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A Report for the Wild Salmon Center

Toxicological shortcomings of the Pebble Project Final Environmental Impact Statement (FEIS)

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EXECUTIVE SUMMARY

Bristol Bay is one of the United States' last, largest remaining nearly undeveloped and pristine watersheds. That fact, combined with long-term, careful fisheries management; widespread occurrence of lakes and near-surface groundwater; and overall habitat quality, quantity, and complexity combine to produce the world's largest sockeye salmon fishery, critical to subsistence and commercial activities. Collectively, Bristol Bay's nine subwatersheds produce about half of sockeye salmon globally. The currently proposed Pebble Mine and its associated infrastructure straddle the two most productive subwatersheds within Bristol Bay: the Nushagak and Kvichak drainages which together produce about half of Bristol Bay salmon, or one quarter of sockeye salmon globally. While the majority of the currently proposed mine footprint sits in the Nushagak drainage, most other infrastructure (i.e., the road and pipeline corridor) will be located in the Kvichak drainage. Consequently, mine development would introduce toxic metals and other contaminants to both watersheds. In light of the Pebble Project Final Environmental Impact Statement (FEIS) conclusion that mine development would not have measurable impacts to fish, this report briefly describes: current baseline conditions in waters potentially impacted by mine related contaminants; the qualitative likelihood of such

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impacts occurring; and potential consequences of those impacts to aquatic life. The report also reviews general concepts of toxicology including acute, chronic, sublethal, and indirect effects of metals and other mine related contaminants Pebble would introduce to pristine area waters. Lastly, it addresses examples of specific shortcomings of the FEIS with respect to contamination, ultimately concluding that impacts of mine development to fish and other aquatic life that support them are likely if not certain to occur.

WATER CHEMISTRY AND TOXICOLOGY

The United States Environmental Protection Agency (USEPA) estimates 40% of western US headwater streams are contaminated by hard rock mining (USEPA 2000). Persistent impacts of mining to aquatic insects, fish including salmon, and their habitat are widely documented (Kemble et al. 1994, Pascoe et al. 1994, Farag et al. 1998, Barry et al. 2000, Maret and MCoy 2002, USGS 2004). Moreover, arctic and subarctic fish species tend to be more vulnerable than more southern fishes to contamination caused by mining (Lemly 1993). Because of the geology of the proposed Pebble porphyry-mineral deposit, mining activities would generate acid mine drainage (AMD), lowering the pH of ambient waters, and resulting in the leaching of metals unearthed by mining into area streams (PLP 2011). Metals can be toxic to fish and other aquatic life at lethal and sublethal levels, and through direct and indirect pathways. Furthermore, ambient waters that drain the mine site and that will coincide with infrastructure are especially susceptible to harmful impacts of acid mine drainage and metals leaching. Bristol Bay headwaters exhibit exceptionally low alkalinity and dissolved organic carbon (DOC; Zamzow 2011, PLP 2011). Low alkalinity streams provide little buffering capacity to neutralize AMD and a lack of DOC limits little the ability of waters to assimilate metals (i.e., most metals leached into surrounding waters would likely remain bioavailable and consequently a greater risk to aquatic life; Zamzow 2011, PLP 2011).

The Pebble project is predicted to produce AMD and associated increases of metals concentrations in both ground and surface waters, an impact the FEIS does predict to some extent, though vastly underestimates (e.g., Soblewski 2020, Wlostowski 2020). Water in contact with various mine workings (rock and water storage facilities, tailings storage facilities, and underground workings) is predicted to seep into area groundwaters. For much of the project area, shallow groundwater is characterized as upwelling through porous soils while surface water conversely infiltrates groundwater aquifers, suggesting contaminated groundwater may enter fish-bearing surface waters should mining proceed (PLP 2011).

The Pebble project is also expected to alter surface water flow and chemistry during mine operation and after closure. Impacts to water quality develop primarily from the exposure of sulfide-rich rock unearthed in the mining process to air and water, producing AMD and increasing metals concentrations. This results largely from surface disturbances associated with mine development (e.g., pit excavation, waste rock storage, road and quarry building, etc.). Additional sources of contaminants include discharge from wastewater treatment plants (which will be required to treat contaminated waters long beyond the life of the mine—theoretically in perpetuity), and accidental chemical spills (including along the transportation and pipeline

corridor), construction and operation of the road itself, and potentially catastrophic dam breaches. Geochemical testing suggests waters downstream of Pebble are likely to experience increases in total levels of metals including copper and selenium which are only two likely byproducts of mine development and are extremely toxic to fish and aquatic life (PLP 2011, Zamzow 2012).

A minor improvement to the FEIS over the draft EIS with respect to toxicity is the inclusion of some discussion regarding toxicological impacts of a few metals to fish: selenium, copper, and mercury. Cadmium toxicity is also very briefly discussed (see Appendix K4.24). However, that consideration overlooks many other metals, reagents, hydrocarbons, and other contaminants that are likely to be elevated as a result of project development. In general, the FEIS also underestimates impacts of contaminants by relying on the sufficiency of Alaska water quality criteria for the protection of aquatic life, and the reliability of treatment to achieve water quality criteria. **The vast majority of Alaska water quality criteria exceed current ambient conditions at the proposed mine site by 2 to over 2000 times** (Table 1). The water treatment efficiency described in the FEIS is unrealistic (Sobolewski 2020). Moreover, even modern, urban wastewater treatment plants commonly experience temporary failures, releasing untreated or partially treated water into the environment (e.g., Seattle, WA, Suffolk, NY, Burlington, VT). Failures are also common with mining treatment operations (e.g., West Line Creek, Gold King Mine and see Gestring 2019). Given that treatment at the Pebble site will be required for unprecedented volumes in perpetuity, and in a remote and extremely wet environment, occasional failures are inevitable and will exceed water quality criteria which may have lethal, sublethal, and indirect impacts on fish and other aquatic life. With respect to mining, one study showed that water quality criteria were exceeded in groundwater in 77% of US mines, and in surface water in 60% of mines (Kuipers et al. 2006). Moreover, water quality was usually worse than mining companies predicted (Kuipers et al. 2006). In the case of a catastrophic tailings dam breach, the FEIS predicts contamination of some metals reaching as far as Nushagak Bay. Even without such a catastrophic breach however, **water quality will nearly inevitably suffer significant degradation during the course of mine construction and operation, which will ultimately impact fish and other aquatic life.**

Pacific salmon are known to have evolved adaptations to their local environment, including water chemistry (Olsén 1992, Dittman and Quinn 1996, Quinn 2005). Even subtle changes in chemistry can impact behavior including feeding, predator avoidance, and the ability to home to their natal habitat. **Collectively, these processes could have population level impacts that the FEIS fails to predict.** Those impacts could ultimately degrade the biocomplexity essential to maintaining the overall sustainability of Bristol Bay's salmon fisheries (Hilborn et al. 1993, Schindler et al. 2010, McIntyre et al. 2012, Reeves 2020).

Impacts of Metals Exposure to Fish

The field of toxicology is vast and still growing, but relates to the potential harmful effects of chemicals on living organisms (Rand 1995). To date, the majority of toxicological research is based on laboratory tests used to determine **direct effects**, or concentrations of chemicals at

which deleterious effects occur to a test organism (e.g., rainbow trout, a zooplankton species, etc.). Direct effects measured in a lab can be **acute**—occurring within a short period of time (i.e., hours to days) typically at high contaminant concentrations, or **chronic**—occurring over longer periods (days to years) typically at low contaminant concentrations. **Indirect effects** result from impacts of a chemical to some component of the freshwater foodweb which in turn affects other organisms. Examples of indirect effects include reduced salmonid abundance due to toxic effects on food species like zooplankton or aquatic insects, or due to toxic effects on plants that provide habitat structure. Unfortunately, indirect effects are more difficult to measure, and consequently they are far less understood and documented than direct effects.

Within the field of toxiciology, metals are generally divided into **essential** and **non-essential.** Essential metals are needed for life as, for example, components of proteins, amino acids, or cell production processes. Biota tend to exhibit symptoms of deficiency at low concentrations of essential metals, and toxicity at high concentrations with a plateau at levels optimal for physiologic function. Conversely, non-essential metals are thought to be superfluous to physiologic function, though many can be tolerated at low concentrations at which they can be excreted or otherwise detoxified. It is important to note that impacts of multiple metals in the same environment—a scenario common to metals mining and other industrial effluents—can be additive (when two metals have twice the effect of either metal individually), antagonist (when two metals have less than twice the effect of either metal individually), or synergistic (when two metals have more than twice the effect of either metal individually). While some research in this regard has been conducted in aquatic environments, a great deal remains unknown about synergistic effects of metals mixtures (e.g., Franklin et al. 2002b). Consequently, any impact prediction or analysis should be extremely conservative in order to be sufficiently protective. **By ignoring synergistic interactions of multiple metals, depending on unproven technology, and relying on ADEC criteria to protect aquatic life, the FEIS dismisses the significance of toxicological effects of mine development to salmon and their foodwebs. Even at increases of some contaminants within water quality criteria, salmon are known to be impacted in ways that can ultimately decrease their survival.**

Table 1. Water quality criteria (to which discharge water will be treated) compared to ambient water quality conditions (PLP 2011, Zamzow 2012), and predicted Wastewater Treatment Plant (WTP) effluent during mine operations (From FEIS Section 4.18). T = Total, D = Dissolved, NR= Not Reported. NK119B and UT100D are sites close to two of the proposed wastewater treatment plant discharge locations. Predicted effluent concentrations are from FEIS Chapter 4.18 regarding soil and water chemistry.

	Units	Water Quality Criteria	Current average concentrations NK119B	Current average concentrations UT100D	Predicted effluent concentrations WTP#1	Predicted effluent concentrations WTP#2
Nitrate + nitrite as N	mg/L	10	0.428	0.26	5.7	6.4
Ammonia as N	mg/L	5.9	0.0289	0.37	0.6	0.2
Alkalinity	mg/L	20	11.6	42	27.0	32.4
Chloride	mg/L	230	0.701	0.678	157.8	32.4
Flouride	mg/L	1	0.0348	0.045	0.2	0.1
Sulfate	mg/L	250	3.79	5.97	125.5	71.6
Aluminum	µg/L	87	27.2	84.7	36[2]	0.02[2]
Iron	µg/L	1000	83.8	487	18.4[2]	0.5[2]
Antimony	µg/L	6	0.0463	0.074	1.0[2]	3.6[2]
Arsenic	µg/L	10	0.145	0.23	0.91[2]	1.24[2]
Cadmium	µg/L	0.07	0.00997	0.01365	0.024[2]	0.002[2]
Chromium	µg/L	100	0.226	0.357	0.21[2]	0.01[2]
Copper	µg/L	1.84T, 1.77D	0.425T, 0.414D	0.618T, 0.501D	0.23[2]	0.00015[2]
Lead	µg/L	0.28T, 0.3D	0.051T, 0.054D	0.108T, 0.0500D	0.0006[2]	0.0002[2]
Manganese	µg/L	50	3.9	49.8	17.9[2]	0.75[2]

[2] According to Sobolewski (2020): "The proposed WTPs are large, complex and, contrary to the USACoE assertion, do not use industry standards and proven processes and technologies. On the contrary, the chemical process proposed for selenium removal is unproven, will be ineffective and result in exceedances of ADEC standards during mine operation. The treatment performance predicted for other contaminants in overly optimistic: there is a high risk that WTPs will not meet stringent discharge criteria. Worse, these claimed performance are not supported by testwork, published literature, or case studies. It is unacceptable that a treatment system proposed in an EIS—one that uses unproved technology—should be accepted on faith." He goes on state that "The removal rates [for at least cadmium, copper, manganese, mercury, molybdenum, selenium, sulfate, and zinc at WTP#2] are not substantiated in FEIS by any testwork, literature or case studies…these removal rates are not credible…and cannot be considered reliable."

Table 1 cont'd. Water quality criteria (to which discharge water will be treated) compared to ambient water quality conditions (PLP 2011, Zamzow 2012), and predicted Wastewater Treatment Plant (WTP) effluent during mine operations (From FEIS Section 4.18). T = Total, D = Dissolved, NR= Not Reported. NK119B and UT100D are sites close to two of the proposed wastewater treatment plant discharge locations. Predicted effluent concentrations are from FEIS Chapter 4.18 regarding soil and water chemistry.

	Units	Water Quality Criteria	Current average concentrations NK119B	Current average concentrations UT100D	Predicted effluent concentrations WTP#1	Predicted effluent concentrations WTP#2
Molybdenum	µg/L	10	0.123	0.185	1.37[2]	1.70[2]
Nickel	µg/L	10.5	0.179	0.55	3.27[2]	0.33[2]
Selenium	µg/L	5	0.134	0.14	1.74[2]	0.537[2]
Zinc	µg/L	24.0T, 23.7D	1.42T, NRD	2.27T, 1.90D	0.38[2]	0.023[2]
Mercury	µg/L	0.05	0.00112	0.00132	0.00002[2]	0.00002[2]
TDS	mg/L	500	30.6	63.1	453.0	190.0
Cyanide	mg/L	5.2	0.0016	0.0015	N/A	N/A

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TOXICOLOGY OF SPECIFIC METALS AND OTHER CONTAMINANTS

Here I review toxicity of metals predicted to be elevated according to mine developers baseline data (Humidity Cell and Field Barrel tests; PLP 2011) as well as other likely mine related contaminants.

Aluminum

Aluminum (Al) is geologically abundant but serves no known biological function and exposure to Al could potentially be deleterious to all forms of aquatic life (Gensemer and Playle 1999). Aluminum contamination is typically associated with acid rain or deliberate addition of Al for algae or other plant control purposes, however elevated Al levels are predicted to result from Pebble mining activity.

Acute and Chronic Toxicity

Mechanisms of Al toxicity to fish are either:

1. Ionoregulatory, meaning they disrupt salt and water balances across the gill and other cellular membranes, and/or
2. Respiratory, leading to clogging of gills by mucus at high Al concentrations and insufficient oxygen exchange (hyperventilation and eventually suffocation).

Like most metals, Al toxicity increases in the acidic environments associated with metal-sulfide mines. Calcium, or increased hardness, provides some protection against Al toxicity, though reported hardness levels near the Pebble mine site are low (Gensemer and Playle 1999, PLP 2011, Zamzow 2011). Larvae emerging from gravels may be the most sensitive salmonid life stage to Al (Delonay et al. 1993), which is concerning given that all six salmonid species as well as Dolly Varden and cutthroat trout incubate in the gravels around and downstream of the Pebble Mine site. Salmonids have demonstrated an ability to acclimate to increased Al concentrations in laboratory environments (Orr et al. 1986), however a metabolic cost may be associated with acclimation (Wilson and Wood 1992).

Sublethal Toxicity of Aluminum

Below levels known to induce mortality, Al can have sublethal impacts on salmonid physiology and behavior. When Al accumulates on the gill surface, mucous production can increase by up to four times normal levels, inhibiting respiration (Wilson et al. 1994). Stress associated with impaired respiration can inhibit the ability of salmonids to deal with additional stressors, including natural stressors like smoltification (Dennis and Clair 2012). For example, juvenile Atlantic salmon exposed to Al exhibited a 20-30% reduction in survival and reduced seawater tolerance (Krogland and Finstad 2003, Monette et al. 2008). In addition, Al can reduce salmonid growth rates and swimming speeds. Aluminum can also impair salmonid olfaction which is critical to locating predators and prey, mates and kin, and homing to natal streams.

Interference with any of these processes essential to survival and successful reproduction could ultimately lead to populations level impacts.

Indirect Effects of Aluminum

Although less toxic to invertebrates than fish, Al does have deleterious effects on zooplankton and insects known to be important diet items for salmonids (Wilson and Wood 1992, Wilson et al., 1994). Aluminum is also toxic to algal species which form the base of the aquatic foodweb and are a main diet item for many macroinvertebrate species. Consequently, deleterious effects of Al can reverberate throughout the foodweb with ultimately negative impacts on salmonid growth and survival, particularly for those species which spend time rearing in freshwater (i.e., Chinook, coho, sockeye, rainbow/steelhead, and Dolly Varden).

Cadmium

Like Al, Cadmium (Cd) is biologically non-essential. Although it occurs at low concentrations in aquatic systems, it commonly occurs in sulfide-ore bodies like Pebble. Historic mine sites are frequently contaminated with cadmium exceeding background levels by as much four orders of magnitude (Farag et al. 2003, Mebane et al. 2012, Johnson et al. 2016). It is extremely toxic to aquatic life.

Acute and Chronic Toxicity

Exposure to cadmium (Cd) in fish occurs primarily through water in the gill and kidney (waterborne exposure) or in the intestine (dietary exposure; Franklin et al. 2002b). Cadmium mimics calcium (which *is* biologically essential), inhibiting its uptake which can lead to death (McGeer et al. 2011). Consequently, waters naturally high in Ca (naturally hard) waters ameliorate the toxic effects of Cd. Waters draining the Pebble deposit, however, exhibit low Ca levels. Dissolved organic matter, which is also low in waters draining Pebble, can also decrease the bioavailability or overall toxicity of Cd. Salmonids are more sensitive to acute levels of Cd toxicity than aquatic macroinvertebrates or other fishes (Farag et al. 2003, Mebane et al. 2012). However invertebrates (particularly amphipods) are more sensitive to chronic exposures of Cd (Mebane 2010). Less is known about mechanisms of dietary exposure to cadmium, though dietary uptake has been proven more toxic than waterborne exposure for some invertebrate species (Mebane 2010). Cadmium also induces neurotoxic effects in fish including hyperactivity leading to decreased growth and increased detection by predators (Mebane 2010). Examinations of life-stage sensitivity suggest that emerging fry are most sensitive in Chinook salmon, while emerging fry and rearing parr are equally sensitive to Cd in rainbow/steelhead (Chapman 1978).

Sublethal Toxicity of Cadmium

Sublethal physiological impacts of Cd include reduced growth and condition factor (unit weight per unit growth—an index of fish health; Riddell et al. 2005, Lizardo-Daudt and Kennedy 2008).

Reproduction is also impacted, with impaired egg development and premature hatching (Lizardo-Daudt and Kennedy 2008). Furthermore, immune response may be depressed after Cd exposure as evidenced by elevated stress chemicals in exposed salmonids (Ricard et al. 1998). Documented behavioral effects of Cd on salmonids include a diminished ability to avoid predators—possibly due to olfactory inhibition (Scott et al. 2003), diminished foraging success (Riddell et al. 2005), and altered social behavior including less aggressive competition (Sloman et al. 2003). At extremely elevated Cd levels, salmonids have been documented avoiding waters altogether (Mebane 2010). If contamination from groundwater, a tailings dam breach, storage water spill, or treatment plant failure occurred at Pebble, particularly during salmon spawning, spawners could fail to reproduce altogether, or stray to nearby streams, potentially eroding the diversity essential to maintaining overall sustainability.

Indirect Effects of Cadmium

Deleterious effects of Cd can reverberate throughout the foodweb with ultimately negative impacts on salmonid growth and survival, particularly for those species which spend time rearing in freshwater (i.e., Chinook, coho, sockeye, rainbow/steelhead, and Dolly Varden). Although invertebrates are less sensitive to acutely toxic levels of Cd, some invertebrates exhibit increased sensitivity to Cd at chronic levels of toxicity. Because dietary exposure is a known pathway of Cd contamination to fishes, indirect effects of Cd through food is poorly understood but highly likely.

Copper

Copper (Cu) is a naturally occurring, essential element that frequently increases in areas with active sulfide mining. It is one of the most pervasive and toxic elements to aquatic life and has been documented at levels one to three orders of magnitude greater than background in mining areas (Grosell 2011). Copper is utilized in growth and metabolism of all aerobic organisms.

Acute and Chronic Toxicity

Copper toxicity increases in acidic conditions, soft waters (low hardness), and in waters depauperate of dissolved organic matter—all of which occur in waters draining the Pebble deposit. Exposure to Cu in fish occurs primarily through water in the gill, kidney, olfactory receptors, and lateral line cilia (waterborne exposure), or in the intestine (dietary exposure; Grosell 2011). Because it is essential to biological function, it is readily incorporated into fish tissues. Olfactory inhibition resulting from Cu exposure occurs within minutes and lasts for weeks or longer, with the potential to affect all aspects of salmonid biology (Grosell 2011). It is known to reduce growth, immune response, reproduction, and survival (Eisler 1998). Specific examples of toxic effects include disrupted migration; altered swimming; oxidative damage; impaired respiration; disrupted osmoregulation and pathology of kidneys, liver, gills, and other stem cells; impaired mechanoreception of lateral line canals; impaired function of olfactory organs and brain; and altered behavior, blood chemistry, enzyme activity, cortiocosteroid

metabolism, and gene transcription and expression (Hodson et al. 1979, Knittel 1981, Rougier et al. 1994, Eisler 2000, Craig et al. 2010, Tierney et al. 2010). The effects have been demonstrated for juvenile and adult life stages primarily of coho and Chinook salmon and rainbow trout.

Sublethal Toxicity of Copper

Many sublethal effects of Cu are identical to those causing mortality. Physiological effects of Cu exposure include decreased growth, swimming speed or activity, and feeding rates (Waiwood and Beamish 1978a, Waiwood and Beamish 1978b, Marr et al. 1996). Coho salmon exhibit diminished immune response after exposure to Cu (Stevens 1977, Schreck and Lorz 1978). Reproductive performance also decreases in adult salmonid (Jaensson and Olsen 2010). Very slight increases in Cu concentrations (5-25 parts per billion) inhibit olfaction in coho and Chinook salmon and rainbow trout, with potential to inhibit recognition of predators, prey, mates, kin, and natal streams (Hansen et al. 1999a, Hansen et al. 1999b, Sandahl et al. 2007, Baldwin et al. 2011, McIntyre et al. 2012). Chinook salmon and rainbow trout avoid Cu contaminated waters altogether, except after long-term sublethal Cu exposure, after which their avoidance response may be impaired (Hansen et al. 1999a, Meyer and Adams 2010). Avoidance can lead to degradation of spawning patterns and resulting genetic diversity which are essential to maintaining overall population structure and sustainability. Adult spawning migrations are delayed or interrupted in Cu contaminated streams, and downstream smolt migration is likewise delayed and osmoregulation of smolts in seawater is impaired (Lorz and McPherson 1976, Schreck and Lorz 1978, Hecht et al. 2007). Copper-exposed salmon are also more vulnerable to predation (Sandahl et al. 2007, McIntyre et al. 2012).

Indirect Effects of Copper

Numerous studies document adverse effects of Cu on freshwater algae, zooplankton, mussels, and other invertebrates, which could result in reduced prey abundance and quality to support fish growth and reproduction (Wootton 1990, Scannell 2009). Copper is one of the most toxic metals to algae, which form the base of the salmonid food chain. Algae production can decline at Cu increases of only 1-2 parts per billion (ppb; Franklin et al. 2002). Zooplankton and other invertebrates that rely on algae for food suffer decreased growth and reproduction when primary production decreases (Urabe 1991). Zooplankton and lotic macroinvertebrates are also extremely sensitive to Cu increases (Farag 1998, Zipper et al. 2016).

Iron

Iron (Fe) is an essential element involved in oxygen transfer, DNA synthesis, and immune function in all life. Like other metals, it is frequently associated with mining activity and its effects tend to increase in the presence of acidic conditions and the absence of dissolved organic matter. Relatively little is known about mechanisms of Fe toxicity.

Acute and Chronic Toxicity

Primary mechanisms of Fe exposure are waterborne and dietary. On the gills, iron precipitate accumulates causing physical damage and clogging. Resulting respiratory impairment is likely the main toxic effect of Fe contamination to salmonids (Dalzell and MacFarlane 1999). Additionally, elevated Fe concentrations during fertilization caused hardening of eggs in

Sublethal toxicity of Iron

Little information is available regarding sublethal effects of Fe. Coho salmon actively avoided Fe-enriched water in one study, which has implications for degradation of genetic diversity and population structure and sustainability (Updegraff and Sykora 1976). In studies of other vertebrates, Fe had impacts on brain function and social behavior (Bury et al. 2011).

Indirect Effects of Iron

Similar to fish gills, red-colored Fe-precipitate commonly associated with mine waste also settles on aquatic insect gills, resulting in decreased insect abundance and diversity, ultimately decreasing food resources for rearing fishes (Gray and Delaney 2010).

Mercury

Mercury is a metal which is non-essential to physiologic functions of life. While mercury occurs naturally at low levels in the environment, anthropogenic actions including mining have increased background mercury levels by two to four times in the aquatic environment even in remote places due to atmospheric deposition (Jewett and Duffy, 2007, Kidd and Batchelar 2011).

Acute and chronic toxicity

While mercury can be acutely toxic, its toxicity to wild fish is more commonly related to chronic exposure to methylmercury (a bioavailable form of mercury) via diet (Kidd and Batchelar 2011). Like selenium, methylmercury bioaccumulates up aquatic food webs, with highest concentrations generally occurring in largest, oldest, piscivorous fish (e.g., Northern pike—*Esox lucius*, Arctic grayling—*Thymallus arcticus*, Dolly Varden—*Salvelinus malma*; Jewett and Duffy 2007). In freshwater environments, methylmercury bioaccumulates in both lakes and streams (McIntyre and Beauchamp 2007, Kwon et al. 2012), though mercury concentrations in fish in rivers generally exceed those of fish in lakes in the western US and Canada (Eagles-Smith et al. 2016). Highest concentrations of methymercury in fish tissue are also associated with rivers influenced by wetlands and acidification—both of which could compound impacts from Pebble Mine and associated infrastructure development (Ward et al 2010). Chronic methylmercury exposure has impacts at very low levels (muscle or whole-body concentrations of 0.5-1.2 µg/g; Kidd and Batchelar 2012), including: neurotoxicity causing brain lesions and organ damage that impairs abilities to locate and capture prey and avoid predation; inhibition of reproductive

success and growth; damage to intestines, digestion, cellular metabolism, organs; and alteration of stress hormones (Kidd and Batchelar 2012).

Indirect effects of Mercury

Indirect effects of methylmercury exposure which alter behavior and ultimately survival include decreased competitive feeding abilities, swimming performance, and predator avoidance (Kidd and Batchelar 2012). Of additional concern is the bioaccumulation of methylmercury in important subsistence species (e.g., Northern pike and Arctic grayling) which can lead to increased risk of heart disease, higher miscarriage rates, lower female fertility, decreased coordination, brain damage *in utero*, and higher blood pressure in children of adult consumers (Loring et al. 2010).

Molybdenum

Molybdenum (Mo) is an essential element involved in purine metabolism. It is frequently associated with mining activity (Phillips and Russo 1978, Reid 2002). Although it is less toxic compared to other metals, relatively little is known about mechanisms of Mo toxicity (Reid 2012). The US Environmental Protection Agency (USEPA) does not consider Mo to be a priority pollutant apparently because of a lack of information about its impacts to aquatic or human life (Reid 2012).

Acute and Chronic Toxicity

Molybdenum is transported across the gills and accumulates in the liver, though mechanisms of and other potential sites of accumulation in fish bodies are unknown (Reid 2012). Based on limited research, it appears Mo is potentially a non-specific gill irritant and is associated with gill damage, organ hemorrhaging, and discoloration of kidney and livers in rainbow trout (McConnell 1977). In kokanee exposed to Mo, breathing and mucus secretion increased (Reid 2002). No known studies have examined mechanisms of chronic Mo toxicity (Reid 2012).

Sublethal toxicity and indirect effects of Molybdenum

Little information is available regarding sublethal or behavioral effects of Mo, raising concerns for unintended and unpredictable consequences of increased concentrations associated with mining activity. Research on fish in the Mekong delta suggests reproduction may be impacted by Mo exposure (Yamaguchi et al. 2007).

Selenium

Selenium (Se) is an essential trace element important to protein synthesis, but is one of the most hazardous elements to fish. The margin between essentiality and toxicity of Se is very slim (Janz 2012). Unlike other metals, decreased water temperatures increase Se toxicity. Some metals mining operations and ore smelting are commonly associated with Se

contamination. There are no examples of modern, operating mines which have successfully treated selenium to the levels required by Alaska water quality criteria (please see DEIS comment memo submitted by Zamzow et al. 2019, NAMC 2013, Sobolewski 2020).

Acute and Chronic Toxicity

Acute Se toxicity rarely results from anthropogenic activity. Chronic Se exposure, however, is teratogenic (causing malformation) to early life stages of fish (i.e., embryos, alevins, and fry; Lemly 2004). Unlike other metals, toxic effects occur primarily through dietary as opposed to waterborne pathways. Adult life stages are relatively tolerant of dietary Se intake, but can pass its effects to their offspring (Janz 2012). Selenium is deposited into eggs during their formation resulting in deformations typically in the skeleton, skull, or fins (Janz 2012).

Sublethal Toxicity of Selenium

Few studies have investigated sublethal Se effects. Avoidance of Se contaminated waters has not been documented, nor have changes in reproductive behavior of fishes in increased Se concentrations (Janz 2012). In one study, swimming speed, frequency, and distance were reduced after Se exposure in non-salmonid fishes (Janz 2012).

Indirect Effects of Selenium

Unlike most trace elements, selenium bioaccumulates (accumulates faster than metabolic or excretory loss) and sometimes biomagnifies (increases in animal tissue at successively higher levels of the food chain). Bioaccumulation and biomagnification cannot be predicted from Se concentrations, making sufficiently protective water quality guidelines exceedingly difficult to estimate. Since diet is the primary source of Se to fish, its efficient uptake by algae and macroinvertebrates contributes to Se toxicity. Interestingly, algae and invertebrates themselves exhibit little sensitivity to Se exposure (Janz 2012). Consequently, relatively low Se concentrations can lead to fish toxicity via bioaccumulation. Population level effects of Se contamination have been documented in multiple freshwater ecosystems, though further investigation is needed. In multiple case studies, the majority of fish species have been extirpated as a result of Se exposure (Lemly 2004, Janz 2012).

Zinc

Zinc (Zn) is an essential element used by vertebrates in protein (including hemoglobin) synthesis. It is a common contaminant associated with mining activity. Like Cd, Zn mimics calcium, inhibiting its uptake which ultimately leads to death (McGeer et al. 2011). Consequently, waters naturally high in Ca (naturally hard) waters ameliorate the toxic effects of Zn. Waters draining the Pebble deposit, however, exhibit low Ca levels.

Acute and Chronic Toxicity

Dietary uptake poses lower risk to fish than waterborne exposure primarily through gills. Waterborne exposure competitively inhibits Ca, binding to sites on fish gills and leading to impaired gas exchange, gill inflammation, and ultimately suffocation, or decreased survival, growth, reproduction, and hatching (Hogstrand 2011). Dissolved organic matter, which is low in waters draining Pebble, can also decrease the bioavailability or overall toxicity of Zn. Fish kills and/or the absence of fish (including salmonid) species are commonly associated with elevated Zn, Cu, and Cd concentrations downstream of mining activity (Farag et al. 2003, Hogstrand 2011).

Sublethal Toxicity of Zinc

Increased stress and decreased immune response has been attributed to Zn exposure in rainbow trout (Wagner and McKeown 1982, Sanchez-Darden et al. 1999). Juvenile rainbow trout and other salmonids have also been documented avoiding Zn-contaminated waters (Hogstrand 2011). Other effects of Zn on behavior include increased ventilation and cough rates, altered swimming patterns, and decreased growth (Hogstrand 2011).

Indirect Effects of Zinc

Like other metals, effects of Zn can reverberate throughout the foodweb with ultimately negative impacts on salmonid growth and survival, particularly for those species which spend time rearing in freshwater (i.e., Chinook, coho, sockeye, rainbow/steelhead, and Dolly Varden). Invertebrates are more sensitive to acutely toxic levels of Zn than fish, so decreased feeding opportunities are a likely pathway for indirect effects of Zn (Santore et al. 2002).

Impacts of Non-metal Contaminants to Fish

Cyanide

Although USACE and PLP indicate cyanide will not be used under the alternatives described in the FEIS, its use is considered a 'Reasonably Foreseeable Future Action' under cumulative impacts with full mine build out.

Acute and Chronic Toxicity

Cyanide is known as extremely toxic to aquatic and other life (Doudoroff 1976). Cyanide is absorbed through inhalation, ingestion, and skin contact, and is readily distributed throughout the body via blood. It is a potent and rapid-acting asphyxiant, and induces tissue and cell hypoxia (lack of oxygen). Fish kills from accidental discharges of cyanide gold mining wastes are common, including one incidence of tens of thousands of steelhead killed from Canadian mine tailings pond breach (Eisler 2004). In other US watersheds that do not support anadromous Pacific salmon, cyanide-contaminated water is documented killing **all** aquatic life 28 km (>17

mi) downstream of its release (Eisler 2004). In other mine related releases, cyanide is considered responsible for the loss of entire fish populations and communities and greatly reduced populations of other aquatic life (Eisler 2004). While all aquatic life is susceptible to impacts from cyanide exposure, fish are the most sensitive aquatic organisms (Eisler 2004).

Sublethal Toxicity

Cyanide is known to cause oxidative stress and liver damage, significantly impacting cellular function (David and Kartheek 2016). Very low concentrations (10 µg/L) cause behavioral changes in salmonids in lab environments including impaired swimming ability and reproduction, increased susceptibility to predation, and avoidance behavior (Doudoroff 1976, Eisler 2004). Developmental abnormalities of salmonid embryos including malformations of eyes, mouth, and vertebral columns also occur at concentrations of 10 µg/L in a lab environment, suggesting potential for population-level impacts in the presence of chronic low levels of cyanide contamination (Eisler 2004).

Indirect Effects of Cyanide

Like other contaminants, effects of cyanide can reverberate throughout the foodweb with ultimately negative impacts on salmonid growth and survival, particularly for those species which spend time rearing in freshwater (i.e., Chinook, coho, sockeye, rainbow/steelhead, and Dolly Varden). Because cold-water fish (i.e., salmonids) are more sensitive to cyanide than other forms of aquatic life, the impact to juveniles via reproductive and behavioral impairments could cause a reduction of forage fish important to growth and survival particularly of more mobile freshwater residents like Dolly Varden and rainbow trout.

Hydrocarbons

Hydrocarbon contamination is frequently associated with development and road operation, and can exert significant impacts to aquatic life. Although impacts to marine ecosystems are better characterized, impacts to freshwater ecosystems have also been documented. For example, Duggan et al. (2018) documented a massive fish-kill of about 10,000 brown trout (*Salmo trutta*) and mottled sculpin (*Cottus bairdii*) extending several kilometers downstream of a tanker truck accident in Colorado. When fish and aquatic insect populations were evaluated four years after the spill, their populations had not recovered. A major diesel oil pipeline spill in South Carolina caused a fish kill extending 37 km (23 mi) downstream, with population-level effects lasting over four years (Kubach et al. 2011). Impacts to aquatic insect communities from diesel spills to aquatic insect populations for months to years, an impact which could compromise feeding and growth opportunities particularly for smaller, less mobile fishes (Lytle et al. 2001, Perhar et al. 2014, Peterson et al 2017). At least one diesel spill related to Pebble Project exploration activities has already occurred, underscoring that accidents and leaks of this nature are virtually inevitable (ADEC 2010).

Sediment

An additional impact associated with all mines is the generation and deposition of fine sediments associated with mine waste as well as road building and maintenance (Pascoe et al. 1994, Farag et al. 1998). Sediments are often contaminated with metals, and can extend downstream from mine sites for over 100 miles (USEPA 2016). Even without metals contamination, sediments impact salmon and other aquatic organisms reproduction, incubation and growth.

Acute and Chronic Toxicity

Sediments within the water column (turbidity or suspended sediment) can be acutely toxic as a result of gill tissue damage, inhibited oxygen exchange across gill tissue cells, physical abrasion, or burial of benthic organisms and eggs (Berry et al. 2003). Furthermore, sediments enriched with metals associated with mine activity can cause acute and chronic toxicity based on mechanisms described above.

Sublethal Toxicity of Sediment

By inhibiting photosynthesis, sediments can directly affect primary producers which form the base of all foodwebs (e.g., algae, diatoms).

Indirect Effects of Sediment

Inhibition of primary production indirectly effects secondary production (e.g., zooplankton, aquatic insects which depend on algae for food), and so on through the foodweb (Berry et al. 2003, Kjelland et al. 2015). However, the primary indirect effect of sediment to salmonids is the loss of spawning and incubation habitat caused by deposition of sediments into spawning gravels, associated decreases in oxygen transfer into gravels, and generally decreased spawning and hatching success (Berry et al. 2003, Quinn 2011, Kjelland et al. 2015).

Xanthates

Xanthates are commonly used in mining flotation and are suspected to be highly toxic to fish and other aquatic life. According to the EIS, sodium ethyl xanthate will be present both in trucks on the Pebble access road corridor, as well as in the pipeline with outgoing concentrate. Unfortunately, information on concentrations and mechanisms of toxicity are glaringly absent from the literature (Xu et al. 1988). However, xanthate spills into streams have been documented causing fish kills (Webb et al. 1975, Alto et al. 1977). Algae and invertebrates are also sensitive to xanthates, so even in the absence of fish, spills could cause foodweb effects ultimately leading to reduced fish growth, and survival (Vigneault et al. 2009).

SPECIFIC SHORTCOMINGS OF THE PEBBLE PROJECT FINAL EIS

In general, the EIS relies on dilution, infeasible water treatment technology, and small sizes of spill to minimize the estimation of water quality and toxicological impacts of project development. However, there are also several statements within the EIS that indicate the possibility—and in some cases even likelihood—of contamination. In light of those factors, the ultimate conclusion of the EIS that the Pebble Project will not have measurable impacts to fish is simply unsupported by both the document as well as the track record and technology of mining and water treatment in general (Gestring 2019, Sobolewski 2020).

The remainder of this review addresses examples of specific shortcomings in the main body (Sections 4.18, 4.24, and 4.27) and two appendix sections (K.18 and K.24) of the FEIS regarding toxicological impacts to fish and other aquatic life. While not an exhaustive review, it provides many examples of how the Pebble Project is indeed likely if not certain to have population-level impacts to salmon and other fishes.

Chapter 4.18 Water and Sediment Quality

P. 4.18-17:

> Effects from Small Spills of Hydrocarbons or other Toxins—Inadvertent release of hydrocarbons or other potentially toxic compounds would result in a direct impact to surface water quality if spilled materials come into contact with surface water. The likelihood of these small spills from mine-related sources (e.g., mine machinery, product or waste storage facilities, or transfer operations) would be reduced through the application of BMPs, including the use of certified containers to transfer and store fuels and lubricants; secondary lined containment around bulk storage facilities; and managed storage, reuse, and/or disposal of used fuel products and other potentially toxic materials. Should a small spill occur, controls would be implemented, including automatic shutoff devices, and in-place spill response equipment and procedures (PLP 2020d). Section 4.27, Spill Risk, describes the potential for and effects of large-volume spills, which would have the potential for greater magnitude and extent of direct effects on surface water and sediment quality.

Comment: While briefly addressing (if minimizing) potential hydrocarbon contamination, the chapter addressing water and sediment quality largely dismisses all other toxic elements. The Pebble Limited Partnership (2011) humidity cell and other data indicate contamination will inevitably result from development. While some treatment will occur, unanticipated WTP failures, unproven WTP technology, and the cumulative impacts of spills—both small and large—will undoubtedly result in significant alterations to the ambient water chemistry to which fish in the region have adapted over millenia.

Chapter 4.24 Fish Values

Comment:

p. 4.24-11

> Instream flows in the mainstem and certain tributary reaches of the NFK, SFK, and the UTC would be temporarily reduced during construction. These changes in surface water flow and groundwater result in indirect impacts to aquatic resources in approximately 66 miles of stream habitats. The duration of flow changes would be permanent, beginning at project construction, and continuing through mine operations and post-closure.

Comment: This paragraph contradicts itself, though seemingly indicates permanent changes in streamflow to streams draining the deposit. However, it fails to extend consideration of those impacts to physical habitat, water temperature, chemistry, and foodweb and fish productivity, and the extending downstream impacts of those combined.

p. 4.24-20:

> Indirectly, the loss of connection between Tributary NK 1.190 and the mainstem NFK because of mine site features could also result in permanent effects on the quantity of invertebrate drift transported downstream into the mainstem NFK.

Comment: Permanent effects to invertebrate drift will inevitably result in permanent effects salmon and other fish productivity. Coho and Chinook salmon in particular rely largely on invertebrate drift during the 1-3 year freshwater stream residence. With less invertebrate production, salmon will grow less, which ultimately decreases the probability of their survival to spawning (Quinn 2011).

p. 4.24-21

> The importance of marine-derived nutrients (MDN) in Bristol Bay watershed lakes from returning salmon is well documented (see Section 3.24, Fish Values). The amount of adult salmon biomass actually available for ingestion by fish (directly via salmon eggs or fragmenting tissue, or indirectly through ingesting invertebrates that assimilate carcass tissue) would be expected to be a small fraction (estimated between 0.1 to 1 percent) of what enters headwater systems, after accounting for removal by vertebrates (Cederholm et al. 1989; Gende et al. 2004) and other "losses" from flushing, fragmentation, physical adsorption, or burial (Cederholm et al. 1989; Gende et al. 2002; Moore et al. 2004).

Comment: There is no basis for this estimate of changes to biomass, but from a toxicological perspective, also no consideration for how changes in ambient chemistry are likely to interact with contaminants. For example, losses in salmon-derived carbon could further reduce any ability of ambient waters to assimilate copper and other metals, in turn leading to any number of acute, chronic, sublethal, and indirect effects.

4.24-27

> Permitted discharges would be in compliance with APDES permit stipulations; that is, discharge process water would have been treated to achieve the water quality criteria that are protective of aquatic life. Based on an independent review of the WTP source terms and processes (Appendix K4.18, Water and Sediment Quality; AECOM 2018i), discharge water from the WTPs is expected to meet ADEC criteria. Therefore, release of metals to surface water via point discharges of process water are not expected to induce metal toxicity (lethal and sublethal) to fish and aquatic invertebrates.

Comment: Again, the FEIS is overly reliant on the sufficiency of water quality standards (Table 1), and the reliability and feasibility of treatment plant operation (Gestring 2019, Sobolewski 2020).

p. 4.24-27

> The results of analysis indicate that bioaccumulation of heavy metals in the food chain would not be expected to occur from development of the mine site.

Comment: Again, this unreasonably relies on the sufficiency of water quality standards (Table 1), and the reliability and feasibility of treatment plant operation (Gestring 2019, Sobolewski 2020). Moreover, it contradicts its own conclusions regarding mercury, spills, and tailings dam failures (see below).

p. 4.24-28: "Permitted discharges from the mine could affect fish and aquatic habitat"

Comment: This is one example of the FEIS reasonably concluding that water chemistry would change from ambient conditions with project development, even if discharges were constantly in compliance with water quality standards in perpetuity. Because fish, and particularly salmon with respect to spawning and maintenance of genetic biocomplexity, are adapted to specific conditions, any deviation is likely to have negative and potentially population level impacts.

Chapter 4.27 Spill Risk

p. 4.27-26

> Most adult and juvenile fish exposed to a diesel spill are mobile, and generally capable of limiting exposures until concentrations attenuate. Depending on the location, a spill occurring between mid-May and June could have impacts on out-migrating juvenile salmon species. These fish could experience acute toxicity, particularly in shallow water, stream margins, and off-channel habitats, where low stream currents could accumulate fuel. Impacts to these fish and invertebrates could include potential mortality, depending on the concentration and exposure time.

Comment: Expecting fish to simply swim away from contamination overlooks their specific adaptations which maintain the biocomplexity essential to the overall sustainability of Bristol

Bay salmon and the foodwebs that support them. As previously discussed, diesel is documented causing fish and aquatic insect kills extending tens of miles from the spill site and persisting for years. One spill could easily have longstanding impacts to individual stream populations on the road corridor (for example), and multiple spills could leave to watershed way population-level effects.

p. 4.27-82:

> Severall [sic] factors are likely to limit metals bioavailability when they are released to surface water, including binding by natural ligands (such as dissolved organic matter) and binding phases on particulates. EPA's recommended aquatic life WQC for copper is based on the Biotic Ligand Model to account for various factors that modify its aquatic toxicity (EPA 2007b). Metals bioavailability in the current evaluations presents uncertainties, but site-specific toxicity tests (as discussed in more detail below under Pyritic Tailings Release) are indicative of limited impacts on fish species.

Comment: As discussed in the introduction of this report, site-specific conditions are highly likely to facilitate bioavailability of many metals including copper due to exceptionally low dissolved organic matter. The uncertainties mentioned in this paragraph are seemingly ignored by the conclusion of no impacts to fish from mine development.

p. 4.27-88:

> The EPA reports that the presence of xanthate would render the tailings slurries toxic; but that in the event of seepage from the TSF, degradation and dilution in the TSF would likely render the downstream waters non-toxic (EPA 2014). EPA notes that this would depend on xanthate's ability to break down in the tailings facility.

Comment: Again, the uncertainty described here combined with that surrounding dozens of other aspects of mine development, water treatment, etc. suggest toxicological (and other) impacts to fish are likely.

p. 4.27-98:

> Fluids held in tailings (pore water) and above the tailings (supernatant fluid) would have elevated concentrations of dissolved metals, as described above. Dissolved metals would be bioavailable, and could have toxic effects on aquatic biota. In the event of an unplanned release, these metals would be introduced into the downstream waters, and would cause downstream waters to exceed applicable WQC. The released fluid would be diluted by stream water, and flushed downstream. Depending on the volume and the rate of release, the downstream water quality would be in exceedance of WQC for an unknown length of time and an unknown distance before the released fluid is sufficiently diluted below water quality exceedance.

Comment: While this statement seems quite reasonable, it simply does not align with the conclusion of no impacts to fish.

p. 4.27-119:

> Tailings slurry with residual xanthate that are released into downstream waters could create toxic conditions in downstream waters, although the concentration of xanthate would be low, and would be diluted in downstream waters.

Comment: Xanthates are extremely toxic to fish and other aquatic life. Should a spill occur during spawning windows, significant population-level impacts could occur. Even outside of spawning windows, however, xanthates could impact juvenile coho and Chinook salmon rearing in streams, and importantly, the entire aquatic foodweb upon which they rely.

p. 4.27-136:

> TSS—An increase in TSS from the released pyritic tailings would impact water quality for approximately 230 miles of drainages, from below the pyritic TSF all the way downstream to the Nushagak River Estuary, where it enters Nushagak Bay, part of greater Bristol Bay. The turbidity of the downstream water would be elevated above baseline conditions (pre-development levels) in Tributary SFK 1.240, the SFK, the mainstem Koktuli, the Mulchatna, and the Nushagak River where it feeds into Nushagak Bay, part of the greater Bristol Bay.

Comment: Although the FEIS failed to model a full tailings dam failure scenario (Wobus 2020), it still concludes potential toxic contamination extending hundreds of miles could result from a partial failure. Population level impacts would be near certain to occur with this extent of sediment input, particularly if the failure occurred during spawning migrations, but likely regardless of timing.

p. 4.27-138:

> The metals that would be present in the highest concentration would be cadmium, lead, manganese, molybdenum, and zinc. Copper levels in the released fluid would also be elevated above the most stringent WQC. Due to the large volume of fluid released in this scenario, downstream water quality would be impacted for tens to hundreds of miles downstream (Knight Piésold 2018p):
>
> - Copper would remain at levels exceeding the most stringent WQC until the Mulchatna River below the Koktuli River confluence, about 80 miles downstream of the mine site.
> - Lead, manganese, and zinc would remain at levels exceeding the most stringent WQC until the Nushagak River below the Mulchatna River confluence, about 122 miles downstream of the mine site.
> - Cadmium and molybdenum would remain at levels exceeding the most stringent WQC as far downstream as the Nushagak River Estuary, approximately 230 miles downstream from the mine site. 4.27-138
>
> These metals would remain at elevated levels above WQC for several weeks while the flows are flushed downstream.

Comment: Again, this statement quite clearly contradicts the conclusion that population level impacts to fish could not occur due to mine development.

Appendix Chapter K4.18 Water and Sediment Quality

p. K4.18-19:

> In a separate study from the geochemical modeling predictions described above, aquatic toxicity testing was conducted on samples of process water generated during plant water testing by Nautilus (2012). Samples of "non-gold" process plant water in the study are considered representative of process water that would be pumped from the mill to the TSFs and main WMP, undiluted by precipitation or other inflows (such as tailings beach runoff, SCP return water, WTP reject flows) (Knight Piésold 2019s). The results indicated no acute toxicity effects in the 96-hour rainbow trout and fathead minnow tests, and no chronic toxicity effects to survival or growth in the 7-day fathead minnow tests, with 100 percent survival rates and no growth impairment in undiluted process water. The results using Ceriodaphnia dubia (a daphnid or water flea) indicated 50 percent survival in undiluted process water after 48 hours, and chronic reproductive effects of 55.8 and 89.6 percent at IC25 and IC50 [inhibition concentration resulting in 25 and 50 percent reductions in reproductive output], respectively, after 7 days. Potential effects on aquatic life in the event of a release from mine site facilities are further discussed in Section 4.27, Spill Risk.

Comment: Upon review of the described Nautilus study, it is conspicuous that no growth or reproduction tests were conducted for rainbow trout, and so chronic effects of process water were not evaluated for salmonids. Fathead minnow are not closely related to any fishes that occur in Bristol Bay. Moreover, the sensitivity of *C. dubia* (a zooplankton taxa) to process water is alarming given the reliance of sockeye salmon on zooplankton during their juvenile freshwater residence. In general, this seems to downplay the potential effects of process water spills using insufficient data.

p. K4.24-2:

> Predicted project-related changes in selenium concentrations in various waterbodies during operations and post-closure activities are not sufficiently large to adversely impact sensitive fish and bird populations via aquatic or bioaccumulation pathways...To be conservative, various assumptions are made in the model that bias the predicted concentrations to be higher than would be expected under realistic conditions. The conservative, high-end, long-term selenium concentrations in the rivers and lake are estimated to range from 0.32 to 1.4 µg/L. These predicted selenium concentrations are below ADEC's aquatic life criterion of 5.0 µg/L and the EPA's aquatic life criteria of 1.5 µg/L and 3.5 µg/L for lentic and lotic waters.

Comment: Sobolewski (2020) indicates that selenium may be the most problematic element to treat given untested technology. In B.C.'s Elk River Valley, a WTP intended to treat toxic levels of selenium ultimately increased concentrations before closing entirely. Given the extreme toxicity of selenium combined with its ability to bioaccumulate with increasing trophic levels,

this statement appears a grave underestimation of potential impacts of regular mine operations (see Frissell 2019 and Zamzow et al. 2019).

p. K4.24-4:

> Overall, evaluations of copper toxicity on behavior and chemo/mechanosensory responses in fish indicate inhibitory concentrations as low as 0.7 µg/L (as dissolved copper) depending on species, life stage, exposure duration, and water chemistry. Furthermore, hardness-based criteria and Biotic Ligand Model-based criteria are generally protective against aquatic toxicity of copper, but they may not be protective for specific behavior and olfactory responses under specific conditions (such as low hardness).

Comment: This is again an example of a supportable statement that contradicts the overall conclusions of the FEIS. It also contradicts statements shortly following it:

p. K4.24-5:

> Changes in metals concentrations downstream of NFK, SFK, UTC, and Frying Pan Lake were predicted based on a model that accounts for the effluent discharge from the WTPs, project-related dust deposition on the lake, and runoffs from surrounding terrestrial areas receiving project-related dust deposition (see Appendix K4.18). To be conservative, various assumptions were made in the model that bias the predicted concentrations to be higher than would be expected under realistic conditions. The conservative, high-end, long-term copper concentrations in the rivers and the lake were estimated to range from less than 0.5 to 1.71 µg/L (see Table K.4.18-19). These concentrations are below the ADEC's aquatic life criterion of 2.2 µg/L, and the reported olfactory impairment threshold of 2.4 µg/L for fish in low hardness waters (Morris et al. 2019b).

Comment: In addition to contradicting the previous statement quoted, ADEC's water quality criteria still exceed current ambient copper concentrations in the North Fork Talarik and Upper Talarik Creek by 3-4 times (Table 1).

p. K4.24-5:

> However, at criteria concentrations (i.e., at the ADEC water quality criterion), cadmium is unlikely to accumulate to levels that would result in adverse effects to aquatic invertebrates, fish, or wildlife from the ingestion of aquatic life that have accumulated cadmium in their tissues.

Comment: This statement ignores the potential for spill and/or WTP spills and insufficiencies. Moreover, the ADEC water quality criterion for cadmium exceeds area concentrations by 5-7 times (Table 1).

p. K4.24-6:

> Mercury concentration in the effluent from WTPs during operation and closure phases would be estimated to be 1.6*10^-5 µg/L or lower (see Table K.4.18-13 and Table K.4.18-16), which is orders of magnitude lower than the ADEC aquatic water quality criterion of 0.012 µg/L. Downstream of the discharge point, concentrations of mercury would be expected to represent baseline conditions.

Comment: This statement relies on unproven technology and perfect WTP operation in perpetuity. Moreover, ADEC water quality criteria exceed ambient conditions by at least one order of magnitude.

p. K4.24-8-9:

> Owing to the uncertainties in the qualitative assessments discussed in this section, increased methylmercury production by project-related sulfate loading cannot be ruled out, particularly where conditions conducive to the MSR process and sulfate deficiency overlap...Ideally, porewater data from sediment and wetland environments serve as the best indicators for mercury methylation potential; however, site-specific porewater data are not available.

Comment: Particularly given the toxicity of methylmercury and the fact that it bioaccumulates with increasing trophic levels, sufficient data should be obtained to predict its production before concluding mining will not have measurable impacts to fish (Zamzow et al. 2019).

p. K4.24-11:

> Above considerations indicate that the conditions in project area waterbodies vary widely. Although the conditions in the majority of areas do not appear to be conducive to the MSR [microbial sulfate reduction which is a primary process producing methylmercury] process, conditions in significant portions of the areas do.

Comment: Same comment as previous. This statement is an example of many that make the final EIS conclusions appear to be based on conjecture.

p. K4.24-11-12:

> Finally, abundance of wetlands connected to an aquatic system is known to be one of the most important factors in determining methylmercury concentrations in surface waterbodies (Nagorski et al. 2014; USGS 2019)...Observations of mercury in baseline fish tissue samples demonstrate that methylmercury is being produced, and is available in the project area watershed. In those areas, including sediments and wetlands, that are conducive to the MSR process and are also deficient in sulfate, project-related sulfate loading would stimulate and/or enhance methylmercury production. The degree to which this stimulation or enhancement occurs is likely to be lower than that observed in warmer areas. Nonetheless, overall impacts of project-related sulfate loading on mercury methylation and subsequent methylmercury-related concerns cannot be ruled out.

Comment: Again, this is an indication that the conclusion of no impact to fish (or humans, to which mercury is more toxic) is not supported by the substance of the FEIS, much less its shortcomings.

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