline under Alternative 2.

Operations and Maintenance; and Closure, Reclamation, and Monitoring

As described under Alternative 2, impacts to sediment quality resulting from operations and closure of the pipeline are assumed to be negligible. Relative to the natural gas pipeline proposed under Alternative 2, operation and termination of a diesel pipeline would result in increased potential for impacts to sediment quality as a result of spills or pipeline rupture. However, under normal operating conditions, erosion control measures including vegetation maintenance, BMPs, and mitigation measures would minimize impacts to sediment quality resulting from the operation of the pipeline. If the pipeline is cleaned effectively and abandoned in place, then any impacts to sediment quality caused by removal of the pipeline would be avoided.

#### 3.7.3.4.2 SUMMARY OF ALTERNATIVE 3B IMPACTS

Under Alternative 3B, the primary mechanisms responsible for impacts to surface water quality, groundwater quality, and sediment quality at the mine site would be the same as discussed under Alternative 2. The decreased requirement for diesel storage at the mine site is not expected to affect any changes to water quality at the mine site during the construction period relative to Alternative 2. The additional use of diesel at the mine site under Alternative 3B would result in increased potential for diesel fuel spills; however, under normal operating conditions (i.e. no spills) the impacts to water quality at the mine site would be the same as those proposed under Alternative 2. Overall impacts to water quality resulting from the construction, operations, and closure of the mine facilities, as well as perpetual monitoring and maintenance of the pit lake would be minor to moderate.

For the transportation facilities, Alternative 3B would result in the potential for additional low intensity impacts to surface water quality in Upper Cook Inlet resulting from the extension of the Tyonek North Foreland Facility dock during the construction phase. There would also be a reduction in sediment quality impacts from reduced barging, but any impacts would be offset by small increases in sediment impacts for the additional port site at Tyonek. However, these impacts would not change the overall impacts associated with transportation facilities for Alternative 3A from those described under Alternative 2, which would be minor.

While the diesel pipeline proposed under Alternative 3B would result in substantially greater risk to surface water and groundwater resources from spills or pipeline rupture relative to the pipeline under Alternative 2, under normal operating conditions overall impacts to water quality associated with the pipeline would still be considered minor. Impacts associated with climate change would be the same as those discussed for Alternative 2.

Design features, Standard Permit Conditions, and BMPs related to water quality are described under Alternative 2. Additional mitigation and monitoring measures are also described under Alternative 2. If these mitigation measures were adopted and required for Alternative 3B, the summary impact rating would similar to Alternative 2, minor to moderate for the mine site, and minor for the transportation facilities and pipeline.

### 3.7.3.5 ALTERNATIVE 4 – BIRCH TREE CROSSING (BTC) PORT

#### 3.7.3.5.1 GEOCHEMISTRY

Geochemical direct, indirect, and cumulative impacts under Alternative 4 would be the same as discussed for Alternative 2, as the mine site and associated facility footprints would be the same.

Surface Water Quality

*Mine Site*

Effects to surface water quality at the mine site under Alternative 4 would be the same as those described for Alternative 2.

*Transportation Facilities*

Alternative 4 would move the upriver port site from Angyaruaq (Jungjuk) to BTC. This would result in a shorter distance for barging on the Kuskokwim River, but would require a longer road to connect the port to the mine site relative to Alternative 2. Construction techniques, operations, maintenance, and closure of the transportation facilities would be the same as described under Alternative 2.

Alternative 4 would result in some additional impacts to surface water quality relative to Alternative 2 as a result of the increased length of the road and the increased number of stream crossings associated with the BTC Road relative to the mine access road of Alternative 2 Material sites along the road would provide the material for road construction. NAG rock would not be used to construct the BTC Road. Impacts to surface water quality could result from leaching of arsenic, selenium, antimony and possibly other constituents of concern from the material used for road construction. The potential for such impacts would be controlled by testing materials from borrow sites for metal leaching potential prior to use for construction. Materials that could act as sources of contaminants of concern would not be used and alternative material sites would be identified.

In addition, runoff and sedimentation resulting from road construction could have minor impacts on surface water quality at stream crossing sites along the BTC Road corridor. The geographic extent of such impacts would increase under Alternative 4 relative to Alternative 2 due to the increased number of stream crossings associated with the BTC Road. Under Alternative 4, such impacts would be considered low intensity because receiving waters would comply with most stringent applicable water quality standards which specify that turbidity levels in freshwater streams may not exceed 5 NTU above natural conditions when the natural turbidity is 50 NTU or less, and may not have more than 10 percent increase in turbidity when the natural turbidity is more than 50 NTU, not to exceed a maximum increase of 25 NTU. Although the geographic extent of the impacts would increase under Alternative 4 relative to Alternative 2, in either instance the impacts would be considered local because only discrete portions of the project area would be affected. Impacts to surface water quality resulting from construction of the BTC Road would be temporary, as water quality would return to pre-activity levels following the cessation of the construction activities. Because surface water

streams are relatively abundant in the area under consideration, the impacted resources are considered common to important.

Positioning the upper terminal at BTC instead of Angyaruaq (Jungjuk) would eliminate barge-related impacts to surface water quality in the Kuskokwim River upstream from BTC. As with Alternative 2, concentrations of sediment suspended in the water may increase in some shallow locations as a result of low-water barge traffic down-river from BTC port, but there would be fewer critical sections under Alternative 4. Such impacts would be low in magnitude and local in extent, and the duration of any changes to surface water quality resulting from barge passage under normal operating conditions would be temporary as water quality would be expected to return to pre-activity levels within hours of a barge passing.

*Natural Gas Pipeline*

Effects to surface water quality associated with the construction, operations, and closure of the natural gas pipeline under Alternative 4 would be the same as those described for Alternative 2.

## Groundwater Quality

*Mine Site*

Effects to groundwater quality at the mine site under Alternative 4 would be the same as those described for Alternative 2.

*Transportation Facilities*

The overall impacts to groundwater quality resulting from the construction, operations, and closure of transportation facilities would be considered negligible. The impacts to groundwater quality resulting from all phases of the transportation infrastructure proposed under Alternative 4 would be the same as those described under Alternative 2. The only difference between Alternative 4 and Alternative 2 is the location of the upriver terminal facility. Changing the location from Angyaruaq (Jungjuk) Port to the BTC Port would potentially transfer the location of impacts associated with alterations in the rates of exchange between surface water and shallow groundwater deposits along the banks of the Kuskokwim River (bank storage effects), however, in either instance the geographic extent of such impacts would be limited to the areas immediately adjacent to the terminal facilities and the effects on the composition of the groundwater and availability for beneficial uses would be negligible.

*Natural Gas Pipeline*

Effects to surface water quality associated with the construction, operations, and closure of the natural gas pipeline under Alternative 4 would be the same as those described for Alternative 2.

## Sediment Quality

*Mine Site*

Effects to sediment quality at the mine site under Alternative 4 would be the same as those described for Alternative 2.

*Transportation Facilities*

The primary project-related mechanisms of impact to sediment quality under Alternative 4 in the transportation corridor would be associated with the construction of shoreside facilities at Bethel and the BTC port, and river bottom sediment erosion caused by propeller wash at critical (shallow) sections of the river, which would be fewer in number under Alternative 4. In-stream construction has the potential to contribute to increased sediment loads, which could potentially affect sediment quality at downstream locations. Under Alternative 4, the mechanisms and intensity of impacts to sediment quality at the port sites would be the same as those described under Alternative 2, except that the impacts associated with placement of the upstream facility would occur at BTC, instead of at Angyaruaq (Jungjuk). Impacts from propeller wash would be less than Alternative 2, but still of low intensity at critical sections downstream of the BTC Port.

*Natural Gas Pipeline*

Effects to sediment quality associated with the construction, operations, and closure of the natural gas pipeline under Alternative 4 would be the same as those described for Alternative 2.

#### 3.7.3.5.2 SUMMARY OF ALTERNATIVE 4 IMPACTS

Effects to surface water quality, groundwater quality, and sediment quality at the mine site and along the natural gas pipeline under Alternative 4 would be the same as those described for Alternative 2. Like Alternative 2, the principal mechanisms of impact to water quality associated with the mine site (e.g., pit lake, TSF, WRF) do not change under Alternative 4. Overall impacts associated with Alternative 4 are considered minor to moderate for the mine site, and minor for the pipeline. Impacts associated with climate change would be the same as those discussed for Alternative 2.

For the transportation facilities under Alternative 4, impacts to surface water quality would increase slightly at stream crossings along the BTC Road, and would decrease slightly in the Kuskokwim River at locations between the BTC and Angyaruaq (Jungjuk) ports relative to Alternative 2. Low intensity impacts to groundwater quality resulting from the placement of the upriver terminal facility would occur at the BTC Port, instead of at the Angyaruaq (Jungjuk) Port as described under Alternative 2. However, these impacts would not change the overall impacts associated with transportation facilities for Alternative 4 from those described under Alternative 2, which is minor.

Design features, Standard Permit Conditions, and BMPs related to water quality are described under Alternative 2. Additional mitigation and monitoring measures are also described under Alternative 2. If these mitigation measures were adopted and required for Alternative 4, the summary impact rating would similar to Alternative 2, minor to moderate for the mine site, and minor for the transportation facilities and pipeline.

### 3.7.3.6 ALTERNATIVE 5A – DRY STACK TAILINGS

Alternative 5A would use the dry stack tailings method instead of the wet slurry tailings storage method that would be used under Alternative 2. Dry stack tailings can be described in the simplest terms as finely ground, dewatered, and processed tailings material, which, due to its low water content relative to conventional tailings slurry, can be stacked in stable layers.

Under Alternative 5A, the TSF would be located in the Anaconda Creek Valley, in the same general location as under Alternative 2. Tailings would be dewatered in a filter plant using specialized equipment to produce a partially saturated, compactable material (filter cake). This material would be delivered to the TSF by conveyor or truck and spread and compacted in layers using bulldozers. Process-affected water removed from the tailings would be transported to an operating pond via a pipeline. Reclaimed water from the operating pond would be pumped back to the process plant for reuse. The dry stack tailings material would be progressively reclaimed during the operations phase and would be covered at closure with the same planned cover material as for Alternative 2. At closure, the operating pond water and any residual solids would be pumped to the open pit. The operating pond and main dam liners would be removed, the dam walls would be breached and graded back into the footprint, and the footprint reclaimed. Seepage recovery would continue as necessary and monitoring in closure and post-closure would be the same as Alternative 2.

#### 3.7.3.6.1 GEOCHEMISTRY

Alternative 5A has different effects associated with the TSF and the post-closure pit lake at the mine site, discussed below. Impacts associated with the WRF and overburden stockpiles would be the same as those discussed under Alternative 2.

<u>Mine Site</u>

*Construction; and Operations and Maintenance*

Alternative 5A includes a dry stack tailings disposal in contrast to the Alternative 2 conventional slurry tailings disposal within a lined TSF. This disposal method involves dewatering the tailings in a filter plant to produce a compactable, partially saturated material called a filter cake, with a moisture content of 19 percent by mass (BGC 2014a). The TSF of Alternative 5A would include an upper cell of filtered tailings, a lower fully lined operating pond, an SRS, fresh and contact water diversion channels, and overburden stockpiles. Return water from dewatering and filtration would either be pumped back to the plant process water or released into the operating pond. Any tailings that cannot be filtered to the specified moisture content would also be stored in the pond.

While detailed water quality modeling has not been conducted for Alternative 5A, it is anticipated that metals and TDS concentrations in dry stack porewater would be the same or higher than those of tailings porewater under Alternative 2 (BGC 2014a), likely due to less leaching and dilution by recirculated process water.

Issues involving the selection of dry stack design with regard to liners, seepage flow, and long-term water quality are complex and do not lend themselves to an obvious single option at a conceptual level of design. In light of the trade-offs associated with particular TSF design features, the following two options, as described by AECOM (2015e) and BGC (2015d) are considered:

> Option 1 – Unlined Dry Stack with LLDPE Cover: The dry stack tailings would be placed on existing overburden material following removal of ice-rich or saturated overburden. The foundation material would typically consist of colluvium and loess, with alluvial deposits in the valley bottom. A rock underdrain would be placed in the

major tributaries of the facility as described in BGC (2014a). As dry stack facilities usually do not require basal liners, Option 1 is consistent with the current state-of-practice.

- Option 2 – Lined Dry Stack with Pumped Overdrain: This design provides the advantage of minimizing (but not preventing) the potential for water quality impacts to groundwater and Crooked Creek, and the ability to optimize water management based on an ongoing understanding of seepage flow. After closure, the dry stack top and bottom surfaces would both be sealed by artificial liners in order to minimize or eliminate the flow of water through the dry stack over the long term.

Under either Option 1 or Option 2, construction of the dry stack would be ongoing throughout the mine life as the tailings are produced. The operating pond size would be expanded in campaigns every 4 years to store the anticipated volume produced during the intermediate years (BGC 2014a). The SRS would be constructed downstream of the main dam and operating pond. The water collected would be pumped either to the operating pond, the lower CWD, or to the process plant for use as process water.

#### *Closure, Reclamation, and Monitoring*

##### Open Pit/Pit Lake

Alternative 5A is expected to result in a substantial increase in the volume of water that is stored in the operating pond and then pumped to the pit at closure. Accordingly, the pit lake would fill more rapidly than for Alternative 2, reaching its controlled discharge elevation in approximately Year 42 to 47 after closure, depending on the option (see Section 3.7.3.6.2, Surface Water Quality below).

Preliminary modeling of the effects of pumping the dry stack tailings water to the pit indicates that lake stratification would likely occur at an approximately 40 percent shallower depth, and surface water concentrations of metals would likely be higher than for Alternative 2. As shown in Appendix H, the modeled pycnocline in Alternative 2 becomes shallower and the chemical gradient weakens over time as the pit lake evolves after closure. Assuming the Alternative 5A modeling shows similar pit lake evolution over time to that observed for Alternative 2, the shallower pycnocline observed under Alternative 5A likely increases the chance of the lake overturning and mixing to the surface over a shorter period of time. Also, with higher surface water concentrations under Alternative 5A, a greater potential exists for ice melt to cause seasonal near-surface stratification and continued concentration of surface waters over time if more dilute ice melt is preferentially withdrawn for treatment and discharge each spring.

##### Tailings Storage Facility

At mine site closure, an LLDPE geomembrane liner would be incorporated into a soil cover for each of the options described above. A cover system of stripped overburden would be placed over the dams which would be flattened to 3H:1V. The operating pond and water from the SRS would be drained into the open pit and the liner removed. An additional SRS would be constructed downstream from the upper dam to collect underdrain seepage from the dry stack to be pumped to the pit. After Year 10 of closure, it is expected that the surface water runoff from the dry stack cover would be of suitable quality for discharge to Crevice Creek.

The water quality of seepage from the dry stack TSF of Alternative 5A is predicted to exceed AWQC for several constituents, and would be handled similarly to those in Alternative 2. At closure, the dry stack TSF drainage would be pumped to the pit lake. Once the pit lake reaches its maximum allowable elevation at or about Year 43 post-closure, the surficial water is to be treated to meet AWQC and then discharged.

#### 3.7.3.6.2 SURFACE WATER QUALITY

Mine Site

*Construction*

Under Alternative 5A, impacts to surface water quality resulting from construction phase activities at the mine site would be similar to those described under Alternative 2. The main source of water discharged to Crooked Creek during the construction period would be the pit dewatering wells; the groundwater derived from the pit perimeter and in-pit dewatering wells would be expected to require treatment prior to discharge in order to meet applicable water quality standards and expected effluent limits (BGC 2014a). The water would be treated to meet applicable standards prior to discharge to Crooked Creek using a High Density Sludge (HDS) Water Treatment Plant, as described in Section 3.7.3.2.1 (SGS 2012). Under Alternative 5A, impacts to surface water quality resulting from runoff from construction materials and from erosion and sedimentation at the mine site would be similar to those described under Alternative 2. The construction of the dry stack TSF would occur within the Anaconda Creek watershed, and the footprint of the facility would largely overlap with that of the wet slurry TSF proposed under Alternative 2.

*Operations and Maintenance*

Under Alternative 5A, the volumes of water and slurry stored behind the tailings main dam during the operational period would be lower relative to Alternative 2, and progressive reclamation of the TSF would be conducted during the operational period. Runoff would be controlled by diversion of non-contact water away from the dry stack; contact water would be collected and transported to the operating pond via a pipeline, where it would be managed and treated similar to Alternative 2. According to BGC (2014a), while specific water quality modeling has not been carried out for the dry stack alternative, it is expected that the concentrations of metals and TDS in the porewater would be the same or higher than that under Alternative 2 (see Appendix H, Geochemistry).

Under Alternative 5A, a seepage recovery system (SRS) would be constructed downstream of the main dam and operating pond. The SRS would comprise a collection pond, diversion ditches, seepage recovery wells, and a pumpback system. The underdrains constructed under the liner and TSF would capture groundwater base flows from upgradient of the operating pond and dry stack, precipitation infiltrating through the dry stack, and potential seepage through the operating pond liner due to liner defects, and direct them to the SRS (BGC 2014a). The water in the collection pond would be pumped to the operating pond, lower CWD, or directly to the process plant. Seepage from the dry stack would not be discharged without treatment under either Option 1 or Option 2. The AWT methodology described in Section 3.7.2.1.1 would be used to treat seepage SRS water to comply with the most stringent applicable

water quality standards before discharge to Crooked Creek and therefore the intensity of surface water quality impacts resulting from either Option 1 or Option 2 would be considered minor. While water and tailings slurry volumes would be reduced under Alternative 5A and the dry stack would be progressively reclaimed, the magnitude of impacts to downgradient surface water resources in the Crooked Creek watershed in operations would be the same as Alternative 2, because water captured by the TSF dams and SRS would be recycled through the process plant under either alternative.

The primary impacts to surface water quality associated with Alternative 5A would be related to fugitive dust from the dry stack tailings facility and potential runoff from precipitation to the surface of the tailings stack. The amount of fugitive dust generated by wind erosion would depend upon the frequency and magnitude of disturbances of the erodible surface of the tailings material, and the rates of progressive reclamation of the dry stack tailings facility during the operational period, as each new lift would expose unreclaimed tailings material to wind and precipitation. Besides concurrent reclamation, the dry stack dust would be mitigated through the application of a polymer dust control at 3-foot lift intervals and windbreaks (BGC 2014a).

As described in Section 3.2, Soils, and Section 3.8, Air Quality, the dry stack would have a 60 percent greater surface area potentially exposed to wind erosion than the exposed tailings beach under Alternative 2. This increase represents about a 0.1 percent increase in fugitive dust emissions for the mine site as a whole, as other major sources of dust would not change under this alternative (e.g., pit, roads, etc.). The amount of dust generated from the dry stack under Alternative 5A relative to the tailings beach under Alternative 2 may be higher than a simple surface area correlation would suggest, however, due to lower moisture content, increased heavy equipment use, and higher elevation of exposed tailings (greater wind exposure) at the dry stack. The increase in fugitive dust emissions resulting from exposure of the dry stack surface would be largely offset by the elimination of fugitive dust emissions from the TSF beach area under Alternative 2. The total increase in $PM_{2.5}$ and $PM_{10}$ emissions under Alternative 5A relative to Alternative 2 would be 2.9 percent and 8.3 percent, respectively (Air Sciences 2015b). Given the small incremental increase in overall mine site dust above Alternative 2, the pattern of dust extent under Alternative 5A is expected to be largely similar to that of Alternative 2, depicted on maps in Section 3.8, Air Quality.

The composition of fugitive dust generated from the tailings stack would be similar to that of the tailings solids of Alternative 2, described in Section 3.2.3.2.4 (Soils, Quality) and shown in Table 3.2-2 (Soils) and Table 3.7-46. The tailings would have relatively high concentrations of arsenic, antimony, and mercury (Fernandez 2014e).

There is some uncertainty with regard to the effectiveness of the dust control mitigation between polymer lift applications. Direct deposition of fugitive dust and indirect deposition from runoff to surface water within the area affected by dust could result in elevated concentrations of antimony, arsenic, and mercury in surface water. The increase in fugitive emissions due to the dry stack would be offset by the elimination of fugitive dust emissions from the TSF beach area. Under both Alternative 2 and Alternative 5A, some mercury from the TSF would enter the air as a result of volatilization, and it is likely that the rate of volatilization from tailings would be greater from the dry stack (Alternative 5A) relative to wet slurry tailings

**Table 3.7-46: Ore (Tailings) Metals Concentrations**

| Element | Concentration (mg/kg) | N |
|---|---|---|
| Arsenic | 907 | 8625 |
| Mercury | 1.2 | 7439 |
| Antimony | 16 | 8624 |

**Notes:**

Based on compiled As, Sb, and Hg concentrations for the ore using the assay analysis from drill core samples in combination with the pit design model. The tailings material would be represented by the material designated as ore in the pit model. The As, Sb, and Hg concentrations are represented by the geometric mean of the individual values. The sample size, n, for each metal is also shown (Fernandez 2014e).

Source: Fernandez 2014e.

(Alternative 2). The geographic extent of potential effects could range from the American and Anaconda creek watersheds, in which most runoff would be captured by the lower CWD and operating pond, to adjacent or other watersheds. Depending on the rates of deposition and other factors, it is likely that concentrations of these constituents would be measurable and possible that they could exceed the most stringent AWQC in surface water, particularly for elements that are close to, or exceed, AWQC in baseline (e.g., arsenic, mercury; Table 3.7-2 through Table 3.7-4). Thus, potential impacts to surface water resulting from fugitive dust under Alternative 5A could reach high intensity. The impacts would be considered long-term and regional, because water quality would potentially be reduced throughout the life of the project and return to background ranges sometime after the end of mine life, and effects could be felt throughout the mine site and potentially outside the project footprint. As with Alternative 2, the context of the impacted resources would range from common to important.

Changes to equipment at the mine site under Alternative 5A relative to Alternative 2 include the addition of a pressure filter system to dewater the tailings prior to placement within the tailings disposal area. The operation of the pressure filter system is not expected to result in any differences in impacts to surface water quality relative to Alternative 2.

### *Closure, Reclamation, and Monitoring*

#### Surface Water Runoff

Under Alternative 5A, the dry stack tailings material would be progressively reclaimed during the operations phase and completed at closure. Progressive reclamation would be essential to reduce dust generation and resulting impacts to surface water quality (Davies and Rice 2002). After successful reclamation, fugitive dust and potential migration of contaminants to surface water would no longer occur. The dry stack cover, which is included in both Options 1 and 2, would prevent fugitive dust releases, minimize erosion from runoff, and provide medium for vegetative recolonization of the site. Progressive reclamation would occur on the south and west facing slopes of the dry stack as the lifts advance. It is anticipated that completion of dry stack reclamation in closure would occur over a 5-year period.

During the closure period, surface runoff would be directed to the relocated SRS, where it would be pumped to the open pit, and the cover surface would be graded to direct surface

runoff to the southeast of the TSF (BGC 2014a). Surface runoff water to the SRS would be held and tested for water quality. It is assumed that a 5-year period would be necessary to demonstrate that water quality running off the cover is acceptable for discharge; during this period, all cover runoff would be pumped to the pit lake (BGC 2014a). It is further assumed that after Year 10 of closure, this water would be of suitable quality for discharge, and runoff from the pond would be permitted to drain to Crevice Creek from Year 11 of closure onwards via a spillway that would be excavated in the ridge dividing Anaconda and Crevice Creeks (BGC 2014a). Provided that runoff from the reclaimed dry stack meets permitted effluent limits prior to discharge during the post closure period, the impacts to surface water quality resulting from implementation of Alternative 5A would be similar to those described under Alternative 2.

Dry Stack Seepage

Under Alternative 5A-Option 1, runoff infiltrating the dry stack would report to the underdrain and mix with upstream runoff and groundwater baseflow also reporting to the underdrain. This combined flow would report to the downstream SRS and would then be pumped to the ACMA Pit via pipeline at closure. SRS water would be transferred to the pit in the closure and post-closure periods until such time that seepage flow through the dry stack reduces to the point that the SRS may be able to be decommissioned. It is estimated that it would take roughly 200 years for seepage flow to reach the same rate as that predicted for the TSF under Alternative 2 (BGC 2015d). Water levels in the ACMA Pit would reach an elevation of 328 feet in about 42 years, which is the target elevation at which treatment of pit lake water would commence.

Under Option 2, runoff infiltrating the dry stack would be pumped directly from the overdrain to the pit lake at closure (Figure 3.5-38, in Section 3.5, Surface Water Hydrology). The SRS would still be required downstream of the Option 2 dry stack to capture underdrain flow and potential seepage through the dry stack liner. Assuming that there is no liner leakage beneath the Option 2 dry stack, it is estimated that underdrain flows to the SRS would be suitable for discharge to Anaconda Creek and the SRS would be able to be decommissioned after 10 years of closure. This would reduce the SRS discharge volume to the pit lake, and the lake elevation of 328 feet would be reached in about 47 years. It is possible, however, that the liner beneath the dry stack would leak at the same rate as that assumed for the Alternative 2 TSF. In this case, the time it would take for the SRS to be decommissioned would be similar to that of Alternative 2 (about 51 years).

Thus, the main difference between Alternative 5A-Option 1, Alternative 5A-Option 2, and Alternative 2 with respect to surface water quality is the time it takes for the SRS water to clean up to the point that it can be discharged to Anaconda Creek, that is, roughly 200 years under Option 1, and about 10 to 50 years under Option 2 and Alternative 2. Under either option, effects on downgradient water quality in Crooked Creek would be the same as Alternative 2, provided that the SRS water is contained and conveyed to the open pit, as all pit lake water would be treated prior to discharge.

Risk of SRS Pump Failure

The hydraulic containment system of the SRS would require monitoring, analysis, operation, periodic repair, and management to assure its continuing functioning and effectiveness in post-closure. Considering the long duration of pumping, the harsh climate and the remote location, the potential for pumping failure is high and the consequences of a failure merit examination. As a mechanical system with many task-critical components, system failure should be regarded

as a distinct probability (see Section 3.6, Groundwater Hydrology). The risk of SRS pump failure under Option 1 would be worse than that of Option 2 or Alternative 2, due to the longer time that the SRS would need to remain operational and be maintained in post-closure.

In either option, if the SRS pumping system were to go completely off-line, the SRS would likely fill to overflowing and/or lose hydraulic containment with respect to groundwater in approximately 2 weeks, although there are many variables such as time of year and amount of drawdown at the start of the failure that could affect this calculation (see Section 3.6, Groundwater Hydrology). If hydraulic containment of the groundwater system is lost, it is likely that contaminated groundwater would enter the flow system towards Crooked Creek, and it would be impractical to retrieve because the water would migrate outside of the radius of influence of the SRS pond. In the event of a prolonged SRS pumping failure during post-closure, the unpumped SRS water would migrate downgradient in the Anaconda Creek watershed, eventually influencing the quality of surface water in Crooked Creek.

The magnitude of the impacts to surface water quality in Anaconda Creek and Crooked Creek would depend upon the timing of the pump failure, connectivity between the seepage and surface water resources, and the rates of seepage flow relative to Crooked Creek discharge. Under both Options 1 and 2, an event leading to the release of uncontained SRS water to the surface waters of Anaconda Creek or Crooked Creek would result in high-intensity impacts to surface water resources because the concentrations of several constituents in both tailings porewater and groundwater would exceed applicable water quality standards. Under Alternative 2, concentrations of antimony, arsenic, cobalt, copper, manganese, molybdenum, nickel, selenium, thallium, mercury, and sulfate in tailings water would exceed the most stringent water quality standards for natural waters (see Section 3.7.3.2.2 - Closure, TSF and SRS Water Quality; and Table 3.7-43). While detailed water quality modeling has not been conducted for Alternative 5A, it is anticipated that metals and TDS concentrations in dry stack seepage would be the same or higher than those of tailings porewater described under Alternative 2 (BGC 2014a), likely due to less leaching and dilution by recirculated process water (AECOM 2015e).

The possible impact of pump failure on downstream water quality would be greater under Option 1 than Option 2 due to greater tailings seepage reporting to the underdrain in early post-closure. For Option 1, seepage flow at the beginning of the closure period represents about 16% of the total flow reporting to the SRS (about a 6:1 dilution), compared to 4% or less for Option 2 and Alternative 2 ($\geq$24:1 dilution) (Section 3.7.3.2.2 - Closure, TSF and SRS Water Quality). Based on dilution alone, if dry stack porewater quality were similar to that of the wet tailings, predicted SRS concentrations under Option 1 would be about 1-1/2 to 4 times higher than those under Option 2 or Alternative 2 in the early closure period, depending on background concentrations of individual constituents (AECOM 2015e). Downgradient water quality could still be impaired under Option 2 due to liner leakage and elevated baseline conditions, but less so than under Option 1.

Thus, any unplanned release of SRS water under either Options 1 or 2 could result in high magnitude impacts to surface water quality because effects could be sufficient to exceed water quality regulatory limits. The duration of such impacts would likely be temporary, provided that resources are readily available to repair or replace the failed pumping device in perpetuity. The geographic extent of such impacts would be local because only discrete portions of the project area in the Anaconda and Crooked Creek watersheds would be affected. The affected

resources would be considered common to important in context because surface water resources similar to those that could be impacted in the event of an SRS pump failure are considered relatively common in the region, but are protected by the Clean Water Act and other legislation. Thus, considering the proposed lifespan of the SRS pumping system under Alternative 5A, particularly for Option 2, the possibility for high intensity impacts to result from the potential failure of the system cannot be ignored.

*Transportation Facilities*

Under Alternative 5A, effects on surface water quality associated with the construction, operations, and closure of the transportation facilities would be the same as those described under Alternative 2.

*Natural Gas Pipeline*

Under Alternative 5A, effects on surface water quality associated with the construction, operations, and closure of the natural gas pipeline would be the same as those described under Alternative 2.

#### 3.7.3.6.3 GROUNDWATER QUALITY

Mine Site

*Construction*

The primary sources of impact to groundwater quality at the mine site during construction would be associated with localized inputs of dissolved metals and TDS from waste rock used in the construction of the lower CWD. Although groundwater pumping to achieve pit depressurization would begin approximately 1.75 years before the beginning of operations, pit depressurization is not expected to have a substantial influence on groundwater quality during the construction period. These sources of impact would be identical under Alternative 5A and Alternative 2; therefore, the impacts to groundwater quality at the mine site during construction would be the same as discussed under Alternative 2.

*Operations and Maintenance; and Closure, Reclamation, and Monitoring*

Like Alternative 2, the dry stack would be designed to reduce potential impacts to the quality of groundwater. Construction of the dry stack would occur from the valley bottom up. As described above, two options described by AECOM (2015e) and BGC (2015d), are considered: Option 1 – Unlined Dry Stack with LLDPE Cover, and Option 2 – Lined Dry Stack with Pumped Overdrain.

Under either Option 1 or Option 2, diversion structures and ditches would be constructed upgradient to reduce surface water deposition to the TSF, and the surface of the dry stack would be graded towards the operating pond to shed contact runoff water and decrease infiltration into the stack.

Under both options, flows collected in the dry stack underdrains would be conveyed beneath the upper dam, the operating pond, and the main dam before discharging to the SRS. The potential for long-term degradation of the underdrains in post-closure is not considered a

concern, because they would be wrapped in geotextile to filter out tailings and native soils; the granular rock blanket filter underlying the upper dam would provide a drainage path for dry stack seepage through the dam; and infiltration through the dry stack would be minimized by progressively grading the dry stack throughout operations to facilitate surface runoff (BGC 2014a). Under both options, placement of the impermeable LLDPE cap at closure would limit infiltration to the dry stack facility during the closure and post-closure periods.

Under Option 1, tailings seepage could potentially reach groundwater beneath the dry stack, although the underdrains would be expected to continue to capture some if not all of the tailings seepage. Seepage reaching groundwater would either 1) flow to the underdrains prior to reaching the SRS, or 2) flow through native material under the operating pond, and be captured by the cone of depression created by pumping the SRS and/or sentinel wells. Following removal of the operating pond and dam in closure, if contaminated groundwater is present in native materials beneath the dry stack or operating pond footprint, it would continue to migrate towards, and be captured by, the SRS and/or wells, and report to the pit lake. Meanwhile, the supply of tailings porewater that could potentially feed the contaminant plume would be reduced by the impermeable cover, and seepage flow through the dry stack would gradually reduce to the same as that predicted under Alternative 2 (and Option 2) after 200 years. In other words, a contaminant plume, if present under Option 1, would eventually improve in quality to that of Option 2 and Alternative 2. Beyond 200 years, the amount of seepage flow under Option 1 is expected to continue its gradual decline as a result of the impermeable cover blocking infiltration of water to the flow system.

Under Option 2, the presence of a liner under the dry stack would limit tailings seepage from contaminating groundwater beneath it, although there could still be a small amount of liner leakage similar to that under Alternative 2. The groundwater quality beneath the dry stack and operating pond would likely be better than Option 1 for a period of time between early closure and 200 years, although in both cases groundwater would be captured by the SRS, pumped to the pit lake, and monitored until it can be shown to meet water quality standards.

As dry stack facilities usually do not require basal liners, Option 1 is consistent with the current state-of-practice. Option 2 would provide the additional advantage of minimizing (but not preventing) the potential for water quality impacts to groundwater and Crooked Creek, and the ability to optimize water management based on an ongoing understanding of seepage flow into the rock overdrain.

#### Transportation Facilities

Under Alternative 5A, effects on groundwater quality associated with the construction, operations, and closure of the transportation facilities would be the same as those described under Alternative 2.

#### Natural Gas Pipeline

Under Alternative 5A, effects on groundwater quality associated with the construction, operations, and closure of the natural gas pipeline would be the same as those described under Alternative 2.

#### 3.7.3.6.4 SEDIMENT QUALITY

Mine Site

As discussed in Section 3.7.3.6.2 (Alternative 5A – Surface Water Quality), direct deposition of fugitive dust from dry stack wind and indirect deposition from runoff to surface water within the area affected by dust blown from the dry stack could result in elevated concentrations of antimony, arsenic, and mercury in surface water. BMPs and mitigation measures would be used to minimize adverse impacts associated with fugitive dust from the tailings stack under Alternative 5A. The majority of mercury potentially deposited as a result of fugitive dust would be particulate mercury. Some of the particulate Hg would be transported downstream, and some would rapidly settle out of the water column and become buried in stream sediments. Depending on the rates of deposition and other factors, it is likely that concentrations of these constituents in the sediments would be measurable, and possible that they could exceed applicable regulatory guidance levels for sediment in the region of the mine site. Thus, potential impacts to sediment quality resulting from fugitive dust under Alternative 5A would be considered high intensity. The impacts would be considered long-term and regional, because sediment quality would potentially be reduced throughout the life of the project both throughout the mine site and potentially outside the project footprint. Like Alternative 2, the context of the impacted resources would be considered common to important. Under Alternative 5A, the dry stack tailings material would be progressively reclaimed during the operational period. After successful reclamation, fugitive dust deposition would no longer occur.

Transportation Facilities

Under Alternative 5A, effects on sediment quality associated with the construction, operations, and closure of the transportation facilities would be the same as those described under Alternative 2.

Natural Gas Pipeline

Under Alternative 5A, effects on sediment quality associated with the construction, operations, and closure of the natural gas pipeline would be the same as those described under Alternative 2.

#### 3.7.3.6.5 SUMMARY OF ALTERNATIVE 5A IMPACTS

Alternative 5A (both options) includes a dry stack tailings disposal in contrast to the Alternative 2 conventional slurry tailings disposal within a lined TSF. The water quality of dry stack seepage and SRS water under both options is predicted to exceed AWQC for several constituents, and would be treated similarly to those in Alternative 2 prior to discharge. The main difference between Option 1, Option 2, and Alternative 2 with respect to surface water quality is the time it takes for the SRS water to clean up to the point that it can be decommissioned, that is, roughly 200 years under Option 1 (unlined dry stack), and about 10 to 50 years under Option 2 (lined dry stack) and Alternative 2. Option 2 would provide the additional advantage of minimizing (but not preventing) the potential for water quality impacts to groundwater. Under either option, effects on downgradient water quality in Crooked Creek

would be the same as Alternative 2, provided that the SRS water is contained and conveyed to the open pit.

High intensity impacts to surface water resources could occur in the event of a prolonged SRS pumpback failure during the post-closure period under both options of Alternative 5A as well as Alternative 2, although the risk of failure and level of contaminants in SRS water would be greater under Alternative 5A-Option 1 than Option 2 or Alternative 2. Like Alternative 2, the principal mechanisms responsible for high impacts to groundwater quality in other areas of the mine site would be inputs of seepage from the WRF to shallow groundwater resources underneath and immediately adjacent to the WRF, and the discharge of water from the pit to the surrounding deep bedrock groundwater.

Under both options, there could also be an increase in indirect impacts to surface water and sediment quality resulting from dry stack fugitive dust atmospheric deposition and terrestrial runoff from dust depositional areas. Such indirect impacts could be considered high intensity, because they could be sufficient to exceed water quality regulatory limits. Increased deposition of mercury to sediments and the potential for increased rates of mercury methylation would be considered high intensity impacts to sediment quality because the effects would likely be measurable and could be sufficient to exceed regulatory guidance levels. Overall impacts to water quality associated with the mine site under Alternative 5A would be considered moderate to major. Impacts associated with climate change would be the same as those discussed for Alternative 2.

Effects on surface water quality, groundwater quality, and sediment quality along the transportation corridor and the natural gas pipeline under Alternative 5A would be the same as those described for Alternative 2. There would be no difference in the types of impacts or the amount of ground disturbance associated with these facilities. Overall impacts associated with the transportation facilities and the pipeline under Alternative 5A would be minor.

Design features, Standard Permit Conditions, and BMPs related to water quality are described under Alternative 2. Additional mitigation and monitoring measures are also described under Alternative 2. If these mitigation measures were adopted and required for Alternative 5A, the summary impact rating would similar to Alternative 2, moderate to major for the mine site, and minor for the transportation facilities and pipeline.

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

#### 3.7.3.7.1 GEOCHEMISTRY

Geochemical direct and indirect cumulative impacts under Alternative 6A would be the same as discussed for Alternative 2, as the mine site and associated facility footprints would be the same.

## Surface Water Quality

### *Mine Site*

Under Alternative 6A, effects on surface water quality associated with the construction, operations, and closure of the mine site would be the same as those described under Alternative 2.

### *Transportation Facilities*

Under Alternative 6A, effects on surface water quality associated with the construction, operations, and closure of the transportation facilities would be the same as those described under Alternative 2.

### *Natural Gas Pipeline*

Under Alternative 6A, natural gas pipeline construction techniques and associated impacts to surface water quality would be substantially similar to those described under Alternative 2. The Dalzell Gorge alignment would cross the Happy River and the South Fork of the Kuskokwim River using HDD and resulting impacts to surface water quality would be low intensity at those locations. As described under Alternative 2, impacts to surface water quality resulting from the normal operation of the pipeline under Alternative 6A are expected to be negligible.

## Groundwater Quality

### *Mine Site*

Under Alternative 6A, effects on groundwater quality associated with the construction, operations, and closure of the mine site would be the same as those described under Alternative 2.

### *Transportation Facilities*

Under Alternative 6A, effects on groundwater quality associated with the construction, operations, and closure of the transportation facilities would be the same as those described under Alternative 2.

### *Natural Gas Pipeline*

As described under Alternative 2, potential impacts to groundwater quality during construction and operations of the natural gas pipeline are expected to be minimal, and limited to a short period during construction. The primary impacts would be associated with installation of the pipeline at river and stream crossings. The impacts to groundwater quality resulting from the pipeline alignment proposed under Alternative 6A would be substantially similar to those described under Alternative 2; however, the specific locations of the impacts would be different as a result of the pipeline realignment proposed under Alternative 6A. Groundwater drainage and recharge patterns should reestablish after site reclamation has been completed, and any impacts to groundwater quality resulting from the normal operation of the pipeline would be negligible to minor. The pipeline would be abandoned in place, and therefore, no additional impacts to groundwater quality would be associated with the closure phase.

Sediment Quality

*Mine Site*

Under Alternative 6A, effects on sediment quality associated with the construction, operations, and closure of the mine site would be the same as those described under Alternative 2.

*Transportation Facilities*

Under Alternative 6A, effects on sediment quality associated with the construction, operations, and closure of the transportation facilities would be the same as those described under Alternative 2.

*Natural Gas Pipeline*

Like Alternative 2, the primary mechanisms of impact to sediment quality resulting from construction of the natural gas pipeline would involve soil erosion associated with installation of the pipeline at river and stream crossings, and clearing of riparian habitat along the pipeline ROW. Because the construction practices and stream crossing techniques employed under Alternative 6A would be substantially similar to those associated with Alternative 2, the resulting impacts to sediment quality would be similar, i.e., of low intensity. The specific locations of potential impacts to sediment quality would be different as a result of the pipeline realignment proposed under Alternative 6A. Expected impacts to sediment quality resulting from the normal operation of the pipeline would be negligible. If the pipe is abandoned in place, then any new impacts to sediment quality caused by pipe removal would be avoided.

#### 3.7.3.7.2 SUMMARY OF ALTERNATIVE 6A IMPACTS

Effects on surface water quality, groundwater quality, and sediment quality at the mine site and along the transportation corridor under Alternative 6A would be the same as those described for Alternative 2. There would be no difference in the types of impacts or the amount of ground disturbance associated with these facilities. Overall impacts under Alternative 6A would be minor to moderate for the mine site, and minor for the transportation facilities. Impacts associated with climate change would be the same as those discussed for Alternative 2.

The specific locations of the impacts associated with the pipeline under Alternative 6A would be different as a result of the pipeline realignment from the route discussed under Alternative 2. Like Alternative 2, the primary mechanisms of impact to groundwater quality and sediment quality resulting from construction of the natural gas pipeline would involve soil erosion associated with installation of the pipeline at river and stream crossings, and clearing of riparian habitat along the pipeline ROW. The construction practices and stream crossing techniques would be similar to those associated with Alternative 2, so the resulting impacts would be similar, i.e., of low intensity. The pipeline would be abandoned in place, and therefore, no additional impacts to groundwater quality would be associated with the closure phase. Overall impacts associated with the natural gas pipeline under Alternative 6A would be minor.

Design features, Standard Permit Conditions, and BMPs related to water quality are described under Alternative 2. Additional mitigation and monitoring measures are also described under Alternative 2. If these mitigation measures were adopted and required for Alternative 6A, the

summary impact rating would similar to Alternative 2, minor to moderate for the mine site, and minor for the transportation facilities and pipeline.

#### 3.7.3.8 IMPACT COMPARISON – ALL ALTERNATIVES

A summary of impacts from Alternative 2 is presented in Table 3.7-45, and a comparison between alternatives is presented below in Table 3.7-47. Although there are differences among alternatives in the project components that would affect water quality, they are relatively small. Overall there is little difference in the range of impacts to water resources for the various alternatives, as the scope and scale of the three project components are such that changes to a single mine structure, road, port, or pipeline route result in small changes to overall impacts.

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**Table 3.7-47: Comparison of Impacts by Alternative***

| Impact-causing Project Component | Alt 2 – Proposed Action | Alt 3A – LNG-Powered Haul Trucks | Alt. 3B – Diesel Pipeline | Alt. 4 – BTC Port | Alt. 5A – Dry Stack Tailings (Option 1 – Unlined, Option 2 – Lined) | Alt. 6A – Dalzell Gorge Route |
|---|---|---|---|---|---|---|
| **Mine Site** | | | | | | |
| Geochemistry | Drainages from the WRF and the isolated PAG cells, TSF, and TSF cover are predicted to exceed AWQC for several constituents.<br>Lower CWD and drainage from the SOB predicted to exceed AWQC for several constituents during operations.<br>Surficial pit lake water expected to exceed AWQC for several constituents; at or about Year 52 post-closure, the surficial water would be treated to meet AWQC and then discharged. | Same as Alternative 2 | Same as Alternative 2 | Same as Alternative 2 | Impacts associated with the WRF and overburden stockpiles would be the same as Alternative 2.<br>Pit lake stratification would occur at an approximately 40 percent shallower depth, and surface water concentrations of metals would likely be higher than Alternative 2.<br>At or about Year 42 to 47 post-closure (depending on the option), the surficial pit lake water would be treated to meet AWQC and then discharged. | Same as Alternative 2 |
| Surface Water Quality | Surface water in the American and Anaconda Creek watersheds influenced by the creation and perpetual maintenance of the pit lake and TSF impoundment. Pit dewatering discharge to Crooked Creek would be treated to meet AWQC prior to discharge.<br>Atmospheric deposition of mercury would create high intensity impacts in some cases, depending on watershed location and existing baseline concentrations. | Kuskokwim River barge traffic would be reduced and the Bethel and Dutch Harbor ports would not require as much expansion. Changes would not affect overall impact levels from Alternative 2. | The additional use of diesel would result in increased potential of adverse impacts resulting from diesel fuel spills; however, under normal operating conditions (i.e., no spills), impacts would be the same as Alternative 2. | Same as Alternative 2 | Under both options, effects on downgradient water quality in Crooked Creek would be the same as Alternative 2, provided SRS water is contained and conveyed to the open pit. The main difference between Alt.5A-Option 1, Alt.5A-Option 2, and Alt. 2 is the time it takes for SRS decommissioning: 200 years under 5A-Option 1; and 10-50 years under both Alt.5A-Option 2 and Alternative 2.<br>An increase in indirect effects could result from dry stack fugitive dust atmospheric deposition and terrestrial runoff from dust deposition; these impacts could exceed water quality regulatory limits.<br>High intensity impacts could occur in the event of a prolonged SRS pumpback failure during post-closure; risk and contaminant levels would be greater under Alt.5A-Option1 than either Alt.5A-Option 2 or Alt.2. | Same as Alternative 2 |

**Table 3.7-47: Comparison of Impacts by Alternative***

| Impact-causing Project Component | Alt 2 – Proposed Action | Alt 3A – LNG-Powered Haul Trucks | Alt. 3B – Diesel Pipeline | Alt. 4 – BTC Port | Alt. 5A – Dry Stack Tailings (Option 1 – Unlined, Option 2 – Lined) | Alt. 6A – Dalzell Gorge Route |
|---|---|---|---|---|---|---|
| Groundwater Quality | Inputs of seepage from the WRF to shallow groundwater, and the discharge of water from the pit to surrounding deep bedrock groundwater would occur for a period of approximately 8 years following cessation of pit depressurization; impacts would be limited in geographic extent. | Same as Alternative 2 | Same as Alternative 2 | Same as Alternative 2 | Similar to Alt.2, Alt. 5A-Option 2 would provide an advantage over Alt. 5A-Option 1 of minimizing (but not preventing) the potential for impacts to groundwater quality. | Same as Alternative 2 |
| Sediment Quality | Impacts to sediment quality could result from altered stream flows and water chemistry in Crooked Creek and project-related atmospheric deposition of mercury. However, these impacts would meet AWQC as concentrations of mercury and methylmercury are predicted to remain within the naturally occurring range presently found in the study area. | Same as Alternative 2 | Same as Alternative 2 | Same as Alternative 2 | High intensity impacts (i.e., could exceed regulatory standards) to sediment quality resulting from fugitive dust from the dry stack tailings facility. BMPs and mitigation would minimize adverse impacts associated with fugitive dust from the tailings stack. | Same as Alternative 2 |
| Summary Impact Level | Minor to Moderate | Minor to Moderate | Minor to Moderate | Minor to Moderate | Moderate to Major | Minor to Moderate |
| **Transportation Facilities** | | | | | | |
| Geochemistry | No impact. | Same as Alternative 2 | Same as Alternative 2 | Same as Alternative 2 | Same as Alternative 2 | Same as Alternative 2 |
| Surface Water Quality | Impacts from occasional barge-induced suspended sediment or erosion effects at construction sites would meet AWQC.<br>Runoff of water from NAG rock used for road construction could include inputs from constituents of concern; potential impacts could be reduced through mitigation. | Potential impacts related to surface water quality in the Kuskokwim River resulting from increases in suspended sediment concentrations and turbidity would decrease by approximately 32 percent from Alternative 2 due to reduced barging activity. | Same as Alternative 2, but with increased risk of spills associated with fuel handling at the Tyonek North Foreland Facility, and a decrease in potential impacts resulting from fuel handing at the ports. | Increased road length and increased number of stream crossings from Alternative 2 would result in additional impacts.<br>Material sites along the road would be used for road construction, which could result in leaching from constituents of concern; impacts could be reduced through mitigation. | Same as Alternative 2 | Same as Alternative 2 |
| Groundwater Quality | Placement of sheet pile associated with construction of port terminals could have localized, temporary impacts.<br>Use of groundwater for drinking water supplies at the Angyaruaq (Jungjuk) Port would not impact groundwater quality. | Same as Alternative 2 | Same as Alternative 2 | Same as Alternative 2; impacts would be transferred from Angyaruaq (Jungjuk) Port to the BTC Port. | Same as Alternative 2 | Same as Alternative 2 |
| Sediment Quality | Resettled sediment from barging and construction of the ports would be of similar composition to the existing natural deposit.<br>BPMs and ESC measures would be employed to control erosion and sedimentation effects during construction. | Reduction in barging would reduce the amount of low water river travel by approximately 32 percent, resulting in fewer situations where sediment quality could be impacted. | Reduction in barging would reduce the amount of low water river travel, resulting in fewer situations where sediment quality could be impacted. | Impacts associated with sediment quality at the ports would be the same as Alternative 2, just located at the BTC Port instead of Angyaruaq (Jungjuk).<br>Impacts from propeller wash would be less than Alternative 2. | Same as Alternative 2 | Same as Alternative 2 |
| Summary Impact Level | Minor | Minor | Minor | Minor | Minor | Minor |

**Table 3.7-47: Comparison of Impacts by Alternative***

| Impact-causing Project Component | Alt 2 – Proposed Action | Alt 3A – LNG-Powered Haul Trucks | Alt. 3B – Diesel Pipeline | Alt. 4 – BTC Port | Alt. 5A – Dry Stack Tailings (Option 1 – Unlined, Option 2 – Lined) | Alt. 6A – Dalzell Gorge Route |
|---|---|---|---|---|---|---|
| **Pipeline** | | | | | | |
| Geochemistry | No impact. | Same as Alternative 2 | Same as Alternative 2 | Same as Alternative 2 | Same as Alternative 2 | Same as Alternative 2 |
| Surface Water Quality | Potential erosion impacts and the introduction of fine-grained sediments to surface water associated with the pipeline would be mitigated to meet AWQC. | Same as Alternative 2 | The diesel pipeline would increase risk to surface water resources from spills or pipeline rupture relative to Alternative 2. However, under normal operating conditions, mitigation measures would minimize impacts. | Same as Alternative 2 | Same as Alternative 2 | Impacts associated with installation of the pipeline at stream crossings would be the same as Alternative 2, but repositioned west as a result of the Dalzell Gorge alignment. |
| Groundwater Quality | Installation of the pipeline could result in alterations to groundwater flow patterns, minor pipeline corrosion, and small changes in groundwater quality; it would, however, be temporary in duration. | Same as Alternative 2 | The diesel pipeline would increase risk to groundwater resources from spills or pipeline rupture relative to Alternative 2. However, under normal operating conditions, mitigation measures would minimize impacts. | Same as Alternative 2 | Same as Alternative 2 | Impacts would be the same as Alternative 2; specific locations would be different as a result of the Dalzell Gorge Route under this alternative. |
| Sediment Quality | Sediment quality would be impacted during pipeline construction as a result of increased sedimentation at the more than 400 stream crossing sites. However, impacts would not exceed regulatory limits, and would be minimized through mitigation. | Same as Alternative 2 | The diesel pipeline would increase risk to sediment resources from spills or pipeline rupture relative to Alternative 2. However, under normal operating conditions, mitigation measures would minimize impacts. | Same as Alternative 2 | Same as Alternative 2 | Impacts would be the same as Alternative 2; specific locations would be different as a result of the Dalzell Gorge Route under this alternative. |
| Summary Impact Level | Minor | Minor | Minor | Minor | Minor | Minor |

**Notes:**

* Alternative 1 (No Action Alternative) would have no new impacts to water quality.

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