# 4.0 RISK SUMMARY AND CONCLUSIONS

***The 'predictive' nature of this ERA includes consideration and treatment of unknowns. Historical studies, literature and documented effects to salmon and other aquatic life from current and past hard rock mines were used to reduce unknowns to the greatest extent possible and refine the overall prediction of risk.***

## 4.1 Summary of Risks by Stressor

To characterize the risk posed to salmon resources within watersheds associated with the proposed mine, both quantitative and qualitative information developed through the risk process was used to determine an overall (predictive) *weight-of-evidence* conclusion. Generally, weighing of evidence begins by summarizing the evidence developed for each endpoint selected (e.g., salmon species and/or their supporting habitat), then evaluating whether there is strong *proof* for supporting conclusions of potential *effect, non-effect,* or a point somewhere along this gradient. A major goal of this ERA process was to use the most relevant historical and literature-based findings to reduce the overall uncertainty. This process provided that predicted risk from mine creation, operation and closure would be appropriate and relevant. It is important to understand that the very nature of this **'predictive'** analysis is based upon unknowns. But these unknowns have been considered to the extent possible as potential risks to salmon from mine creation, operation and closure were explored. The information developed by this ERA is not conclusive, nor does it attempt to state with confidence that specific impacts to salmon will or will not occur. It has been developed to provide a gage with which to evaluate the risks that will likely be present should a mine such as the proposed mine be permitted and developed.

The risk assessment focused on two general stressor categories that may affect the viability of salmon within the watersheds under consideration. First, as a result of mine development and operation, physical stressors would occur that directly affect the viability of salmon resources. These include: the loss of instream flow [via changes to surface and groundwater] and subsequent alteration of habitat; impacts from road construction, including culverts' placement; and, effects from fugitive dust during construction and mining activities. Secondly, impacts associated with chemical [primarily metals] stressors within surface waters and/or sediments were evaluated for sources including: fugitive dust; slurry pipeline spills; chemical spills; tailings releases from episodic and large scale pollution events; and acid mine drainage (AMD).

### 4.1.1 Physical Stressors

Physical stressors include permanent removal/reduction of waterways (*Dewatering and Loss of Instream Flow* [*including Groundwater Discharge*] and *Loss or Alteration of Supporting Habitat*) that either directly support fisheries resources or provide necessary flow for species and population viability in downstream reaches. Similarly, stream crossing impacts during *Road Construction* may limit upstream migration and reduce reproductive potential for affected salmon populations. Reduced down-gradient stream water quality and quantity, and subsequent secondary effects to fisheries, could be expected from *Fugitive Dust* emissions, as a result of mine activities.

### *Dewatering and Loss of Instream Flow* [*Including Groundwater Discharge*] *and Loss or Alteration of Supporting Habitat*

- ***33 sq. miles of drainage area lost.***
- ***Approximately 68 stream miles lost.***
- ***14 miles designated salmon streams lost.***
- ***Reduced flow can result in higher temperatures; lower dissolved oxygen; restricted upstream migration.***
- ***Potential effects to spawning and embryonic development.***
- ***Up to 78 stream miles would exhibit some form of flow reduction in the three watersheds evaluated.***

The analysis predicts that physical stressors, including *Dewatering and Loss of Instream Flow* (including *Groundwater Discharge Loss*) would be critical and related to secondary effects such as *Loss or Alteration of Supporting Habitat* for salmon species (especially Chinook and coho) occurring within the watersheds under evaluation. First, approximately 33 square miles of drainage area within the three watersheds is proposed to be lost due to mining uses (e.g., water extraction, tailings ponds, excavation pits, mills, etc.). This 33 square mile area includes approximately 68 linear miles of stream channels, of which over 14 miles are ADFG-designated anadromous streams. As a result of lost up-gradient source water from the eliminated streams, summer low flow conditions in down-gradient mainstem segments of all three streams under evaluation would be exacerbated resulting in reduced pools and backwaters that support juveniles –approximately 78 stream miles would exhibit some form of flow reduction. This in turn would likely result in greater competition for resources such as food and cover. Pools that remain within affected stream reaches could experience increased temperatures.

Reduced low flow during the incubation or inter-gravel phase would also act to reduce salmon production within affected streams. Low flows would limit adult salmon entry into streams or affect their movement up river to stage for spawning. It is predicted that after mine development, velocities during the critical spawning/embryo development period (January–March) within all three streams would be less than optimum. Low flow conditions, along with other associated reductions in water quality conditions (i.e., lowered dissolved oxygen, higher water temperatures) would likely increase stress on individuals, potentially resulting in mortality. Flow reduction would also affect substrate composition in riffle areas within affected mainstem segments through embedded conditions and reduced sediment oxygen concentrations. This is turn would act to diminish the quality of redds, ultimately resulting in negative impacts during embryonic development and fry emergence.

Temperature changes can also occur as a result of stream flow reductions. The most critical period would be summer, when flow is already reduced and temperatures are highest.

Summer water temperatures would likely increase due to diminished riparian areas providing less shade and reduced upstream tributary inflows. Increased temperatures can cause higher stress to salmon (and forage fish). Temperature increases also affect the amount of dissolved oxygen in a stream, a key limiting factor for fish survival, resulting in increased disease outbreaks. In addition to growth and survival, changes in stream temperatures would affect the timing of smolt emigration. Finally, flow reductions have been shown to result in long-term reduced temperatures in winter, ultimately causing deleterious effects to egg/fry survival.

***Road Construction***

- ***Installed culverts along the proposed road could affect 89 streams, 14 of which are officially designated as supporting salmon and 75 of which may support salmon but have not yet been surveyed or survey results are not yet public.***
- ***35 miles of upstream anadromous habitat may be significantly affected for salmon spawning and rearing in the 14 designated anadromous streams.***
- ***Barriers to upstream migration for spawning could result in population fragmentation.***

Culverts installed during *Road Construction* can restrict or eliminate fish movement to upstream habitat, and isolate or modify populations. Effects to populations from culvert placement can include reduced ability to support upstream populations; habitat fragmentation; decreased ability to reach important headwater spawning and rearing sites; and attenuation of upstream species richness. The proposed access road would cross at least 89 streams; 14 of which are designated as ADFG anadromous waters. At these 14 stream crossings, over 35 miles of upstream anadromous habitat could be eliminated or significantly affected for use by salmon as spawning and rearing habitat. In addition, rainfall events could lead to water quality reductions downstream of crossings. Studies have shown that sediment loads are up to 3.5 times higher downstream of road culverts, with material being deposited in cobble stream beds downstream. Again, embedded riffle conditions would reduce the quality of redds and embryonic development and fry emergence, as survival and emergence of embryos and alevins is greatly influenced by the dissolved oxygen supply within the redd. Similar impacts could be expected at anadromous streams which are not yet designated. The overall impact of the proposed road construction, culvert placement, and maintenance at the 14 anadromous streams (and others) crossed could result in long-term reduction of habitat and subsequent reduction of viable salmonid populations presently found in these waterways.

***Fugitive Dust***

- ***Fugitive dust dispersion could conservatively cover 33.5 square miles surrounding the proposed mine.***
- ***33 miles of streams, of which 10 miles are designated salmon habitat, would be affected within the 33.5 mile dispersion zone.***
- ***Over the life of the mine, water quality could be negatively impacted due to vegetation loss and subsequent increased runoff, resulting in elevated stream turbidities and embedded conditions in riffle areas used for spawning.***

*Fugitive Dust* is expected to be generated during open construction and pit mining activities, materials handling, mill and concentrate storage facilities, and from wind-generated dust at mineralized surfaces. Dust dispersion would conservatively affect an area of 33.5 $mi^2$ around the proposed mine, but most likely a larger area. Within this area are approximately 33 miles of ephemeral, intermittent, and perennial streams, of which approximately 10 miles are ADFG-designated anadromous waters. Fugitive dust's impact on water quality over the 40 to 70-year life of the mine would result from denuded riparian habitat and subsequent degraded, embedded stream channels. Plant community and drainage impacts would be most obvious, with shifts and reductions of endemic plant communities replaced by patchy barren ground in areas having highest dust accumulation. Lichens and mosses are sensitive to dust impacts and would be affected to the greatest degree. Down-gradient streams would show incremental negative changes over time as the ecological viability of headwaters that support salmonids, resident species and other aquatic life diminishes.

### 4.1.2 Chemical Stressors

Chemical stressors, including those from *Fugitive Dust*, *Pipeline Spills*, *Episodic and Large Scale Pollution Events*, *Chemical Spills* and *Acid Mine Drainage* will likely act both on short- and long-term time scales, with the magnitude of their effects based on factors such as locale, season, volume and/or stressor type. Evaluation of the risk(s) posed from most of these stressors centered primarily on the potential for exposure of salmonids [and their habitat, including food resources] to copper expected in dust, tailings, slurry and mining wastes. Effects predicted from AMD centered on potential degradation of supporting habitat [surface waters] from reduced pH, but also included evaluation of AMD for mobilizing metals in the water column and directly affecting salmon. Chemical spills focused primarily on potential for impacts to aquatic environments from hazardous materials that are typically used in the hard rock mining industry.

### *Chemical Spills*

- ***Hazardous chemical spills could cause fish kills and habitat destruction.***
- ***Spills would be critical during clean up activities associated with pipeline breaks or tailings dam failures.***
- ***Impacts would be critical if spills occurred in spawning or rearing habitat.***

Transportation and storage of hazardous chemicals near water bodies could result in inadvertent *Chemical Spills* producing fish kills or other acute impacts to fishery populations. Clean-up activities associated with a pipeline break or tailings dam failure may pose the biggest risk to salmon due to the heavy equipment and maintenance materials being required at a site. Impacts would be critical if spills occurred in spawning or rearing habitat.

### *Fugitive Dust*

- ***During early stages of the proposed mine (10 years) copper from dust dispersion could affect benthic communities and subsequently salmon.***
- ***As the mine ages (30-50 yrs), copper from dust accumulation & transport could result in acute and/or chronic effects to aquatic resources, including salmon.***
- ***Toxicity would increase with oxidation of dust particles and in association with and acid mine drainage.***

*Fugitive Dust* is expected to be generated during open pit mining activities, materials handling, mill and concentrate storage facilities, and from wind-generated dust at mineralized surfaces. Risk was evaluated for two potential transport mechanisms; erosion of metal-laden soil particles and metals' leaching. Based on the depositional rates and patterns presented, erosion of soil particles indicate that during the early stages of mining operations [10 years] sediment copper concentration increases within the three watersheds would not be critical, but could include effects to sensitive benthic macroinvertebrates (e.g., mayfly, caddisfly, stonefly) which would occur in the most upstream segments where concentrations feasibly could exceed baseline mean concentrations by factors ranging from 2 to 18. As the mine ages (30-50 years), and dust (metals) accumulation along with erosion impacts are more sustained, stream concentrations could reach levels where chronic aquatic toxicological effects are imminent and acute effects possible. Copper (and other metals) would reach equilibrium, with sediment copper being continually released into interstitial (pore) water / surface waters, and suspended particulate matter in the water column adsorbing free copper ions to be re-deposited back into the substrate. Water quality changes (i.e., reduced pH) from AMD into watersheds would increase the bioavailability of copper, with higher proportions of ionic copper within the water column. Factors such as mixing and floods could both ameliorate local effects or lengthen the contaminant pathway, extending effects to larger portions of the watershed. At the concentrations predicted, salmon would be exposed to copper directly, through olfactory bulbs; through gill uptake of waterborne free cupric ions; and biotransfer in food resources.

Leaching of metals from dust-laden soils suggests that a continuous contribution of dissolved copper into stream systems would be expected to result in long term degradation of water quality. The model predicts that dust generated at the mine would result in metal-laden soils, with transport mechanisms resulting in continuous, long-term contamination of local surface waters that support multiple salmon life stages. This is important, especially considering that the exposure and oxidation of sulfides in both dust [and other mine sources] would result in acid generation and thus pH reduced in local water bodies. This would be most pronounced in upstream portions of the watersheds because dilution, due to proposed water extraction, would not be available. Small increases in dissolved copper above present background concentrations could result in sub-lethal effects to rearing juveniles throughout the watersheds. Salmon genetic acclimation to 'historic' dissolved copper concentrations in the watershed may make impacts from any increase in these concentrations critical. Downstream portions of all watersheds would most likely show reduced impairment as a result of dilution from inflowing tributaries.

### *Slurry Pipeline Spill*

- ***Pipeline releases could send thousands of gallons of slurry into sensitive salmon streams.***
- ***Embedded riffles and increased turbidities would result in down-gradient stream segments.***
- ***Long-term exposures and food chain transfer of copper in water and sediment would impact salmon and other aquatic life.***

A pipeline break or spill could result in thousands of gallons of metal-laden slurry being deposited into sensitive anadromous streams. Impacts from small spills would be similar in perennial streams such as the Newhalen River and Iliamna River, with fine-grained slurry particles being quickly entrained in flowing waters and transported downstream. For a nominal spill into the Newhalen River (100,000 to 200,000 gallons), slurry would be deposited directly into the stream channel. Primary physical impacts would be embeddedness in riffle/spawning proximal areas and increased turbidities resulting in potential gill abrasion and respiratory distress. Habitat quality would be diminished from increased turbidities, lost riparian habitat, and equipment leaks and spills during clean-up activities, for weeks to months. Long-term biouptake and transfer within food chains would likely result from exposure of forage fish species and benthic macroinvertebrates to both water and sediment metals' concentrations. The analysis suggests that impacts would most likely be exacerbated in smaller streams compared to larger streams.

### *Episodic and Large Scale Pollution Events*

- ***A tailings dam release could extend to Bristol Bay;***
- ***Fish kills would occur and tailings in streams would cause long-term effects;***
- ***Spills would result in loss of spawning and rearing habitat;***
- ***Recovery could take decades or longer.***

A failure of one of the tailings dams planned for the proposed mine would have both short and long term impacts on receiving waters, with severity dependent on dam release volume, timing, and location. Analysis predicts that run-out distances could be extensive, ranging to Bristol Bay. Lethal effects to biota in an affected stream would be instantaneous as the slurry travels quickly (up to 60 km/hr) down a stream valley. The bulk of the tailings would likely remain near the spill site and not travel outside of impact area, but overlying, acidic waters (containing dissolved copper and other metals) would affect surface water and adjacent terrestrial areas (affected riparian zones) well downstream of the impact zone.

Response activities would result in long-term stress to salmonid populations that were affected. Post-spill effects could cause direct spawning and rearing habitat losses both within and outside (downstream) of the primarily watershed affected. A conservative estimate of lost stream functional viability within the NFK and SFK watersheds shows that all anadromous streams would be affected. It is expected that salmon further downstream would also be affected to some varying degree. Because affected watersheds are not considered variable or disturbed, it is predicted that recovery would be slow and on the order of decades or longer.

### *Acid Mine Discharge (AMD)*

- ***AMD is expected during the proposed mine's life, and after.***
- ***Instream pH levels from AMD below 5 could occur up to 30 miles from the mine.***
- ***Low pH would result in fish kills and benthic community impacts.***
- ***AMD into streams would result in increased bioavailability of copper (and other metals) from various mine sources (dust, waste piles, accidental ore releases).***

Geochemical characterization of rocks from the proposed mine indicates that they would be acid-generating. Because the mine is proposed to be developed in an area with moderate precipitation, a high water table, numerous small streams, and over geological formations that are susceptible to ground water movement, AMD movement is predicted to be highly likely. Based on the literature reviewed, a pH of 4 (for SFK) and 5 (for NFK) for AMD discharges from tailings ponds/waste piles was used to show the relative spatial changes expected from AMD development and discharge. [AMD formation and discharge via groundwater was assumed but not specifically addressed by the analysis.] Results of the analysis showed that surface water pH values less than 5 would be possible up to 30 miles downstream of the mine.

Water quality changes from AMD into watersheds would result in increased bioavailability of copper (and other metals) already found in surface water and sediments, in addition to metals added to the system from other mine sources previously described (e.g., dust, ore releases, waste piles, etc., may also oxidize and reduce pH in concert with AMD), with higher proportions of ionic copper occurring within the water column. Impacts to salmonids from free cupric ions would be expected. Streams affected by AMD are typically poor in taxa richness and abundance. Based on literature findings, a complete loss of fish in 90% of streams having a pH less than 4.5 could be expected.

## 4.2 Multiple Stressors and Relative Risk

It is important to understand that the potential stressors of concern identified through this risk assessment process would work both independently and concurrently to impact salmon and their supporting ecosystem. For example, stream flow reduction from water extraction/use proposed for the mine has the potential to directly affect individuals and their habitat, with fugitive dust impacts and inadvertent spills and releases also occurring in the same locale. Both physical and chemical impacts from dust and mining activities would act to exacerbate an already stressed fish community in those stream segments where flow has been reduced and habitat has been altered. This example would be considered a chronic, long-term issue, with effects to populations and habitat increasing over decades or longer.

Conversely, episodic and large-scale pollution events alone are generally considered to be the most critical to salmon from a short-term perspective. Based on their size, these events likely would result in acute impacts, but impacts such as habitat destruction and chemical exposures could occur over much longer periods – beginning during initial response and clean-up, and extending into channel rehabilitation and beyond. Additionally, an episodic spill event in streams already stressed by flow reductions, dust or other on-going mining-related impacts, would limit a salmon population's recovery as compared to a stream system that has not experienced reductions in flow and is lacking impacts associated with mining dust dispersion and other similar mining-related impacts.

Based on information developed during the risk process and as described in the preceding summary, stressors of concern impacts were objectively evaluated for each salmon species at three ecologically relevant levels; *individual*, *population* and *habitat*. Impacts to individuals would be those that affect limited portions of a population, typically over short time frames, and are generally not critical for sustaining populations. Chemical and pipeline slurry spills that result in fish kills or temporary relocation are considered relevant stressors for impacts to individuals. Although individual fish would be killed, their loss would not, in most cases, result in changes to stream communities over the long term, if clean-up measures are adequate. Typically the most vulnerable segment of a fishery population are juveniles. So, although subsequent year-class strength may be temporarily diminished in the near term, the overall long-term reproductive potential of a population may not be significantly affected. It is understood that spills may result in significant short-term modification to habitat and local fishery resources during ensuing months following the event, with many factors ultimately influencing the intensity and duration of effects.

Impacts that would be critical to sustainability of salmon populations would include any that negatively influence survivability, reproductive success, limit movement and thus restrict continued populations' interaction or spawning potential, and/or result in long-term degradation of salmon habitat and associated ecological components/attributes. Water flow in a stream affects all aquatic life, and there is a definite relationship between annual flow regimes and the long-term quality of salmonid riverine habitat. Flow rates affect all salmon life stages, including the upstream migration of adults, survival of eggs, the emergence and viability of fry, and timing of smolt out-migration. A long-term reduction of flow within a system would increase the potential for systemic effects to resident salmon populations.

Impacts on populations from metals' contamination, as a result of hard rock mining, would result from loading within various environmental media (sediment and water). Transfer or release into biological receptor groups, including vegetation and benthic organisms, results in chronic exposure to fish via aqueous uptake and trophic exposure routes. Direct exposure to water-borne metals' contamination can cause both acute and chronic effects in fish, while impacts to their food resources (fish and benthic organisms) will likely result in indirect and long term impacts on fish populations. These effects can be associated with stressors of concern such as: fugitive dust dispersion; pipeline spills and episodic and large scale pollutions events when metal-laden tailings/slurry remains in a system; and AMD.

Impacts to habitat are associated with reduced flow, and with other stressors that result in elevated turbidities or embedded conditions, other changes to water quality parameters that are not conducive to fish sustainability, and physical changes to the environment during spill cleanups. AMD that results in long-term reduced water quality or reductions in food resources would also be considered as an impact to habitat.

As a result of the analysis for effects for each stressor, species were assessed relative to life history and life requisite information from both a temporal and spatial perspective. Using criteria of potential scope, severity and duration, impacts predicted for each stressor of concern were qualitatively ranked based on their potential to negatively alter salmon within the primary watersheds addressed by this ERA. For example, based on life history information on spawning habitat requirements, along with data from Woody (2009b) that identified coho and Chinook juveniles in streams associated with the mine site, *Dewatering and Loss of Instream Flow* impacts were deemed more critical to those species than other salmon species. Similarly, impacts expected from pipeline spills would be associated with site-specific downstream watersheds. As such, for a spill into the Newhalen River for example, habitat and species supported both in and downstream (i.e., Lake Iliamna) may potentially be affected. Based on this criterion, sockeye salmon fry would be at risk and thus a relatively higher impact factor was selected. Because of the spatial extent for each of the species under investigation and the large scope of the proposed mine, it was not possible to individually evaluate each stressor's effect for each stream. Also, because the location and extent for some of the chemical stressors is presently unknown, the impact factor was developed based on the preponderance of information for effects to 'most' salmonid species (or their habitat and/or supporting biological community) if an event occurred.

The risk analysis indicates that physical stressors would act to create secondary effects such as loss or reduction of supporting habitat for Chinook and coho salmon for the watersheds evaluated. This determination was based on data that indicates these two species were more prevalent in the local watersheds compared to sockeye, pink or chum. Overall, impacts expected from other individual physical stressors such as fugitive dust dispersion, pipeline spills and chemical spills, were deemed important primarily in portions of watersheds nearest to proposed extraction areas or near the spill location, and thus impacts should be relatively lower. But, it must be considered that these impacts will likely occur much earlier in the mine's life and thus may act to magnify subsequent effects from ore spills and releases, or from long-term AMD.

Contribution of 'clean' surface water and groundwater along mainstem channels away from the mine should act to ameliorate negative impacts to habitat for salmon. But, the potential for AMD through both of these sources could result in habitat degradation further from the mine. Episodic and large scale pollution events and AMD, that could result in significant and long-term effects to populations and habitat (water quality) much further downstream, would result in a higher prediction of risk.

It must be reiterated that many of these stressors would occur simultaneously, creating synergistic effects which would tend to elevate a stressor's risk potential. For instance, it is highly probable that even with mitigation and BMPs employed at the mine, copper and other metals will be mobilized in runoff or leached into surface and/or groundwater during the life of the mine. Long-term metals' contributions to surface waters from dust generated at the mine would act to compound other physical (habitat loss, flow reduction) and chemical (spills, releases AMD) impacts expected from the mine's creation and operation, resulting in cumulative impacts (see Cumulative Risk Analysis, Section 4.3) to salmon populations.

## 4.3 Cumulative Risk Analysis

- ***The magnitude and extent of the 'effect' of an action on a resource depends on whether cumulative impacts exceed the capacity of the resource to sustain itself and remain productive (USCEQ 1997).***
- ***Incremental increases in effects would slowly reduce salmon resistivity and result in magnification of each stress factor.***
- ***Over time, stressors would act synergistically to reduce habitat and food resources, increase effects to sensitive life stages, increase potential for fish kills, increase metals' bioavailability with short and long-term effects, and reduce genetic variability and disease resistance.***
- ***It is predicted that impacts to the surrounding ecosystem would expand over the course of the proposed mine's life. Risks to salmon and their supporting habitat would also increase over time and space as the mine expands. Development of additional mining interests in the area would increase risks.***

A cumulative impact has been defined as "*...the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future action...*" (U.S. Council on Environmental Quality [USCEQ] 1978). The National Environmental Policy Act [NEPA] directs that cumulative analyses are essential for effectively managing the consequences of human activities on the environment. The cumulative analysis necessarily involves assumptions and uncertainties, but provides a method for bringing useful information for making informed decisions (USCEQ 1997).

One of the fundamental issues related to determining cumulative impacts is defining the pre-development baseline condition (Dubé 2003). Baseline conditions provide a measure by which to assess changes to watersheds from a directed project and all other activities that may affect the watershed or resource in the future. Importantly, cumulative risk must consider both the spatial and temporal perspectives of the proposed action, all effects related to the action, and other actions that may have bearing on the resource or species of concern. Spatially, the scale of distribution for the identified species at risk may dictate the level of concern warranted. For instance, for wide-ranging species, society may be willing to accept a larger risk of error than for species that are specialized, endemic or in imminent danger of extinction (Ziemer 1994). Over time, care must be afforded to species that could be negatively affected by changes to supporting habitat through natural and anthropogenic factors in the near and distant future. Thus, the magnitude and extent of the 'effect' of an action on a resource depends on whether cumulative impacts exceed the capacity of the resource to sustain itself and remain productive (USCEQ 1997).

Analysis of cumulative risk on salmon viability within proximal watersheds associated with the proposed mine was based on a two-pronged approach. First, evaluation was made on the potential for individual stressors of concern to affect salmon and/or their supporting habitat, both from a spatial and temporal perspective. Second, the probability that stressors of concern could act synergistically to disrupt salmon populations' viability was considered. Again, both tools were used in the context of temporal and spatial prediction of effects (risk), as compared to current baseline salmon conditions.

From a temporal perspective, a stressor of concern's potential to affect or alter salmon populations considered factors such as distribution, longevity, target organism(s), form, persistence, toxicity and/or magnitude. As provided in the weight-of-evidence analysis (see above), impact potentials for 'populations' and 'habitat' generally indicate that some stressors would be relatively less important (Fugitive Dust, Chemical Spills, Pipeline Spills), with others more critical (Dewatering and Loss of Instream Flow, Loss or Alteration of Habitat, Episodic and Large Scale Pollution Events, AMD). First, an objective long-term prediction for independent effects to salmon population viability for each individual stressor of concern was considered over the proposed life of the mine, and beyond. For the purpose of evaluating a reasonably likely scenario, this analysis assumed that two (2) significant (i.e., ~100,000 - 200,000 gallon) pipeline spills would occur during the mine's operational life (see Section 3.2.4; Slurry Pipeline Breaks and Spills), and one significant episodic and large-scale pollution event (i.e., tailings pond release of ~25% of capacity) would occur (see Section 3.2.5; Episodic and Large Scale Pollution Events).

Generally, magnitudes and extent of all other stressors, excluding AMD, assumed continuous operations would result in increasing incremental stress (and thus risk) to salmonid populations within the watersheds under investigation. It was predicted that AMD generation would occur later in the mine's life (and beyond) and that impacts would increase dramatically near the mid-life stage of the mine. Finally, it was predicted that stressors of concern would act synergistically to exacerbate other physical and chemical effects and result in increased overall risk and lower viability for local salmon populations. For instance, when significant events occur in a watershed, such as an inadvertent dam release or other similar episodic spill event, salmon populations would most likely have little success recovering to pre-event levels because of the historical stress exerted on them from other mine-related stressors. AMD development in the older mine would exacerbate the negative effects on all life stages (and other biota), with risk increasing dramatically and population viability suffering for decades, or even centuries, into the future. The results of this exercise indicate that, based on risk predicted from the various stressors of concern, cumulative risk will likely follow an increasing upward trend over the life of the mine. The trend generally would be most relevant for risk to salmon over time within localized watersheds, but would also be important for other endemic species. The upward trend expected assumes that stressors would act in concert, but does not necessarily assume that all stressor effects would be additive. It also does not attempt to incorporate stressors (e.g., road construction, pipeline spills) that would affect salmon in other watersheds.

The evaluation of long-term impacts to salmon populations from man-made (anthropogenic) disturbances, as predicted for mines such as this proposed mine, is not new to fisheries scientists. The National Academy of Sciences (1996) provided discussions on salmon populations' responses to natural and anthropogenic disturbances. As provided in the NAS report, natural disturbances coupled with frequent, small anthropogenic disturbances results in long-term declines in salmon productivity (Figure 29a). They also note that a very large anthropogenic disturbance has typically been shown to have a significant short-term reduction in salmon productivity, with long-term consequences, where future productivity is much lower than prior to the large-scale event (Figure 29b).

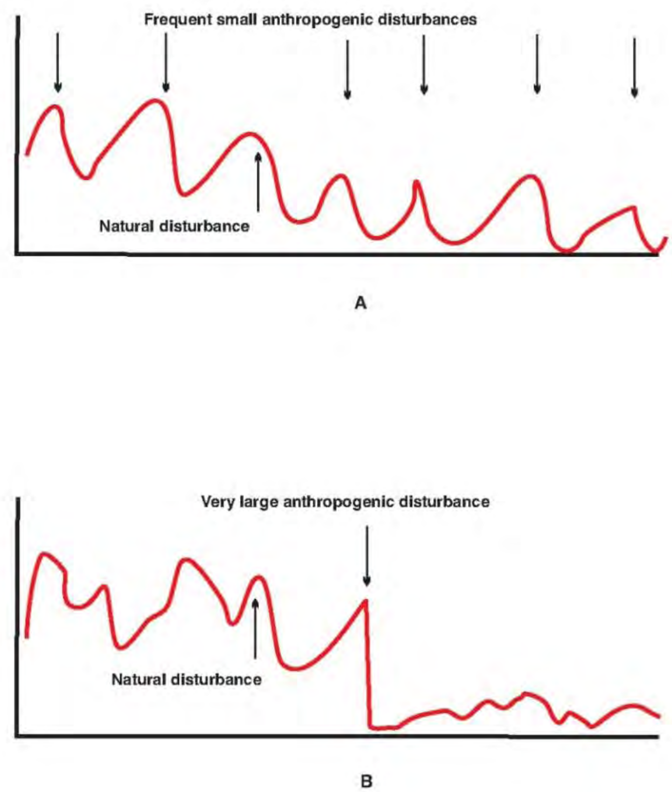


**Figure 29. Hypothetical Response of Fish Populations to Natural and Anthropogenic Disturbances:** ***(A) Frequent small anthropogenic disturbances in concert with Natural Disturbances; (B) Single very Large Anthropogenic Impacts in concert with Natural Disturbance Regime*** (Source: NAS 1996)

This evaluation predicts that mine construction and development would begin to affect local groundwater and surface water resources prior to mining commencement (see Figure 29a). Mine development includes land clearing, building of mine structures (mills, buildings, tailings storage structures and dams) and processing plants, and installation of all necessary equipment (Fourie and Hohm 1992). Next, access to the ore body encompasses removal of soil and barren rock to expose the ore bodies. This process is known as pre-production stripping. This process of stripping the surface away can take months to years. Throughout this process, dust from blasting, trenching, and excavation, in addition to truck and other vehicle traffic, would be created and dispersed across the mine site and beyond. Surface waters would be enveloped by the mine's footprint and groundwater would be used exclusively for construction and future production. It is predicted that construction of the proposed road and pipeline will likely result in impacts over many months. Although regulatory BMPs will be required, it is likely that impacts to streams would occur during this process. All of the pre-production activities, which could take several years, would initially act independently to alter proximal salmon habitat, although specific effects to populations may not yet be measureable during these initial phases.

After mining begins, ore exposure and removal would result in an incrementally larger mine footprint, with increasing amounts of tailings and waste rock generated on site. Through the extended mining period (40-70 years), effects exhibited on salmon habitat and populations (e.g., viability) from each of the stressors of concern would increase. This incremental increase in effects would slowly reduce salmon resistivity and result in magnification of each stress factor (i.e., reduced flow and water quality, reduced habitat quantity and quality, increased copper concentrations) produced. [This step in the risk analysis process did not include consideration of the stressors *Road Construction* or *Pipeline Spills* because it was understood that they would occur outside of the primary watersheds under consideration.] Although from a holistic perspective, it is expected that both of these stressors would act to reduce salmon viability in other watersheds over time. So, from a temporal perspective, cumulative risk to salmon populations associated with the proposed mine area is predicted to be moderate during early stages (years 0 – 25); with subsequent stages resulting in greater risk as each stressor, and their cumulative impact with other stressors, begin to exhibit greater and more pronounced effects on habitat, individual salmon health and population structure.

An *Episodic and Large Scale Pollution Event* during the mine's mid-life (at ~30 years) would most likely exacerbate pre-event natural and anthropogenic stress within local watersheds, with recovery of salmon populations to pre-event levels dubious [per information in Figure 29a and 29b]. The magnitude of the physical and chemical effects during latter stages of a mine's life (and beyond) could act to create environments where salmon, although possibly surviving, would have reduced distributions, limited available habitat, and be genetically susceptible to minor natural or anthropogenic disturbances. Long-term sustainability would most likely be jeopardized in the most critically affected portions of the watersheds. Also, it is predicted that AMD effects could occur during this period and well beyond.

The result of this exercise suggests that risk from the stressors of concern addressed by this ERA would act synergistically over time through: 1) reduction of habitat and food resources; 2) increased negative effects to sensitive salmon life stages as a result of reduced water budgets; 3) increased potential for fish kills; 4) increased bioavailability of metals in solution with subsequent short- and long-term systemic effects to individuals; 5) and reduced genetic variability and disease resistance.

Spatially, cumulative risks from stressors of concern will most likely develop in concert with temporal aspects as described above. *Dewatering and Loss of Instream Flow* would be expected in those portions of the watershed nearest to the mine proper during mine development and operation. Subsequently, reduction of groundwater discharge into down-gradient streams would be expected based on extraction for mine use and reduced upgradient recharge. *Loss or Alteration of Habitat* is expected as flows are reduced and channels re-established. Although most obvious in areas nearest the mine, lesser downstream reductions could affect tributaries and back-water areas that are important as salmon rearing habitat, and could lead to increased stranding, greater predation vulnerability and decreased productivity. As the mine ages (20-30 years), components such as refuse piles, waste rock and/or chemical storage areas would increase in size and become more difficult to manage properly. It is predicted that dust accumulation and transport, discharges, and/or spills would be likely to cause additive stress within the near-mine watersheds. Over time, it is expected that degradation of current high-value salmon habitat and its potential to sustain optimum populations would become more prevalent further away from the mine. Based upon the volume and distance of discharge, an *Episodic and Large Scale Pollution Event* could lead to both acute and chronic impacts within near and distal stream channels. The event in and of itself would most likely disrupt seasonal reproductive cycles and lead to reduced production outside of the zone of impact. Much of the discharged material would remain in the system with secondary effects such as embeddedness, turbidity and copper (and other metals) accumulation in sediment occurring in portions of the watershed much farther from the initial impact zone. These type effects would continue over time with fine-grained, copper-laden sediments (i.e., tailings) being continually transported further downstream with each major flood or snow-melt. As mine tailings ponds increase in size and duration, AMD is likely to occur. Effects within the near-mine watersheds would be expected first as groundwater becomes contaminated. As ponds and waste piles provide a continual AMD source, water quality reductions and downstream shifts in resident fish and invertebrate communities would be expected and result in reduction of salmon sustainability and production.

Although spatial cumulative risks are more difficult to predict, it is important to understand that the preceding risk characterization was based on the preliminary plan for the proposed mine as submitted to the Alaska Department of Natural Resources in 2006 as a part of Northern Dynasty's water rights application. That plan proposed mining 2.5 billion tons of ore (NDM 2006c). A recent news release by Pebble Limited Partnership (2010) indicates that the Pebble deposit has a mineral resource of 10.78 billion tons. History suggests that it is fairly standard in the industry to secure a permit for a smaller mine and then request expansion permits for more mining once the mine is in operation, has a workforce in place, and is paying taxes to local and state jurisdictions. For example, at the Zortman-Landusky mines in Montana, 21 amendments were approved by the regulatory agencies after the mines were initially permitted. This process of initial mine permitting, with subsequent expansions, was demonstrated in 2009 at several mines worldwide:

- Red Dog Mine, AK – expansion will double the life of the mine from 20 to 40 years;

- Keetac-Taconite Mine, MN – expansion will add 2000+ acres and increase output by approximately 33%;
- Smoky Canyon Mine, ID – expands mine by 1,100 acres and increases capacity by 38%;
- Cloudbreak Mine, Australia – major expansion project;
- Antamina Mine, Peru - extends the life of the mine until 2029 and increases ore processing by 38%;
- Metropolitan Colliery, Australia – extends life of mine by 20 years;
- Absaloka Mine, MT – increases mine size by 3,660 acres; and
- Kemess North Mine, BC – expands mine by using 269 hectare lake to store tailings and waste rock [was denied].

This information suggests that even if the initial design of a mine in the Pebble prospect area were to be smaller than that proposed by NDM in 2006, expansion in the future is possible and probable. Moreover, mining development on other claims in the region is also possible. This information suggests that impacts to the surrounding ecosystem would expand over the course of a mine's existence; with noted risks to salmon and their supporting watersheds also expected to increase over time and space as the mine grows. For example, Figure 30 provides a spatial rendition of future tailings ponds' locations that would be needed for storage based on the February 2010 news release. Although the locations and pond sizes as shown are speculative, they were developed considering local topography and information on currently described mine attributes.

In conclusion, this ERA has been developed based on both predicted and expected systematic perturbations and high-profile contamination events within the Nushagak- Mulchatna and Kvichak watersheds that presently support sustainable salmonid populations. Although it is uncertain if all the stressors described by this ERA will actually occur and result in degradation of habitat and reduced health and viability for salmon species (and their supporting ecosystems) that occur, based on historical information gathered for other similar mines and known effects of mining-related heavy metals to salmon and other biological populations, significant negative impacts to the aquatic ecosystem are to be expected over the life of the mine, and beyond.

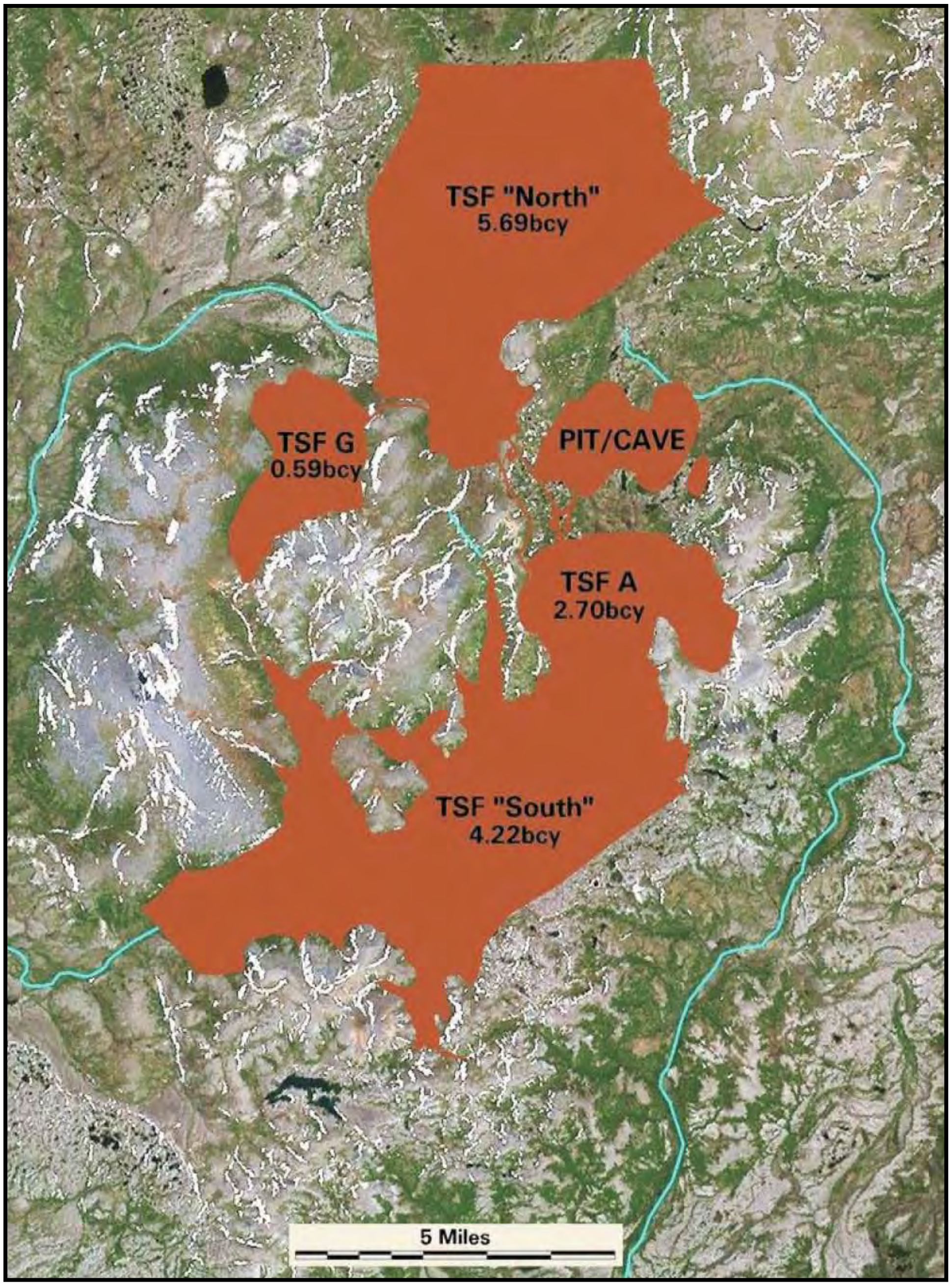


**Figure 30. Hypothetical Rendition of Future Tailings Ponds Placement based on NDM February 2010 News Release of Pebble Deposit Mineral Ore Resource of 10.78 Billion Tons** [image courtesy of The Center for Science in Public Participation and SkyTruth]

## 4.4 Loss of Salmon Production

- ***Determination of lost salmon production requires knowledge of stream habitat within affected watersheds.***
- ***ADFG predicted 2010 sockeye runs of 3.84M and 2.32M, respectively, for Kvichak and Nushagak-Mulchatna river systems***
- ***Stressors that act to affect proximal water bodies could reduce annual salmon production by 1% of 2010 levels.***
- ***Large-scale dam failures could potentially reduce salmon production in downstream portions of the Nushagak-Mulchatna watershed by 25-50% of 2010 levels.***

As discussed throughout this ERA, various impacts from proposed mine development, operation and/or closure could likely result in significant long-term changes to supporting, spawning and rearing habitat in portions of the Nushagak-Mulchatna and Kvichak watersheds. Although various impacts from mining have been shown to be highly probable based on historic information from similar hard rock mining methods, the specific relevance of these impacts to salmon production in affected streams has not yet been addressed.

Habitat alteration and loss can lead to salmon production loss (NAS 1996). Production declines when habitat alteration and loss impair the successful completion of life-history stages in the context of a watershed's landscape, its natural disturbance regime, and its anthropogenic changes (NAS 1996). Research has demonstrated that the quality of freshwater habitat (particularly over-winter habitat) has a direct influence on survival rate. Habitat quality determines the number of salmon smolts that a stream can produce as well as the efficiency with which those smolts are produced (i.e., survival rate).

Historically, models have been developed to estimate production potential and spawner escapement that account for differences in habitat quality (Nickelson 1998). The habitat limiting factors model (HLFM version 5.0; Nickelson *et al.* 1992) was first used in Oregon to estimate smolt potential based on population abundance for the spawning, spring rearing, summer rearing, and winter rearing life stages of coho salmon. The HLFM applied habitat-specific densities by the areas of individual habitat types that were derived from both summer and winter stream inventory data (Nickelson 1998). From this information, the model can then estimate potential smolts by applying survival rates from each of these life stages to the smolt stage. Typically, suitable winter-rearing habitat is in least supply compared with the other habitat types and thus can be the limiting factor to smolt production.

Similar approaches for determining production potential have been used in Oregon (USDOI) and throughout the Pacific Northwest:

- *Coho Salmon Production Potential in the Cle Elum River Basin, Storage Dam Fish Passage Study, Yakima Project, Washington, Technical Report Series No. PN-YDFP-007*, Bureau of Reclamation, Boise, Idaho, March 2007.

- *Assessment of Sockeye Salmon Production Potential in the Cle Elum River Basin,*
- *Storage Dam Fish Passage Study, Yakima Project, Washington, Technical Report Series No. PN-YDFP-008*, Bureau of Reclamation, Boise, Idaho, March 2007.
- *Coho Salmon Production Potential in the Bumping River Basin, Storage Dam Fish Passage Study, Yakima Project, Washington, Technical Report Series No. PN-YDFP-009*, Bureau of Reclamation, Boise, Idaho, March 2007.

These studies generally used two approaches to estimate coho salmon production potential; first, by estimating the number of spawning adults that the available spawning habitat would support, and second by estimating juvenile rearing/overwintering habitat that would be available in accessible river reaches. Suitable spawning habitat is primarily a function of substrate composition and suitable water velocity and depth – spawning site selection by fish is complex and likely based on a range of environmental or microhabitat conditions such as depth, flow, and substrate size (Bjornn and Rieser 1991). This can differ for the same species in different streams (McHugh and Budy 2004).

Other approaches that have been used for smolt density modeling include similar data requirements. Information such as habitat quantity and quality, and whether the habitat supports spawning and rearing, rearing only, or is only used for brief periods as transit corridors and is thus not considered to be spawning or rearing habitat, is typically required. In order to predict lost production from the various impacts discussed throughout the ERA, a comprehensive knowledge of salmon habitat parameters noted above in the affected portions of the watersheds is required. Critical to overall production estimation would be an understanding of the use of stream habitat during the winter period.

Alaska Department of Fish and Game (ADFG) develop annual forecasts for sockeye salmon run to Bristol Bay. Their most recent forecast (ADFG 2009) uses adult escapement and return data from brood years 1976-2006. The annual forecast is the sum of individual predictions for nine river systems (Kvichak, Alagnak, Naknek, Egegik, Ugashik, Wood, Igushik, Nushagak-Mulchatna and Todiak rivers) and for four age classes (age 1.2, 1.3, 2.2 and 2.3; plus ages 0.3 and 1.4 for Nushagak River). ADFG’s current forecast predicts a total of 39.77 million sockeye are expected to return to Bristol Bay in 2010, which compares closely to their last 6 year forecasts where total runs were close to or exceeded 40 million sockeye salmon. For 2010, ADFG predicted total runs for the Kvichak and Nushagak-Mulchatna river systems of 3.84M and 2.32M sockeye, respectively (i.e., 15% of Bristol Bay forecast).

To predict the relative impact to [sockeye] salmon in the three streams evaluated by this ERA, it was necessary to assume that the number of sockeye returning to the watersheds was uniform across all streams that make up the Kvichak and Nushagak-Mulchatna river systems. Return data from ADFG (2010) was used as a surrogate for production based on the presumption that returning sockeye represented some [unknown] percentage of a stream system’s smolt production. This is generally referred to as the smolt-to-adult return (SAR) rate and is specific to a watershed; generally varying from year to year.

SARs are typically determined by counting smolts as they migrate downstream and comparing this to the number of returning adults within a stream or river. Although it was well understood that the many habitat [and other environmental] features within these systems do not provide support to salmon uniformly, this approach was deemed reasonable and was determined to be a method for evaluating relative potential impacts from mining within the focus streams. For instance, both river systems contain large lakes with hundreds of tributaries. Sockeye salmon spawn not only in the rivers and streams in these systems but also along the beaches in these lakes, and some of these habitats may be utilized more than others and it is most likely that some are more productive than others (Baker 2010). Nevertheless, using this approach, an attempt was made to generally predict the impacts to sockeye from several of the stressors presented throughout the ERA.

No long term monitoring studies were found that compared pre- and post-mining salmon production rates, but it is predicted that effects within the localized smaller watersheds would act systemically to negatively affect production in the larger watersheds. In other words, decreased production would be exacerbated downstream and within connective tributaries as stressors' effects expand spatially. Again, as noted in Section 3.1.4.1, the *River Continuum Concept* for a stream translates to a smooth longitudinal gradient of conditions; thus the life requisites for supporting the biological community are interconnected and thus similarly at risk from upstream perturbations. As such, changes to a natural riverine complex will inevitably result in effects, to some degree, that can negatively impact fish (and other biota) viability along this gradient.

Using the National Hydrographic Dataset (NHD; USGS 2008), total stream lengths for both the Nushagak-Mulchatna and Kvichak watersheds were determined (see Figures 31 and 32). Next, for each of the various impact stressors considered, spatial and temporal loss of *production* was predicted based on the stressors' characteristics. Finally, the predicted relative percent loss of *production* [based on the 2010 ADFG forecast] was determined. For example, the Nushagak-Mulchatna watershed has a total stream length of 35,326 km. If all of the 326 km NFK watershed was rendered 'non-producing' as a result of some stressor, then this was determined to represent a loss of approximately 0.9% smolt *production* of the larger Nushagak-Mulchatna watershed.

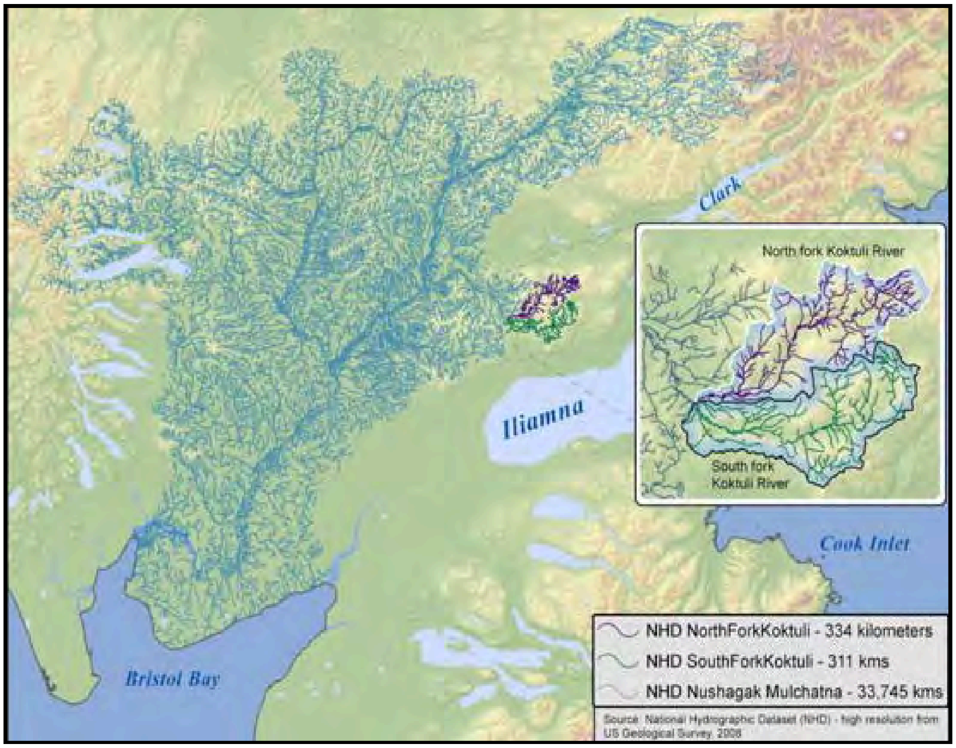


**Figure 31. Watershed Size Comparison of North and South Fork Koktuli to Nushagak-Mulchatna River Systems**

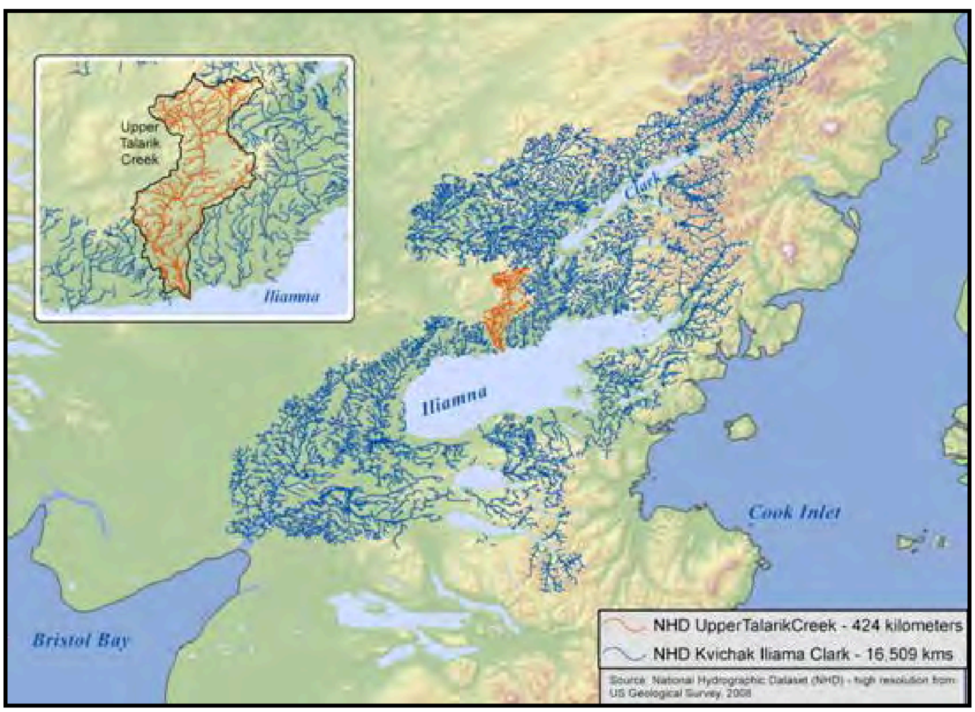


**Figure 32. Watershed Size Comparison of Upper Talarik Creek to Kvichak-Iliamna-Clark River Systems**

It was predicted that for those stressors which may impact a stream incrementally over time and space [i.e., copper and other metals' increased accumulation in water, sediments and biota from fugitive dust, AMD from waste piles runoff and/or increased discharge of contaminated groundwater further from the mine source], annual production losses within a watershed could result from the spatial expansion of these impacts and thus subsequent/additive production losses in the future.

Earlier analysis predicted that *Dewatering and Loss of Instream Flow* (including *Groundwater Discharge Loss*) and subsequent *Loss or Alteration of Supporting Habitat* would eliminate approximately 68 linear miles of stream channels, with 78 stream miles likely exhibiting some form of flow reduction. This in turn would result in greater competition for resources such as food and cover. For example, Washington's Department of Fish and Wildlife have developed empirically-based regression models that use stream flow indices as predictors for wild coho smolt production for several index stocks (Seiler *et al.* 2003). *Fugitive Dust* is expected to be generated during open construction and pit mining activities. Physical impacts from dust dispersion could affect a large area around the proposed mine, with metal-laden soil particles potentially contaminating sediment and water downstream from the impacted area. Other impacts such as inadvertent *Chemical Spills* could cause fish kills or other acute and/or chronic impacts to supporting food sources and habitat. All of these type impacts, if they occur, would likely result in reduced salmon production in the portions of the NFK, SFK and/or UTC watersheds proximal to the mine. The additive nature of these impacts could result in annual sockeye production loss near 1% of that derived by ADFG for the Kvichak and Nushagak-Mulchatna river systems. Temporal and spatial changes to sockeye production over time would depend on adherence to BMPs and/or any mitigation measures designed to reduce off-site contamination.

*AMD* could cause water quality changes in local and downstream watersheds resulting in increased bioavailability of copper (and other metals). If AMD develops, this would most likely result in impacts to relatively greater portions of the Kvichak and Nushagak-Mulchatna river systems compared to impacts discussed above, and could potentially make them unable to support salmon. The spatial extent for the effects from AMD would be dependent on whether discharges are continuous, as a result of groundwater contamination or surface water runoff, or a result of episodic spills or discharges from tailings ponds, or both. If chronic AMD occurs in mid to latter stages of the mine's life, it could impact most of the watersheds under investigation. Xiao *et al.* (2010) described environmental impacts from AMD from the Dexing Copper Mine (largest open pit mine in Asia). Their investigation found AMD up to 75 km from the mine in the Le An River (Xiao 2010). Similar effects within the Nushagak-Mulchatna and Kvichak watersheds could result in changes to water quality well outside of the focus watersheds and potentially cause production losses of greater than 1-2% of the ADFG forecast for both the Nushagak-Mulchatna and Kvichak river systems.

Spills or releases could result in extended impact areas, with salmon production losses associated with the volume released. If AMD develops and is released, sockeye salmon production losses to 1% (or greater) could occur within the Kvichak and Nushagak-Mulchatna river systems. Using the 2010 ADFG sockeye run forecast noted above as baseline, this would mean that if all annual NFK *production* was lost, conservatively, there would be a decrease of 23,200 smolts (e.g., 1%) throughout each of the Nushagak-Mulchatna and Kvichak watersheds.

Again, return data from ADFG (2010) was used as a surrogate for production based on the presumption that returning sockeye represented some [unknown] percentage of a stream system's smolt production. Thus, smolt losses would theoretically be much greater than the predicted number of returning adult sockeye predicted to be lost.

An *Episodic and Large Scale Pollution Event* could affect large portions of the watershed down-gradient from the tailings dam. Lost salmon production could be significant considering the size of the dams planned and the tailings volumes proposed. Based on the analysis of the travel distance for a release within either the NFK or SFK, affected portions of the Nushagak-Mulchatna watershed could result in production losses throughout mainstem channels all the way to Bristol Bay. Post-event production losses very well could be up to 25-50% of the ADFG 2010 levels for many years following a release.

In summary, it is impossible to predict the specific loss of production for salmon found within the watersheds associated with proposed mine activities. As stated previously, mine management practices have not yet been provided, and extraordinary weather events that could trigger large-scale impacts are always unknown. But, based on historical findings from other similar large hard rock mines, it can be predicted with some certainty that salmon (and other indigenous species) will exhibit some effects both temporally and spatially, with subsequent production loss inevitable. Considering the potential for further mine development, as noted in Section 4.3 Cumulative Risk Analysis, continued emphasis is needed on assessing the possible impacts to salmon production.

## 4.5 Uncertainty Analysis

- ***The predictive ERA relied on assumptions, but attempted to reduce uncertainty through professional judgment, analogy with similar chemicals and conditions, and data/information from other mine sites.***
- ***Uncertainty is low for water loss and habitat alteration and creation of dust at Pebble Mine, but high for the potential failure of a tailings dam.***
- ***The uncertainty of impacts from dust runoff into streams and road construction is high, but it is highly certain that over the life of the mine pipeline breaks will occur with subsequent impacts to salmon highly likely.***
- ***Based on historical information from other hard rock mines, there is a high certainty that AMD will develop during the life of the mine and affect downstream waterbodies.***

In an ERA, the uncertainty analysis is an integral part of the characterization of exposure assessment and thus risk prediction. Since this is a predictive ERA, data were unavailable for directly characterizing exposure. As a result, the assessors had to rely on assumptions that inherently include varying degrees of uncertainty. In order to reduce the uncertainties associated with these assumptions, a combination of professional judgment, inferences based on analogy with similar chemicals and conditions, along with estimation techniques and developed data for other mine sites, were used. The following provides information on sources of these uncertainties, and describes the methods used to minimize them, with a final goal of providing relevant characterization of ecological risks associated with each stressor addressed within the ERA.

During the initial stages of the ERA, information developed to date by mining proponents was reviewed to understand the potential scope and breadth of the project and to characterize the large-scale mining proposal. Project specific information that was publically available was reviewed from The Pebble Partnership website (http://www.pebblepartnership.com/), ADNR's Division of Mining, Land and Water (http://dnr.alaska.gov/mlw/mining/largemine/pebble/env_baseline_studies.htm) or any other relevant and reliable sources that provided information on the proposed project location, such as the USGS site (http://pubs.usgs.gov/of/2008/1132/). This effort resulted in a general understanding of the project for facilitating more precise estimates and characterization of risk, but was not comprehensive enough to answer many of the questions regarding mine operations and management. As a result, uncertainty exists for issues such as:

- Tailings/Waste locations (large areas will be required, but specific locations are presently unknown);
- Seismic risk (information is needed on the exact location of the nearest faults and what the proposed mine would use as the design event for tailings dams construction);
- AMD potential (it is known that site rock is potentially AMD producing, but it is unclear how much will be formed);
- Mining methods, amounts, and sequence of mining (it is expected that the proposed mine will use open pit and underground block caving,);
- Road construction materials and method; and
- Dust (it is well known that dust could be a factor is spreading contamination, but quantitative determination has not yet been made).

Development of a comprehensive MMP would facilitate more precise estimates and characterization of risk related to mine development, operation and closure.

For many of the stressors of concern evaluated, ambient meteorological conditions in the proposed project area can play major roles for both timing and sequence, and in their influence on the level of effect. For instance, although flow reduction and subsequent habitat alteration are expected during and after mine creation, rainfall timing and magnitudes can both exacerbate or ameliorate effects predicted within watersheds. Precipitation amounts can influence groundwater levels and movement, surface water dilution capacities and increase or decrease the potential for large-scale pollution events and AMD formation and release. Rainfall, in addition to wind direction and speeds, can affect dust creation, dispersion and concentrations. Finally, seasonal temperature fluctuations and extremes can play a major role in the health and viability of salmon populations, by ultimately affecting a population's resistivity to possible impacts associated with mining. Based on the above, there is much uncertainty associated with predicted stressor impact levels and timing when ambient meteorological conditions and trends are considered.

The amount and degree of impacts to salmon individuals and populations, as predicted in the ERA, generally assumes that the five species spawn, rear and mature within the watersheds being evaluated. Also, without site-specific knowledge, the ERA assumes that habitat requisites are consistent throughout the watersheds. These assumptions were necessary in order to predict with consistency the effects from potential changes in the environment from mining-related activities. As a result, uncertainty exists regarding the level of effects expected to each salmon species under investigation. Although the assessors understood that this could affect predicted risk, it was felt that uncertainty was reduced through information on ADFG-designated anadromous streams, which indicated that salmon species were prevalent within the directed watersheds.

The following provides information on uncertainty for each of the stressors of concern identified and analyzed in the ERA.

#### *Dewatering and Loss of Instream Flow [including Groundwater Discharge] and Loss or Alteration of Supporting Habitat*

Based on the details of the 2006 water use permit applications, there is very little uncertainty associated with the analysis of loss and reduction of stream flow in watersheds near the proposed mine. Of course, as mentioned above, occurrence of specific salmon species in all portions of these watersheds has not yet been definitively established, but the various effects levels (per HSI models) used in the analysis are fairly consistent between species. The geographic applicability of the HSI models used for assessing potential effects will add some uncertainty to the evaluation, but many of these models have been developed from studies in Alaska. The extent for instream flow reduction in streams was based on surface runoff potentials only, because no groundwater flow data was available. Although the uncertainty associated with this analysis could not be quantified, it is important to understand that the mine proposes to use all groundwater within the project site for operational activities, so groundwater contributions to down-gradient flow may be compromised. An understanding of the impacts from mining activities on groundwater migration and flow would help reduce the uncertainty associated with impact prediction.

***Road Construction***

Uncertainties associated with construction of the proposed road include those related to timing, materials and long-term management practices. Since, to date, no information has been provided on these issues, there is much uncertainty regarding the specific impacts to salmon from this activity. Seasonal timing of road construction activities near stream channels could reduce or increase effects predicted from turbidity and sedimentation. Material used for road construction would be critical to understanding the risk potentials for both construction and operational phases of the project. Although information on culvert types expected for stream crossings is unknown, the uncertainty associated with effects to salmon movement from culverts placement is low. Information from Alaska and other states which showed that culverts have historically resulted in impacts to salmon was used to reduce the uncertainty of impacts predicted from this source.

***Fugitive Dust (Physical and Chemical)***

Uncertainties related to impacts predicted from fugitive dust are associated with lack of information on specific construction methods and timing, and management practices to be used for dust suppression. As mentioned above, unknown meteorological conditions during construction and operations can either increase or decrease predicted impact levels and distributions, but local wind conditions were included in the assessment to reduce these as much as possible. Based on data developed from another Alaska mine, there is little uncertainty regarding the potential for dust generation, but it is still unclear what management steps will be taken to minimize these levels. The chemical impacts predicted from copper runoff and leaching from dust-laden soils has a high degree of uncertainty, but factors related to soil pH, copper leachability, transport and retention were built into the models to reduce this to the greatest degree possible.

***Chemical Spills***

Impacts associated with chemical spills were not addressed beyond listing the types of chemicals that are present during mining activities and the potential effects that can occur from releases. The potential for chemical spills to occur during the multi-year construction and 40-70 year life of the mine is high. There is little uncertainty that some of these spills will affect salmon. The longevity of these effects is unknown and would not be known until a spill occurs. A MMP that addresses the chemicals of concern and response activities required would provide the approach for dealing with spills and limiting salmon exposures.

***Pipeline Spill***

Discharge scenarios and potential impacts associated with slurry pipeline breaks were based on well-documented historical information at similar mines across the U.S. and Canada. Based on the information that was developed, there is a high certainty that at some time during the proposed mine's life a pipeline break will occur. Since many pipeline breaks occur near stream crossings, it is also expected that streams and biota would be at risk. Although the magnitude of a spill is always an unknown, for this ERA, the analysis used a nominal predicted volume that was well within upper and lower release volumes identified in historical records and reports. Transport mechanisms and stream flow values were based on literature- and agency-derived information and thus have a high degree of certainty. Potential fate and effects within a stream, should a spill occur, are generally related to flow volume and seasonality, so only inferences to salmon impacts could be derived from the analysis.

#### *Episodic and Large Scale Pollution Events*

As with other aspects of this ERA, there is little certainty that a dam failure and slurry release will occur at the proposed mine. Although, there is a very high probability that if a spill does occur, it would be catastrophic within and down-gradient of the primary watersheds addressed throughout this ERA. The regression models used for determining runout distances from other mine discharges had a moderate degree of success by the original authors in their evaluation. The proposed size of the dams at the proposed mine were off the scale and much larger than any of the events used in their evaluation. As such, one can only infer that larger dams and greater volumes would equate to worse effects. But, these factors in and of themselves do not increase the certainty that a dam failure will occur. Other information sources have noted the increased potential for dam failures due to seismic activity in the area near the mine. This, along with the size of the dams and volumes expected, makes even a low probability for dam failure critical to predicting effects to salmon populations and habitat.

#### *Acid Mine Discharge (AMD)*

Based on geochemical evaluation of rock samples from the Pebble formation, there is a high certainty that acid would be produced in waste piles, other mine refuse and within tailings ponds. Also, because the mine is to be developed in an area with moderate precipitation, numerous small streams, a high water table, and over geological formations that are susceptible to ground water movement, AMD formation and movement is highly likely. Based on these conditions, and historical information on AMD at other hard rock mine, there was a high certainty that waters with pH levels near (or below) 4 would be discharged near mid-life stages of the mine and/or beyond. As a result, some effects would be exhibited in downstream water bodies. Calculation of potential pH levels in the SFK and NFK watersheds only considered surface water contributions for dilution, so there is much uncertainty regarding groundwater's influence on these predictions.

## 4.5 Conclusion

This ecological risk assessment identified a wide range of specific, significant risks to the salmon ecosystems of the Nushagak-Mulchatna and Kvichak watersheds under a specific large-scale mining scenario. Overall, the risk to wild salmon populations of such large-scale mining in this region is very high. Of the wide range of risks analyzed in this assessment, the high likelihood of acid mine drainage both during and after mine operations, the potentially catastrophic though highly uncertain nature of a large-scale pollution event, and the potential cumulative effects of various ecosystem stressors over time, are reasonable cause for significant concern regarding the long-term abundance, diversity and sustainability of salmon species (and their supporting ecosystems) in this region. Although it is uncertain what will actually occur, based on historical information on physical and chemical stressors gathered for other large mines, and the known effects of mining-related heavy metals to salmon and other biological populations, significant negative impacts to the aquatic ecosystem would be expected over the life of large-scale mines in this region. Additionally, such impacts would be likely to persist and in some cases increase long after mine closure.

Finally, cumulative risk associated with construction, maintenance and closure of such mines may also be magnified by concurrent or subsequent development of additional mining interests in the region depending on their location and design.