Consideration of Potential Costs Regarding the Clean Water Act Section 404(c) Recommended Determination for the Pebble Deposit Area, Southwest Alaska

U.S. Environmental Protection Agency
Region 10

1200 Sixth Avenue, Suite 155

Seattle, WA 98101

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ACRONYMS

ANC	Alaska Native Corporation
ANCSA	Alaska Native Claims Settlement Act
BBNC	Bristol Bay Native Corporation
BEA	Bureau of Economic Analysis
CWA	Clean Water Act
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FEIS	Final Environmental Impact Statement
FWS	U.S. Fish and Wildlife Service
GDP	Gross Domestic Product
GHG	Greenhouse Gas
MDN	Marine Derived Nutrients
MW	Megawatt
NDM	Northern Dynasty Minerals Ltd.
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NFK	North Fork Koktuli River
NPV	Net Present Value
OC	Organic Carbon
O&M	Operations and Maintenance
PEA	Preliminary Economic Assessment
PLP	Pebble Limited Partnership
ROD	Record of Determination
SFK	South Fork Koktuli River
USACE	U.S. Army Corps Engineers
USGS	U.S. Geological Survey
UTC	Upper Talarik Creek

WTP	Willingness-to-pay

1. PURPOSE AND INTRODUCTION

This draft report describes the U.S. Environmental Protection Agency (EPA) Region 10's consideration of costs and benefits regarding the Clean Water Act (CWA) Section 404(c) recommended determination to prohibit and restrict the use of certain waters in the Bristol Bay watershed as disposal sites for the discharge of dredged or fill material associated with mining at the Pebble deposit (the recommended determination). CWA Section 404(c) requires EPA to determine that discharges of dredged or fill material into waters of the United States will have an *unacceptable adverse effect* on certain statutorily enumerated resources. In prior CWA Section 404(c) actions, EPA has made its "unacceptability" finding based solely on adverse effects on such resources and did not consider non-environmental costs, such as the forgone economic development of the project in making that finding. *See* 44 Fed.Reg. 58,076, 58,078 (Oct. 9, 1979). If, contrary to EPA's current position, this information is required to be considered under Section 404(c), EPA Region 10 has included a thorough analysis of the costs and benefits of its recommended determination and recommends the prohibition and restriction in Section 5 of the recommended determination in order to prevent unacceptable adverse effects on anadromous fishery areas.

For purposes of this document, EPA Region 10 refers to the "costs" of EPA's recommended determination as the foregone economic activity that could potentially be associated with the construction and operation of a mine at the Pebble deposit. EPA Region 10 refers to "benefits" of EPA's recommended determination as the benefits that would continue to accrue in the absence of the construction and operation of such a mine, by avoiding the harmful impacts of development.

EPA has detailed the potential costs of its CWA Section 404(c) action in this document. These include forgoing the potential economic activity that may be associated with construction and operation of a mine at the Pebble deposit if the Pebble Limited Partnership (PLP),[1] the project proponent, were to receive the necessary financing and all authorizations required by law, including a permit from the U.S. Army Corps of Engineers (USACE) under Section 404 of the CWA. EPA's consideration of costs is based on a review of the financial information provided in the Northern Dynasty Minerals' (NDM) Pebble Project Preliminary Economic Assessment (PEA) (Kalanchey et al., 2022), which evaluates PLP's 2020 Mine Plan (Pebble Limited Partnership, 2020), the employment estimates presented in USACE's Final Environmental Impact Statement (FEIS) developed pursuant to the National Environmental Policy Act (NEPA)[2] (USACE, 2020a), information received during the public comment period, and other public sources.

[1] PLP was created in 2007 by co-owners Northern Dynasty Minerals and Anglo American PLC to design, permit, construct, and operate a long-life mine at the Pebble deposit (Ghaffari et al., 2011). In 2013, NDM acquired Anglo American's interest in PLP, and NDM now holds a 100 percent interest in PLP (Kalanchey et al., 2022).

[2] The 2020 Mine Plan is evaluated in USACE's FEIS and is identified in the FEIS as Alternative 3 – North Road Only Alternative, Concentrate Pipeline and Return Pipeline Variant.

In this document, EPA Region 10 also assesses the environmental, economic, cultural, and other benefits) that would result from avoiding the impacts associated with development of PLP's 2020 Mine Plan (Pebble Limited Partnership, 2020). As discussed in this document, these benefits are currently being realized and many have been accruing for centuries. EPA Region 10's recommended determination (U.S. EPA, 2022) and USACE's FEIS (USACE, 2020a) are the primary sources of information on such benefits. EPA Region 10 also reviewed relevant ecology and economics literature, and considered the submitted public comments in characterizing the significance of the potentially lost and negatively impacted resources.

This document is organized as follows: Section 2 provides an overview of the resource context, including the ecological resources in the Bristol Bay watershed, PLP's 2020 Mine Plan, and the recommended determination. Section 3 provides an overview of how benefits and costs are considered. Uncertainties associated with the assessment of benefits and costs are discussed in Section 4. Section 5 provides a summary of the results of the benefits assessment, and Section 6 provides a summary of the results of the costs assessment.

Two key aspects of EPA's consideration of the potential economic activity associated with the construction and operation of the proposed 2020 Mine Plan are the significant regulatory and financial uncertainty and the economic principle of opportunity cost.

1.1. Significant Regulatory and Financial Uncertainty

The proposed 2020 Mine Plan was denied a CWA Section 404 permit by USACE in November 2020. For the project to move forward, USACE would need to reverse its decision to deny the project proponent's CWA Section 404 permit, a decision which was reached after completion of an extensive CWA and NEPA process.[3] If USACE does not reverse its decision, the proponent of the proposed project would have to successfully challenge USACE's permitting decision in federal court. Additional uncertainty is associated with the probability of the mine operators obtaining the necessary financing to proceed with the project. Therefore, the projected mine capital and operations and maintenance (O&M) expenditures and operational revenue streams, and their resultant employment implications, are estimates based largely on assumptions with a high degree of uncertainty, and a reasonable possibility that none of these would be accrued at all.

[3] If USACE issued a CWA Section 404 permit, the proposed project would require additional permits before mine construction could begin. According to PLP's CWA Section 404 permit application, the project would require 66 different types of reviews, approvals, or permits from 12 federal agencies, six state agencies, and two boroughs. In addition to CWA Section 404 and Rivers and Harbors Act Section 10 permits from USACE, a mine at the Pebble deposit would need state authorizations for the elimination of stream habitat, construction and operation of tailings facilities, use of water and treated water discharges, construction and operation of the natural gas power plant, and approval of a reclamation plan and bonding. Federal Incidental Take Authorizations pursuant to the Endangered Species Act and Marine Mammal Protection Act may be required for port construction and operations (Pebble Limited Partnership, 2020).

EPA's consideration of the PEA does not assess the medium- and longer-term financial sustainability of the 2020 Mine Plan even if construction were authorized to commence. There is uncertainty that the proposed mine project would be profitable, even if constructed. For example, a December 2021 memorandum reviewing the PEA[4] (Midgard Environmental Services LLC, 2021), states,

> "Even with the current exceptionally favorable metals prices, the greater than $6 billion that the Pebble PEA estimates will be required to build the 20-year starter mine represents an exceedingly risky investment that is unlikely to yield a positive rate of return even under exceedingly optimistic permitting and design assumptions."

Because there is significant uncertainty regarding whether the 2020 Mine Plan will be profitable over time, it is therefore also uncertain that the anticipated economic activity will occur at all, or in part. In contrast, however, there is a high degree of certainty that damages to streams, wetlands, and other waters will occur to the extent that project construction begins.

The level of uncertainty associated with the proposed project as a whole distinguishes this analysis from an assessment of the economic impacts typically evaluated by federal agencies, where the agency proposes to adopt a regulation that would impose affirmative obligations (such as adoption of pollution control measures) on extant, ongoing commercial enterprises with historical economic data such as output and revenues.

1.2. Opportunity Cost and Transfers

In addition, the reported costs of the recommended determination, associated with the 2020 Mine Plan, may overstate economic impacts because it does not account for opportunity costs (see Section 4.2).[5] Moreover, the estimates of expenditures, revenue, and employment described in the summary of the cost assessment in Section 6 are not necessarily, or entirely, additive to the Alaskan and U.S. economies because opportunity costs are not considered. Looking at these figures as representing entirely new output is therefore inaccurate.

Opportunity costs represent the forgone gains from choosing one option over another alternative. In case of this recommended determination where an option is removed from the choice set, one must consider the differential in forgone gains between the option removed from the choice set and the next best choice still available. Making this assessment requires understanding how many of the resources that were to be used in the removed choice may be re-purposed in the still-allowed alternative. In general, capital and labor markets are not without alternative demand sources and, if not used in a venture to mine the Pebble deposit, at least some portion of these resources would in all likelihood be used for other productive business endeavors elsewhere in the economy.

[4] The memorandum was prepared for the Natural Resources Defense Council by Richard Borden of Midgard Environmental Services, LLC.

[5] Certain benefits are subject to similar cost interpretation issues. *See* Section 4.1.

An alternative way to describe this movements of economic resources between ventures is as a "transfer." These transferred investments do not impact overall societal welfare because economic outputs of equivalent values are produced under both use alternatives. For example, if investments are not made in mining the Pebble deposit, capital may alternatively be transferred to another productive venture like the construction of housing and apartments at an alternative location resulting in increased economic activity in the area or in alternative locations like Anchorage or other Western U.S. urban areas. Although this may not result in the same level of economic return as a mining project, the increase in jobs and economic output from this alternative activity could offset the potential loss from the mining project not moving forward. This offset amount would be equal to the transfer that occurred between the productive alternatives.

The reported output and employment from the 2020 Mine Plan does not account for the alternative potential uses for the capital and labor invested in the mining project. For example, given that investors are profit maximizers, the financial resources that could have been used to potentially fund the purchase of capital equipment for the mine would not sit idle in the economy if the 2020 Mine Plan is not constructed. Instead, it would likely be invested in other projects, like additional manufacturing of construction capital equipment, offering returns as close as possible to those offered by the mine, that would generate economic activity in other locations. EPA notes that the alternative projects (forgone in favor of the 2020 Mine Plan) may also produce environmental externalities which could be less than, or greater than those of the 2020 Mine Plan.

The extent of lost economic opportunity would depend on the community considered, the location of those expenditures, and the potential alternative ventures available in the economy. For communities in the Bristol Bay region, there may be fewer alternate employment opportunities than other areas impacted by mine expenditure, such as Anchorage or other areas of the U.S. However, in the wider regional and national context the actual impacts of any employment opportunity generated by mining of the Pebble deposit—assuming it is even viable—are likely to be smaller than projected.

Though EPA has not assessed the degree of opportunity cost in the mining capital and labor markets, if the 2020 Mine Plan is not constructed, the actual economic consequences for the Alaskan and U.S. economies is likely to be smaller than the PEA's projections of expenditure, revenue, and employment which do not address opportunity costs as part of their analysis (for further discussion see Section 4.2).

2. RESOURCE CONTEXT

This section provides an overview of the ecological resources of the Bristol Bay watershed, with an emphasis on its fishery resources (Section 2.1); discussion of the watershed's geological resources in the context of the proposed mine at the Pebble deposit (Section 2.2); and an overview of EPA Region 10's recommended determination to prohibit and restrict the use of certain waters in the Bristol Bay watershed as disposal sites for the discharge of dredged or fill material associated with mining at the Pebble deposit (Section 2.3).

2.1. Ecological Resources

This section considers the Bristol Bay watershed's ecological resources, with particular focus on the region's fish habitats and populations and the watershed characteristics that support these resources (for additional details, see Section 3 in U.S. EPA (2022)). The Bristol Bay watershed supports the world's largest runs of Sockeye salmon, producing approximately half of the world's commercial Sockeye salmon catch (Ruggerone et al., 2010; McKinley Research Group, 2021). This productivity, for Sockeye as well as other Pacific salmon species, reflects the fact that Alaska's Bristol Bay watershed represents a largely pristine, intact ecosystem with outstanding ecological resources. It is home to at least 29 fish species, more than 40 terrestrial mammal species, and more than 190 bird species. This ecological wealth supports a number of sustainable economies that are of vital importance to the region, including subsistence, commercial, and sport fishing; subsistence and sport hunting; and non-consumptive recreation. The Bristol Bay watershed is an area of unparalleled global ecological value, boasting salmon diversity and productivity unrivaled anywhere in North America. As a result, the region is a globally significant resource with outstanding value. The Bristol Bay watershed provides intact, connected habitats—from headwaters to ocean—that support abundant, genetically diverse wild Pacific salmon populations. These salmon populations, in turn, help to maintain the productivity of the entire ecosystem, including numerous other fish and wildlife species (U.S. EPA, 2022).

The Bristol Bay watershed's streams, wetlands, and other aquatic resources support a more than 4,000-year-old subsistence-based way of life for Alaska Natives, as well as world-class, economically important commercial and sport fisheries for salmon and other fishes. Bristol Bay is perhaps most renowned for its Sockeye salmon populations, which represent the most abundant and diverse populations of this species remaining in the United States. Bristol Bay's Chinook salmon runs are also frequently at or near the world's largest, and the region supports significant Coho, Chum, and Pink salmon populations. Roughly 50 to 70 percent of Bristol Bay's Sockeye salmon and large numbers of its Coho, Chinook, Pink, and Chum salmon are sustainably harvested in subsistence, commercial, and recreational fisheries before they can return to their natal lakes, rivers, and streams to spawn. Thus, these salmon resources have significant nutritional, cultural, economic, and recreational value, both within and beyond the Bristol Bay region. Because no hatchery fishes are raised or released in the watershed, Bristol Bay's salmon populations are entirely wild and self-sustaining. Bristol Bay is remarkable as one of the last places on Earth with such bountiful and sustainable harvests of wild salmon.

One of the main factors leading to the success of this fishery is the fact that its diverse aquatic habitats are largely untouched and pristine, unlike the waters that support most other salmon fisheries worldwide (U.S. EPA, 2022). The Bristol Bay watershed's habitat diversity has supported evolution of significant genetic diversity within Sockeye and other Pacific salmon species that originate in the watershed. Researchers have identified several hundred discrete populations of salmon within the Bristol Bay watershed. These populations, with habitat-driven adaptations to the unique river, stream, wetland, or lake conditions where they spawn, have developed unique characteristics expressed through both phenotypic and genetic diversity. This diversity of populations creates a "portfolio effect" that acts to buffer salmon populations from sudden and extreme changes in abundance, thereby maintaining overall productivity in Bristol Bay's salmon fisheries (Schindler et al., 2015; Griffiths et al., 2014; Schindler et al., 2010; Lindley et al., 2009; Figge, 2004).

The Bristol Bay watershed's pristine, diverse, aquatic habitats—and the diverse salmon populations they support—generate significant economic activity in the region. The total economic value of the Bristol Bay watershed's salmon resources, including subsistence uses, was estimated at more than $2.2 billion in 2019 (McKinley Research Group, 2021). The Bristol Bay commercial salmon fishery generates the largest component of this economic activity, resulting in 15,000 jobs and an economic benefit of $2.0 billion in 2019, $990 million of which was in Alaska (McKinley Research Group, 2021). Because salmon return to the region each year, and its genetically diverse populations buffer against sudden and extreme changes in abundance, Bristol Bay's salmon fishery provides a sustainable economic engine for the region.

2.2. Geological Resources and Proposed Mine at the Pebble Deposit

In addition to significant and valuable ecological resources, the Bristol Bay watershed contains mineral resources. The largest known and most explored deposit is the Pebble deposit, a large, low-grade deposit containing copper-, gold-, and molybdenum-bearing minerals.[6] The Pebble deposit is located at the headwaters of the pristine Bristol Bay watershed. The Pebble deposit underlies portions of the South Fork Koktuli River (SFK), North Fork Koktuli River (NFK), and Upper Talarik Creek (UTC) watersheds. The SFK, NFK, and UTC drain to two of the largest rivers in the Bristol Bay watershed, the Nushagak and Kvichak Rivers.

Since 2001, NDM and subsequently PLP have been conducting data collection and analysis as part of efforts to pursue the development of a large-scale mine at the Pebble deposit. Construction and operation of a mine at the Pebble deposit would necessitate the discharge of dredged or fill material into

[6] Deposits that are "low-grade" contain relatively small amounts of target metals relative to the amount of ore.

wetlands, streams, and other waters of the United States and would therefore require a CWA Section 404 permit from USACE. In December 2017, PLP submitted a CWA Section 404 permit application to USACE to develop a mine at the Pebble deposit, which triggered the development of an Environmental Impact Statement pursuant to NEPA. In response to the Section 404 permit review/NEPA review process, PLP submitted a revised permit application in June 2020 (the 2020 Mine Plan) (Pebble Limited Partnership, 2020).

In the 2020 Mine Plan, PLP proposed to develop the Pebble deposit as a surface mine at which 1.3 billion tons of ore would be mined over 20 years. The project consists of four primary elements: (1) the mine site, situated in the headwaters of the SFK, NFK, and UTC watersheds; (2) the Diamond Point port; (3) the transportation corridor, including concentrate and water return pipelines; and (4) the natural gas pipeline and fiber optic cable. Under the 2020 Mine Plan, PLP would progress through four distinct mine phases: construction, operations (also referred to as production), closure, and post-closure. The construction period would last approximately 4.5 years, followed by 20 years of operation. Closure, including physical reclamation of the mine site, is projected to take approximately 20 years. Post-closure activities, including long-term water management and monitoring, would last for centuries (USACE, 2020a).

On July 24, 2020, USACE published a Notice of Availability for the FEIS[7] in the *Federal Register* (USACE, 2020a), and on November 20, 2020, USACE issued its Record of Decision (ROD) denying PLP's CWA Section 404 permit application on the basis that the 2020 Mine Plan would not comply with the CWA Section 404(b)(1) Guidelines and would be contrary to the public interest (USACE, 2020b).

- USACE found that the proposed project failed to comply with the CWA Section 404(b)(1) Guidelines because, "[t]he proposed discharges of dredged or fill material would cause significant degradation to the aquatic environment. The proposed avoidance, minimization, and compensatory mitigation measures would not change the determination" (USACE, 2020b; Pages B2-6 to B2-9).

- In its Public Interest Review, USACE "concluded that the benefits of the proposed elimination and alteration of wetlands, streams and other waters within the USACE jurisdiction do not outweigh the detriments that would be caused by such eliminations and alterations" and since "those eliminations and alterations would be necessary to realize any benefits from the proposed project, . . . the proposed project is contrary to the public interest" (USACE, 2020b). In making this finding, USACE specifically highlighted the following Public Interest Review factors: wetlands, fish and wildlife values, soils, and water quality (USACE, 2020b; Page B3-27).

[7] The 2020 Mine Plan is evaluated in USACE's FEIS and was identified in the FEIS as Alternative 3 – North Road Only Alternative, Concentrate Pipeline and Return Pipeline Variant.

On January 19, 2021, PLP filed a request for an appeal of the USACE permit denial with USACE. USACE accepted the appeal on February 25, 2021, and review of the appeal is ongoing.

2.3. Recommended Determination

EPA Region 10's recommended determination (U.S. EPA, 2022), like USACE's permitting decision, is based on significant concerns regarding the large-scale destruction and degradation of headwater streams, wetlands, and other aquatic resources that would result from the discharge of dredged or fill material for the construction and routine operation of the 2020 Mine Plan. Discharges of dredged or fill material to construct and operate the proposed mine site alone would result in the permanent loss of approximately 8.5 miles (13.7 km) of anadromous fish streams, 91 miles (147 km) of additional streams that support anadromous fish streams, and approximately 2,108 acres (8.5 km^2) of wetlands and other waters in the SFK and NFK watersheds that support anadromous fish streams. These discharges would also result in streamflow alterations that would adversely affect approximately 29 miles (46.7 km) of additional anadromous fish streams downstream of the mine site due to greater than 20 percent changes in average monthly streamflow.

As discussed in the recommended determination, aquatic resources that would be destroyed or degraded play an important role in supporting salmon populations in the SFK, NFK, and UTC watersheds; aquatic resource losses and degradation at the scale identified in the 2020 Mine Plan would be likely to result in unacceptable adverse effects on anadromous fishery areas in these watersheds. To prevent these unacceptable adverse effects, the recommended determination would prohibit the specification of certain waters of the United States at the mine site for the 2020 Mine Plan located in the SFK and NFK watersheds as disposal sites for the discharge of dredged or fill material for the construction and routine operation of the 2020 Mine Plan. The recommended determination also restricts the use of certain waters of the SFK, NFK, and UTC watersheds as disposal sites for the discharge of dredged or fill material associated with any future plan to mine the Pebble deposit that would result in adverse effects similar or greater in nature and magnitude to those associated with the 2020 Mine Plan (U.S. EPA, 2022).

3. APPROACH TO BENEFIT AND COST CONSIDERATION

This section provides an overview of how benefits and costs associated with the recommended determination are considered. As discussed in Section 2.3, the recommended determination would prohibit and restrict the use of certain waters in the Bristol Bay watershed as disposal sites for the discharge of dredged or fill material associated with mining the Pebble deposit. The recommended determination would, if affirmed, prohibit discharges of dredged or fill material for the construction and routine operation of the 2020 Mine Plan into certain waters of the SFK and NFK watersheds. The recommended determination would, if affirmed, also restrict discharges of dredged or fill material associated with any future plan to mine the Pebble deposit into certain waters of the SFK, NFK, and UTC watersheds that would result in adverse effects similar or greater in nature and magnitude to those associated with the 2020 Mine Plan. Therefore, the recommended restriction would create benefits that are similar or greater in nature and magnitude to the benefits from the recommended prohibition, because it would be preventing adverse effects that are similar or greater in nature and magnitude.

Because the potential construction and mineral production of the project could be realized only if the mine site as well as the transportation corridor, pipelines, and port are completed according to the 2020 Mine Plan (Kalanchey et al., 2022), EPA's assessment in this document will include all parts of that proposed mine plan. Likewise, because the transportation corridor, pipelines, and port would not be constructed unless the mine site is developed, EPA is considering the benefits associated with avoiding negative environmental and cultural impacts from the development of the mine, as well as the transportation corridor, pipelines, and port, providing parity across the benefit and cost categories discussed in this document. The 2020 Mine Plan mine site and transportation infrastructure would also be expected to be representative of infrastructure needed to access the Pebble deposit for any future developments, such as those that could be impacted by EPA Region 10's recommended determination. For example, previous plans to mine the Pebble deposit and alternatives considered to mine the Pebble deposit have proposed similar infrastructure with similar attendant economic activity.

More specifically, as described in the PEA for the 2020 Mine Plan (Kalanchey et al., 2022), the project being assessed in this document would include the following main infrastructure in addition to the mine site:

- a 270-megawatt (MW) natural gas-fired combined cycle power plant located at the mine site;
- three 2-MW natural gas-fired engine generators located at the marine terminal;
- a 164-mile natural gas pipeline connecting existing supply on the Kenai Peninsula to the power plants at the marine terminal and mine sites, respectively;
- an 82-mile transportation corridor from the mine site to the marine terminal, located north of Diamond Point in Iliamna Bay on Cook Inlet, consisting of: a private two-lane unpaved road that

also connects to the existing Iliamna/Newhalen road system; the on-shore portion of the natural gas pipeline, buried adjacent to the road; and a concentrate pipeline to transport copper-gold concentrate from the mine site to the port with a return water pipeline to the mine site, both buried adjacent to the road; and

- a marine terminal incorporating: concentrate dewatering, storage and handling; fuel and supply storage; and barge docks for receiving supplies and facilitating bulk transshipment of concentrate to an offshore location in Iniskin Bay for loading onto bulk carriers.

EPA reviewed and considered quantitative costs and benefits, where possible, as well as qualitative costs and benefits. EPA also considered the relative uncertainties associated with quantified costs and benefits, as discussed in Section 4. This approach is consistent with EPA's Guidelines for Preparing Economic Analyses (U.S. EPA, 2010) which states:

> Ideally, all benefits and costs of a regulation would be expressed in monetary terms, but this is almost never possible because of data gaps, unquantifiable uncertainties, and other challenges. It is important not to exclude an important benefit or cost category from BCA even if it cannot be placed in dollar terms. Instead, such benefits and costs should be expressed quantitatively if possible (e.g., avoided adverse health impacts). If important benefit or cost categories cannot be expressed quantitatively, they should be discussed qualitatively.

The consideration of quantified and non-quantified costs and benefits is also supported by other federal guidance for the conduct of economic analysis (e.g., Circular A-4 guidance for Regulatory Impact Analyses under Executive Order 12866 "Regulatory Planning and Review"; U.S. Office of Management and Budget, 2003). EPA discussed the qualitative benefits and costs that may accrue as well as their limitations and uncertainties in Sections 4 (Uncertainty with Benefit and Cost Assessment), Section 5 (Benefits), and Section 6 (Costs).

3.1. Consideration of Benefits

EPA Region 10 assessed the environmental and cultural benefits that would result from avoiding the impacts associated with the 2020 Mine Plan (Kalanchey et al., 2022). EPA considered this information in light of the uncertainty associated with benefits described in Sections 1 and 4.1. These benefits are currently being realized and many have been accruing for centuries. EPA Region 10's recommended determination (U.S. EPA, 2022) and USACE's FEIS (USACE, 2020a) are the primary sources providing environmental information on the permanent and temporary impacts to streams, wetlands, and other waters that would be affected by the 2020 Mine Plan. The FEIS also provided information on the potential impact to cultural resources, including impacts to Alaska Natives, Tribes, and Alaska Native Corporations (ANCs). EPA Region 10 also reviewed relevant ecology and economics literature to characterize the significance of the potentially lost and negatively impacted resources.

3.2. Consideration of Costs

EPA Region 10's consideration of costs is based on a review of the financial information in NDM's Pebble Project PEA Technical Report Update (Kalanchey et al., 2022)[8], the employment estimates presented in the USACE FEIS (USACE, 2020a), and the economic contribution assessment of the Proposed Pebble Project to the US national and state economies produced by IHS Markit created for NDM/PLP, hereafter referred to as the IHS Markit report (IHS Markit, 2022).[9] EPA considered this information in light of the uncertainty associated with the proposed project's potential to move forward in the absence of any final action by EPA under CWA Section 404(c), the uncertainty regarding the long-term financial viability of the proposed project, and the estimation of uncertainty in the specific financial data provided in the PEA, IHS Markit assessment, and FEIS (see Section 1 and Section 4.2 for additional information on uncertainty).

Specifically, EPA Region 10's consideration of costs for the project relies on cost data described as the "full capital cost" scenario from the PEA[10]. The PEA also considers an additional scenario, where the effective capital cost is reduced to the primary mine development firm by relying on partners to provide up front capital and develop some of the infrastructure, in exchange for the right to buy gold at reduced prices. This assessment does not examine this additional scenario; for the purposes of this assessment, the full capital cost scenario best represents the economic impacts associated with expenditures on infrastructure and other economic activity-producing investments of the proposed project, because it includes all capital expenditures needed for mine construction.[11] EPA Region 10 also considered Midgard Environmental Services, LLC's review of the PEA (Borden, 2021) as an additional public source of information (see Section 4.2).

The PEA provides information on expenditures for both the construction phase and operations phase (also referred to as production phase) of the 2020 Mine Plan. The construction period is projected to last 4.5 years and the operations phase is projected to last 20 years.

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[8] Notable changes for the costs outlined in NDM's 2021 PEA (Kalanchey et al., 2021) and the 2022 PEA Technical Report Update (Kalanchey et al., 2022) are from the update to include the new royalty agreement where an investor has contributed $12 million for the right to receive 2% of payable gold production and 6% of payable silver production over the life of the mine. The investor also has the option to invest additional increments of $12 million over the next two years up to a maximum of $60 million to receive the right to 10% of payable gold production and 30% of payable silver production (Kalanchey et al., 2022). The overall impact on project costs is minimal, however some small changes have been made to the annual operating costs because of the royalty's estimated impact on participation payments (Kalanchey et al., 2022).

[9] Note that while the IHS Markit economic impact assessment is based on costs from a now outdated version of the PEA, EPA does not anticipate that the 2022 PEA updates to costs will impact IHS modeled economic impacts significantly.

[10] Note the "full capital cost" scenario evaluates the finances of the 2020 Mine Plan. This assessment does not consider the potential expanded mine scenarios referenced in the PEA.

[11] Note that EPA did not consider the PEA scenario where the effective capital cost to the primary mine development firm is reduced by relying on partners to provide up front capital and develop some of the infrastructure in exchange for the right to buy gold at reduced prices because this scenario only represents economic transfers between parties investing in the mine and does not represent alternative potential changes in social economic impacts.

The PEA also provides expected mine production values for five types of metals: copper, gold, molybdenum, silver, and rhenium. Given these projected metals quantities, the PEA used long-term metal price forecasts to estimate total revenues to the mine (Kalanchey et al., 2022). EPA Region 10 assessed the potential impacts to the commodities markets for the five metals highlighted in the PEA. Based on the review of production estimates from the PEA data, impacts to the copper market were assessed in more depth due to the potential for commodity price impacts (see Section 6.2). The Agency also considered the revenue sharing and employment impacts to local Alaska Natives, Tribes, and ANCs based on information discussed in the PEA and FEIS (see Section 6.3).

The Agency also considered the IHS Markit economic impact assessment (IHS Markit, 2022) that is summarized in Section 6.1. The IHS Markit report presents the results of the full capital case as well as an expansion scenario "Production Year 5 Potential Expansion Scenario with Gold Plant." EPA Region 10 did not consider the expansion scenario for purposes of consistency with the costs considered from the PEA and with the overall recommended determination analysis. The overall analysis did not include the expansion scenario as part of the basis for the recommended determination, because the expansion scenario is not part of the 2020 Mine Plan, has not otherwise been proposed, and would require additional and separate permitting. The IHS Markit report presents estimates of employment, output, value added, labor income, and taxes resultant from the construction, and operation of the 2020 Mine Plan. Taxes represent transfer payments and do not generate net additional economic activity of their own, however they are presented because the distributional impact of taxes on national, state, and local institutions is valuable to consider. To generate economic impact estimates, IHS Markit used IMPLAN, a static input-output modelling software that is commonly used for conducting local economic impact assessments.[12] Input-output models, such as IMPLAN, utilize a series of tables representing each industrial sector within the economy. These tables track what industries are providing inputs to specific industrial sectors and what industries in the economy receive the outputs from the same industrial sectors. Utilizing this information across all industrial sectors allows for the estimation of a series of fixed multipliers. These estimated multipliers "describe the response of the [local] economy to a stimulus (a change in demand or production)" and can be used to analyze changes in final demand and their ripple effects throughout the local economy.[13] Three types of multipliers are used in IMPLAN:

- **Direct Effect –** represents the impacts generated from spending in the primary, or direct, industry that results in final demand changes, such as mine employee income or purchases of mining specific equipment.
- **Indirect Effect –** represents the impact generated in secondary industries due to spending in the primary, or direct, industries. For example, the jobs supported by the manufacturing of

[12] Uncertainties and the appropriateness of IMPLAN are discussed more in Section 4.2.

[13] How IMPLAN Works, available at: https://support.implan.com/hc/en-us/articles/360038285254-How-IMPLAN-Works

mining specific equipment, or the purchase of materials required for those specific pieces of equipment.

- **Induced Effect –** represents the impact created in all local industries due to expenditures arising from the new household incomes generated by the direct and indirect effects. For example, grocery store workers whose jobs are supported by the purchases made by workers in the direct and indirect categories would benefit from increased income to these households.

IHS Markit worked in coordination with NDM to attribute expenditures during the initial capital and operations phases of the mine across IMPLAN's 546 industry sectors to generate the model estimates.[14] Mapped project costs were used as inputs for the IMPLAN model, creating a subset of all industries that were anticipated to experience direct impacts, for example expected spending on specialized mining equipment would be allocated to sector 263 – Mining Machinery and Equipment Manufacturing. The expected expenditures, or direct impacts, for each of the impacted industries were then fed into the multiplier tables to create estimates of the economy wide economic impacts. The IHS Markit analysis did not provide specific project costs or mapping of project costs to IMPLAN sectors that would have allowed EPA to assess the underlying model assumptions used and therefore the reliability of the modeled results. In a separate analysis to determine the economic impacts generated by the copper output of the mine, IHS Markit used IMPLAN's multiplier data to link industrial sectors downstream from the copper refining sector in order to estimate what proportion of sales in the downstream industries that are enabled by copper products. That proportion was multiplied by the report's calculation of what percent of U.S. copper demand would be generated by the 2020 Mine Plan to estimate the economic impacts from the mine's output.

[14] The IHS Markit report (IHS Markit, 2022) does not explicitly state what inputs were used in the IMPLAN modeling. The report states that NDM provided key inputs for the models (IHS Markit Report pg. 4 and 8), but does not mention whether the inputs to the model are the costs from the 2021 PEA (Kalanchey et al., 2021), which was the most current PEA at the time IHS Markit published their report.

4. UNCERTAINTY WITH BENEFIT AND COST ASSESSMENT

Section 1 of this document, the Purpose and Introduction section, 1describes sources of uncertainty that affect both benefits and costs, including (1) uncertainty regarding the proposed project's ability to secure all necessary permits even in the absence of any final action by EPA under CWA Section 404(c), and (2) uncertainty regarding the financial viability of the proposed project. This section discusses additional sources of uncertainty associated with benefits (Section 4.1) and costs (Section 4.2).

4.1. Uncertainties Associated with Benefits

Documented sources of uncertainty affect several benefit categories discussed in Section 5, including the extent of potentially affected aquatic resources (Table 5-1), commercial fisheries (Section 5.1), subsistence (Section 5.2), recreational use (Section 5.3), salmon-based ecosystem (Section 5.5), health and safety (Section 5.7), and potential spill and dam failure risks (Section 5.11). As discussed below, many of the sources of uncertainty are more likely to indicate a potential underestimation of the benefits associated with the recommended determination. Additional sources of uncertainty are covered in detail in USACE (2020a) and U.S. EPA (2022).

- The benefits assessment considers all parts of the 2020 Mine Plan, including impacts beyond the SFK, NFK, and UTC watersheds resulting from the transportation corridor, pipelines, and port (see Section 3 for details). Additionally, the benefits assessment considers associated downstream effects to ecosystem services resulting from projected impacts under the 2020 Mine Plan, such as impacts to downstream fisheries in the Bristol Bay watershed. The assessment of downstream effects are subject to increased uncertainty since many additional factors influence those eventual downstream impacts. For example, to understand the impact to fish populations downstream of the directly affected stream reaches on the NFK, SFK, and UTC rivers you must assess the degree to which sediments and chemical pollutants reach downstream areas, how they might affect the plant life and other aquatic species in each the fish species food chain, and the direct impacts of the pollutants on the fish themselves.
- Where high-resolution aquatic resource mapping was not available, the extent of potential impacts to streams, wetlands, and other aquatic resources was estimated in the FEIS using National Wetland Inventory mapping and National Hydrography Dataset data (USACE, 2020a; Section 4.22). Both of these sources have been demonstrated to underestimate the extent of aquatic resources in this region (U.S. EPA, 2022; Section 3).
- Estimates of total fish distribution and abundance across the affected area are likely underestimates because fish populations in the potentially affected watersheds have not been sampled at sufficient spatial and temporal scales to capture population variability in space and time (U.S. EPA, 2022; Section 3). Additionally, since extensive sampling for Rainbow Trout, Dolly Varden, Arctic Grayling,

Northern Pike, and other fishes has not been conducted throughout the potentially affected watersheds, total distributions and abundances of these species are unknown (U.S. EPA, 2022; Section 3).

- The loss of even a small, discrete salmon subpopulation within the Bristol Bay watershed may have larger than expected effects due to the associated decrease in biocomplexity which is critical to the sustainability and productivity of the watershed's salmon population and fisheries. The FEIS analysis (USACE, 2020a) states that the 2020 Mine Plan would have minimal impacts on fish salmon populations but acknowledged that: (1) the proposed project may reduce the local portfolio effect and (2) project modeling of potential impacts to fish populations has limitations, based on the scenarios analyzed, the assumptions made, and potential risks not considered in the analysis due to the very low probability of occurrence (USACE, 2020a; Attachment B8). EPA notes that the FEIS did not consider many of the limitations of the fish population model used in the analysis of fish habitat. Appendix B in U.S. EPA (2022) details effects of specific assumptions and model's limitations on the habitat analysis and explains why the FEIS estimates of changes to fish habitat likely underestimated the extent of the 2020 Mine Plan impacts.

- As discussed in Section 5.11, there is risk of hazardous material spills (e.g., chemical reagents, copper-gold flotation concentrate, tailings, and untreated contact water) over the life of the mining operation. These low probability–high impact events (e.g., hazardous material spills) could also adversely affect fish populations if they occur, further exacerbating the adverse effects of fish habitat losses.

- For wildlife, the analysis area in the FEIS (USACE, 2020a; Section 4.23) was not meant to encompass the home range of all species and instead focused on wildlife that occurred in and transited through the analysis area (and thus may be more likely to be exposed to a variety of impacts from the project), and then moved beyond/outside of the analysis area. By focusing on particular species, the analysis may underestimate impacts to species not explicitly considered. Additionally, the accuracy of the selected radii used by the FEIS to determine the area to be assessed for wildlife impacts is uncertain and may over- or underestimate the actual impacted area (USACE, 2020a; Section 4.23).

- The response of subsistence and recreational users to changes in the accessibility and quality of subsistence and recreational sites is also uncertain. Behavioral responses, as well as economic impacts on subsistence and recreational users, will depend on a variety of factors, including availability and proximity of substitute sites, potential changes in catch rates, and a subjective perception of site quality. Although the FEIS concluded that the extent of recreational fishing impacts would be displacement by mining activities along a short length of the upper Koktuli River and by road crossings of streams with measurable recreational fishing effort (USACE, 2020a; Attachment B8), actual impacts could be larger or smaller when accounting for downstream effects on water quality, availability and proximity of substitute sites, and other sources of uncertainty. Impacts on subsistence uses of the affected resource is even more difficult to predict due to inherent challenges in estimating subsistence harvest and assessing responses of subsistence users to changes (and perceived changes) in resource quality and accessibility (see Section 5.2 for detail).

- Although the FEIS acknowledges the potential for exceedances of water quality criteria over the life of the mine due to reasons such as treatment process upset or record-keeping errors, as has happened at other Alaska mines (USACE, 2020a; Section 4.18), the FEIS (USACE, 2020a; Section 4.24) concludes that treated water discharges are expected to result in “no noticeable changes” in water chemistry and only slight increases in water temperature immediately below discharge points (USACE, 2020a). Section B.5.1 in U.S. EPA (2022) explains in detail why EPA Region 10 disagrees with this conclusion, noting that treated water discharges resulting under the 2020 Mine Plan would substantially increase concentrations of 11 constituents (e.g., chloride, sulfate, calcium, magnesium, sodium, nitrate-N, ammonia, hardness) in receiving waters relative to baseline concentrations. EPA Region 10 concludes that the FEIS underestimated potential impacts of the 2020 Mine Plan to the region’s aquatic resources because it did not consider how water quality changes resulting from losses of upstream aquatic habitats, changes in surface water and groundwater flows, and the release of treated water discharges would impact fish communities adapted to current water quality conditions (U.S. EPA, 2022; Section B.5.1). Although the recommended determination (U.S. EPA, 2022) does not quantify benefits associated with maintaining surface water quality, recent EPA rulemakings (e.g., U.S. EPA, 2015; U.S. EPA, 2009) have demonstrated that even small changes in surface water quality may result in significant impacts to affected households in terms of both use (e.g., recreation) and non-use values. These findings from the Agency’s regulatory actions indicate that preventing even small declines in surface water quality under the recommended determination may yield significant benefits, however, EPA was unable to quantify water quality benefits in the Bristol Bay watershed based on the information provided in the FEIS. As such, the assessment of benefits resulting from the recommended determination, if affirmed, to commercial fisheries (Section 5.1) and recreational fishing (Section 5.3.1) are likely underestimates.

- Although the health and safety analysis in the FEIS (USACE, 2020a; Section 4.10) considered many potential health implications of the 2020 Mine Plan, estimating changes in health and safety outcomes from the recommended determination is challenging due to uncertainty associated with potential environmental exposure to toxic pollutants (e.g., from fugitive dust) and the associated health outcomes as well as the probabilistic nature of mortality and injuries from, for example, traffic accidents. In addition, interacting factors affecting social and mental health make quantifying many health impacts unreliable (See Section 5.7 for detail). The FEIS also acknowledges that the proposed project could produce additional strain on the health and safety services of the potentially affected communities (USACE, 2020a; Attachment B8). The 2020 Mine Plan may also have positive health effects from an increase in income and services. Nevertheless, the overall effect of the 2020 Mine Plan on health and safety is uncertain.

- Economic impacts associated with commercial fisheries (Section 5.1) and recreational use (Section 5.3) are derived from input-output analysis, including jobs, taxes, and economic output. Many of these estimated economic impacts are national in nature, particularly because, as stated in the

McKinley Research Group (2021) report, many of the impacts are associated with economic activity by nonresident fishers. Therefore, many of the same uncertainties associated with the economic impacts discussed in Section 4.2 are applicable to economic impacts in Sections 5.1 and 5.35.1.

4.2. Uncertainty Associated with Costs

The estimated costs, presented and discussed in Section 6, have significant uncertainties associated with them. Cost uncertainties fall into three general categories: (1) uncertainty regarding the proposed project's ability to secure all necessary permits even in the absence of any final action by EPA under CWA Section 404(c), (2) uncertainty regarding the financial viability of the proposed project outlined in the 2020 Mine Plan, and (3) uncertainties that arise from the specific data estimates provided in the PEA (Kalanchey et al., 2022) and the IHS Markit report analysis (IHS Markit, 2022).

EPA Region 10 has discussed the significant uncertainties associated with project implementation due to permitting issues, and financial viability in Section 1 above. The remainder of this section describes uncertainties associated with the PEA expenditure and revenue data, and the IHS Markit report estimates of economic output.

The PEA acknowledges that some of its estimates are highly uncertain (Kalanchey et al., 2022), creating uncertainty about the magnitude of the costs of EPA's recommended determination. The PEA notes that actual capital costs may be 50 percent higher or lower than the values reported in the PEA. The PEA's sensitivity analysis finds that even a 30 percent increase (decrease) in initial capital expenses would lower (raise) post-tax Net Present Value (NPV) by more than 50 percent. Reported employment estimates from the PEA (Kalanchey et al., 2022) and in request for information responses (USACE, 2020a, Section 4.3) also differ significantly, introducing additional uncertainty to cost estimates. Uncertainty in the cost estimates introduces uncertainty into both the financial viability of the proposed project as well as the estimated economic impacts. For example, if actual capital costs are higher than reported in the PEA the project would be less likely to be financially viable. However, those higher capital costs would result in potentially large economic impacts under the static nature of IMPLAN modeling (see discussion below), resulting in a dichotomy of large estimated economic impacts that are less likely to actually be realized.

PEA production and revenue projections depend on metal resource estimates and price assumptions. Inferred resources,[15] which are speculative and would not be included as a basis for economic analysis in a preliminary feasibility study or feasibility study, comprise 41 percent of the copper-equivalent tonnage in the total resource estimate for the Pebble deposit. The PEA assumes that mineral resource estimates will not change, and that all estimates of mineral resources will be found to accurately represent mineral reserves (Kalanchey et al., 2022). If inferred resources do not materialize, production

[15] The Canadian Institute of Mining, Metallurgy and Petroleum defines inferred resources as: An Inferred Mineral Resource is that part of a Mineral Resource for which quantity and grade or quality are estimated on the basis of limited geological evidence and sampling. Geological evidence is sufficient to imply but not verify geological and grade or quality continuity (CIM Standing Committee on Reserve Definitions, 2014).

would be below estimates either due to less material being mined, a higher share of mined material being waste, or a lower head grade (average concentration of valuable metal within the extracted ore). The PEA's sensitivity analysis finds that a 10 percent decrease (increase) in head grade would nearly erase (roughly double) the project's post-tax NPV.

For commodity prices, the PEA averaged major bank and analyst estimates. While commodity prices can fluctuate widely in practice, the PEA assumes constant long-term prices of $3.50/lb for copper (this estimate is lower than other forecasts of copper prices through the mine's projected operation period[16]), $1,600/oz for gold, $10/lb for molybdenum, $22/lb for silver, and $1,500/kg for rhenium (Kalanchey et al., 2022). The PEA's sensitivity analysis shows that a 30 percent copper price decrease (increase) would nearly erase (nearly double) the project's post-tax NPV. A 30 percent gold price decrease (increase) would decrease (increase) post-tax NPV by roughly 50 percent. There is additional uncertainty of how price effects from changes in the supply of mined metals would impact their demand.

There is additional uncertainty regarding the geographic location from which costs outlined in the PEA will accrue. Notably, it is possible that some materials, equipment, and or employees could be sourced from Canada instead of the United States; the primary developer of the Pebble mine project is a Canadian firm and the proposed mine site is in close proximity to Canada. This would reduce the amount of the 2020 Mine Plan's supported economic activity in the United States. The FEIS estimates that 29.4% of operation jobs would be from surrounding communities, with the remaining jobs coming from Anchorage or Kenai (USACE, 2020a; Section 4.3.3.1) and that upwards of 50% of the construction jobs may be imported from outside of Alaska, further introducing uncertainty over the location and magnitude of those economic impacts (USACE, 2020a; Section 4.3.3). This geographic variability introduces uncertainty as to the magnitude and distribution of costs because economic impacts accrue to the location where spending occurs. For example, if machinery is purchased outside of Alaska (even if it is used in the Bristol Bay area), much of the benefits will not end up in the local area. Another example of these uncertainties is that if employees take income earned from the project out of the region, those impacts from increases in income will not accrue to the local community. Though spending associated with the 2020 Mine Plan on materials, equipment, and employees would likely stimulate some demand for local goods and services, the magnitude of the economic multiplier effect is unknown because the IHS Markit report analysis only presents summary results and does not provide industry specific impacts (IHS Markit, 2022).

There is additional uncertainty around the downstream impacts of copper production from the 2020 Mine Plan. The IHS Markit report overestimates the downstream economic impacts of the Pebble mine's copper production because it does not account for the export of Pebble mine copper concentrate for refinement (see Section 6.2 for more detail) (Kalanchey et al., 2022). USACE noted that there is insufficient copper refining capacity in the U.S. to meet the production estimated in the FEIS, and states that some of the mine's output will be exported to Asia (USACE, 2020a; Section 2.2.4.3). PLP, in the PEA,

[16]Snowdon et al. (2021) estimate that prices per pound of copper could reach upwards of $6.80 due to increasing demand.

goes further, stating that all of the copper concentrate will be shipped to smelters in Asia and Europe (Kalanchey et al., 2022). However, and contrary to these facts, the IHS Markit report's estimates of downstream economic contributions are based on the assumption that the mine would produce an amount of copper equal to between 3.3% and 6.9%[17] of U.S. copper demand, and the further assumption that all this production will remain in the domestic market adding between 3.3% and 6.9% to copper sales and jobs in the downstream sectors of the economy. These erroneous assumptions in the IHS Markit report clearly result in overestimated economic impacts given the USACE findings in its FEIS and the PEA statements about the export of copper concentrates for refinement to Asia and Europe (for further discussion see Section 6.2). The extent to which exported copper concentrates from the 2020 Mine Plan will be re-imported as refined copper is uncertain and is based on dynamic global economic factors, but information from the U.S. Geological Survey (USGS; Flanagan, 2022) on the U.S. share of total global demand and U.S. import statistics on refined copper product (see Section 6.2) indicate that a relatively small fraction of refined copper from the Pebble mine will be re-imported to the domestic market.

As noted in Section 3.2, the IHS Markit analysis did not provide the IMPLAN model inputs (IHS Markit, 2022). As a result EPA was unable to assess the underlying model assumptions used and therefore determine the reliability of the results presented in that report. Modeling the 2020 Mine Plan with IMPLAN is highly complex due to the size of the project, the regional scope of impacts, and the wide range of affected industrial sectors, resulting in higher levels of uncertainty in the estimated results. Input-output models, such as IMPLAN, lack realistic behavioral reactions by producers and suppliers to large demand or supply shocks, and are static in nature (U.S. EPA, 2010). This results in economic estimates that may not reflect net increases to economic activity, and instead represent non-additive transfers of economic activity within the economy. Due to the linear relationship between inputs and outputs of static input-output models (such as IMPLAN), as costs change the economic impacts will also change proportionally (e.g., if costs increase two times then the estimated economic impacts will increase two times). The inherent uncertainty in project costs as stated in the PEA (Kalanchey et al., 2022) suggests that similar uncertainties exist in the estimated economic impacts.

The IMPLAN model fixed multipliers do not allow for the estimation of social costs because input-output models do not include utility or demand functions (U.S. EPA, 2017). Input-output models are also based on historical relationships between industries, households, and other macroeconomic data. These historical relationships may not hold in the future, or may not hold when the economy is close to full-employment. The full-employment economy makes labor and other inputs to production more scarce, making it more likely that such inputs are transfers from other sectors of the economy to the sectors supporting development of the 2020 Mine Plan rather than new net gains in economic activity. Therefore, the gains that are represented in the estimated economic impacts may be losses to other sectors, states, or regions of the U.S. According to the Federal Reserve the national economy is currently

[17] Using the annual copper estimates from the PEA and the forecasted US copper demand growth, EPA estimates that the 2020 Mine Plan, if constructed, could generate copper ore equivalent to between 3.3% and 6.9% of US copper demand over its production period.

operating with labor market conditions that are consistent with maximum employment (Powell, 2022). Research by Tüzemen also shows a mis-match between labor demand and supply which has continued with job openings significantly exceeding historical trends and labor supply not keeping up (Tüzemen, 2022). These labor market factors point to the likelihood that increases in labor demand created by the Pebble Mine in areas outside of the local Bristol Bay area, at least in the short-run, would, in part, be a transfer of economic activity from other areas of the economy.

While a larger portion of the economic activity estimated by the IMPLAN model and associated with the construction and operation phases of the 2020 Mine Plan may constitute transfers of economic activity as opposed to net gains in economic activity in the national and larger regional economies, the economies in the immediate vicinity of the Pebble deposit, with differing economic conditions, would see net gains due to employment and spending increases within those communities. In the counties that surround the proposed mine--Bristol Bay Borough, Dillingham Census Area, and Lake and Peninsula Borough--the total population is below 10,000 and each county experiences a seasonal cyclical unemployment rate with unemployment peaking during the winter months.[18] However, individual villages within these boroughs have unemployment rates that are more than double the county rates.[19] During times of high unemployment, employment in the local economy associated with mining the Pebble deposit6.1 could represent net increases in employment rather than transfers of employment from other areas[20]. The local economic impacts discussed in Section 6.36.1 are more likely to represent a net increase in social welfare for the local communities than the IMPLAN estimated state and national economic impacts in Section 6.1. The Section 6.1 state and national economic impacts are more uncertain and more likely to be transfers as opposed to net gains, especially given short-term economic conditions.

In total there are multiple uncertainties associated with the costs of the recommended determination discussed in Section 6. The uncertainties regarding the 2020 Mine Plan project costs, as acknowledged by the PEA (Kalanchey et al., 2022) could result in higher or lower costs of the recommended determination. The uncertainties regarding the economic costs of the recommended determination make it likely that estimates of total domestic economic output in Section 6, derived from IMPLAN modeling, are also uncertain and likely overstated. These uncertainties include the location where the costs will accrue, and their downstream impacts given the copper concentrates will be exported. Additionally, the IMPLAN model has inherent limitations that prevent it from estimating net changes in

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[18] The seasonal unemployment rate for Bristol Bay Borough ranged from 1.7% to 14.8% in 2021. (U.S. Bureau of Labor Statistics, 2020-2022). The seasonal unemployment rate for Dillingham Census area 6.3% to 10.1% in 2021. (U.S. Bureau of Labor Statistics, 2020-2022) The seasonal unemployment rate for Lake and Peninsula Borough ranged from 6.7% to 11.1% in 2021. (U.S. Bureau of Labor Statistics, 2020-2022).

[19] The unemployment rates within individual villages ranged from 0% to 50%. The different villages include three groups, the Lakes Region group, Intermediate Area group, and Distant Region group, based on Loeffler et al. (2017). The Lakes Region group unemployment rates ranged from 0% to 43.8% (U.S. Census Bureau, 2020). The Intermediate Region group unemployment rates ranged from 2.8% to 26.9% (U.S. Census Bureau, 2020). The Distant Region group unemployment rates ranged from 0% to 50% (U.S. Census Bureau, 2020).

[20] This assumes that currently unemployed potential workers have sufficient skills that match with job openings being created, or that job training is available.

social welfare. The IMPLAN model is also unable to incorporate macroeconomic conditions making it likely that the costs of the recommended determination, discussed in Section 6 are overestimated.

5. RESULTS OF THE BENEFITS ASSESSMENT

The recommended determination, if affirmed, would, with a high degree of certainty, result in a broad range of significant benefits. Avoiding the loss and degradation of streams, wetlands, and other aquatic resources would result in preservation of ecosystem services provided by such aquatic resources, including support of commercial fisheries (Section 5.1), benefits to subsistence fishers and hunters (Section 5.2), support of recreational use of the affected resources (Section 5.3), preservation of archeological and cultural values (Section 5.4), support for salmon-based ecosystems (Section 5.5), regulation of ecosystems (Section 5.6), prevention of health and safety hazards (Section 5.7), protection of quality of life (Section 5.8), non-use benefits (Section 5.9), benefits to disadvantaged communities (Section 5.10), and benefits of avoided spill and dam failure risks (Section 5.11).[21]

The benefits assessment considers all parts of the 2020 Mine Plan, including impacts beyond the SFK, NFK, and UTC watersheds resulting from the transportation corridor, pipelines, and port (see Section 3 for details). Additionally, the benefits assessment considers associated downstream effects to ecosystem services resulting from projected impacts under the 2020 Mine Plan, such as impacts to downstream fisheries. The benefits assessment is primarily qualitative; the quantitative values provided throughout this section are intended to demonstrate that the ecosystem services in the Bristol Bay region have significant economic value. The quantitative values are not intended, due to data limitations (e.g., unquantified impacts to Bristol Bay fisheries under the 2020 Mine Plan) and uncertainties (e.g., uncertainties surrounding existing fish distribution and abundance; see Section 4.1 for details), to quantify the specific preservation of economic value associated with the recommended determination. Among available quantitative values, the benefits assessment prioritizes quantitative values from the Bristol Bay region or from the State of Alaska when such values are available but also presents additional values from regions similar to Alaska, such as the Pacific Northwest, when Bristol Bay- or Alaska-specific values are unavailable. Since some benefit categories (e.g., cultural resources, quality of life) are particularly difficult to quantify, quantitative values are not available for all benefit categories. Dollar values presented in 2021 dollars were adjusted from the original dollar year to 2021 using the Bureau of Economic Analysis' (BEA) Implicit Price Deflators for Gross Domestic Product (GDP).[22]

The pristine aquatic resources of the Bristol Bay watershed are unique and highly productive ecosystems, supporting a wide variety of plant and wildlife species. Losses of streams, wetlands, and other aquatic resources and their associated ecological functions could result in substantial declines in the value of services provided by the Bristol Bay watershed. Streams, wetlands (including freshwater

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[21] Although health and safety (Section 5.7), quality of life (Section 5.8), and non-use values (Section 5.9) are not analyzed as part of the recommended determination (U.S. EPA, 2022), the FEIS (USACE, 2020a) considers these categories of impacts under the 2020 Mine Plan. Benefits in these categories resulting from the recommended determination, if affirmed, are potentially substantial and warrant consideration in the benefits assessment.

[22] Table 1.1.9. Implicit Price Deflators for Gross Domestic Product.

emergent wetlands, freshwater forested/scrub-shrub wetlands, freshwater lake, pond, and riverine),[23] and other waters would be directly affected by the discharges of dredged or fill material from the construction and operation of the 2020 Mine Plan. As indicated in the FEIS, other areas outside the Bristol Bay watershed, including the estuarine and marine waters of Cook Inlet, may be impacted by the transportation corridor, pipeline, and port components of the mine infrastructure (USACE, 2020a).

EPA Region 10's assessment of the potential benefits of the recommended determination utilizes data from the USACE FEIS (USACE, 2020a), which described the estimated impacts to streams, wetlands, and other waters that would be lost or degraded as a result of discharges of dredge or fill material for the construction and operation of the 2020 Mine Plan, including the mine site, transportation corridor, ports, and natural gas pipeline. Table 5-1 provides a summary of the estimated impacts from such discharges. Across all project components, the 2020 Mine Plan is projected to permanently impact 184.9 stream miles and 3,841 acres of wetlands and other waters.[24] The 2020 Mine Plan is also projected to temporarily impact 6.2 stream miles and 773 acres of wetlands and other waters. The primary benefits of the recommended determination, if affirmed, are the avoided impacts and resulting unacceptable adverse effects to streams, wetlands, and other waters that would otherwise occur under the 2020 Mine Plan. The recommended determination would also protect the ecosystem services provided by streams, wetlands, and other waters that would otherwise be disrupted under the 2020 Mine Plan, including support for commercial and subsistence fisheries (Sections 5.1 and 5.2), recreational use (Section 5.3), support for salmon-based ecosystems (Section 5.5), and regulation of ecosystems (Section 5.6).

[23] Table 3-2 in U.S. EPA (2022) presents acreage of wetland habitats in the Bristol Bay watersheds by wetland type, including freshwater emergent wetland, freshwater forested/scrub-shrub wetland, freshwater pond, lake, and riverine.

[24] Permanent estimates include both projected "permanent" and "indirect" impacts from the FEIS. "Indirect impacts" were defined in the FEIS as indirect but permanent/long-term consequences from project construction and operations.

Table 5-1. Projected Impacts to Streams, Wetlands, and Other Waters under the 2020 Mine Plan						
Project Component	Permanent		Temporary		Indirect	
	Acres	Miles	Acres	Miles	Acres	Miles
Wetlands						
Mine Site	2,051	-	<1	-	774	-
Transportation Corridor	38	-	26	-	422	-
Port Site	<1	-	-	-	<1	-
Pipeline Route	-	-	5	-	<1	-
Total	**2,090**	**-**	**31**	**-**	**1,196**	**-**
Streams and Other Waters						
Mine Site	111	99.7	<1	<0.1	82	29.9
Transportation Corridor	28	5.7	14	3.9	323	48.5
Port Site	3	<0.1	88	0.1	1	0.4
Pipeline Route	-	-	639	2.2	7	0.8
Total	**142**	**105.4**	**742**	**6.2**	**413**	**79.5**

Source: Pebble Project FEIS, Chapter 4, Section 4.22 (USACE, 2020a).

5.1. Commercial Fisheries

The importance of Bristol Bay commercial fisheries has been well documented (e.g., The National Wildlife Federation, n.d.; USACE, 2020a; McKinley Research Group, 2021; Tiernan et al., 2021). The five species of Pacific salmon found in Bristol Bay (Sockeye, Chinook, Chum, Pink, Coho) are the focus of major commercial fisheries. Salmon rely on clean, cold water flowing over and upwelling and downwelling through porous gravel for spawning, egg incubation, and rearing (Bjornn et al., 1991). Headwater streams and their associated headwater wetlands comprise 65 percent of assessed stream length in the watersheds with mine site impacts under the 2020 Mine Plan (SFK, NFK, and UTC watersheds) and are, thus, key habitat for numerous fish species in the region, including salmon. Of the Pacific salmon species, Coho salmon are most likely to use small streams for spawning and rearing and have been observed in many of the smaller streams near the Pebble deposit (U.S. EPA, 2022). In addition to providing habitat for fishes, headwater streams and wetlands impact stream networks beyond their area footprint by contributing water, nutrients, organic material, macroinvertebrates, algae, and bacteria downstream to higher-order streams in the watershed (Meyer et al., 2007). Headwater streams and wetlands are abundant in the Pebble deposit area and likely play a crucial role in supporting local and downstream fish populations by supplying energy and other resources needed to support salmon and other commercially harvested fish in connected downstream habitats (see Section 3.2.4 in U.S. EPA, 2022 for additional detail). Since the loss of aquatic resources that provide spawning and rearing habitat has been associated with reductions in salmon abundance, particularly Coho salmon abundance (U.S. EPA, 2022; Section 3.2.4), the estimated impacts on streams and wetlands from the 2020 Mine Plan have the potential to reduce salmon abundance beyond the watersheds directly affected by the proposed mine site (SFK, NFK, and UTC) and negatively affect Bristol Bay commercial fisheries vital to the Alaskan economy.

Annual commercial harvest in Bristol Bay for the most recent 20 years (2000–2019) averaged 27.0 million Sockeye, 40,200 Chinook, 1.1 million Chum, 510,000 Pink (even-years only), and 96,400 Coho salmon (Tiernan et al., 2021). Between 2011 and 2016, the Bristol Bay salmon fisheries provided between 4 and 11 percent of the world's wild-caught salmonid harvests, and between 1.1 and 2.3 percent of the world salmon supply (USACE, 2020a). The Bristol Bay salmon harvest, which is comprised of between 95 and 98 percent Sockeye salmon, provided an average of 53 percent of global Sockeye salmon production between 2015 and 2019 (McKinley Research Group, 2021). The 20-year average ex-vessel value of the Bristol Bay salmon fishery, or the dollar amount received by fishers for their catch when delivered to a processor, is approximately $175 million (2021$). Over the last 10 years, the average ex-vessel value has increased to roughly $230.8 million per year (2021$) because of a combination of historic peaks in volume and record market pricing for the fishery (USACE, 2020a; McKinley Research Group, 2021). Over the past four years with complete data (2018-2021), Bristol Bay has produced more than twice as much premium, wild-caught salmon[25] (381,982 metric tons) as all other North American commercial fisheries combined (181,172 metric tons; Bristol Bay Regional Seafood Development Association, 2022a). The first wholesale value of the Bristol Bay salmon fishery, or the value of the raw fish plus the value added by the first processor, averaged $570.9 million per year between 2015 and 2019 (McKinley Research Group, 2021). In 2019, the Bristol Bay commercial salmon fishery generated 15,000 jobs and an economic output of $2.0 billion ($2.1 billion in 2021$) throughout the United States, of which 5,370 jobs and $990 million ($1.0 billion in 2021$) was within Alaska (McKinley Research Group, 2021).

Any adverse impacts on salmon stocks and subsequent effects on commercial fisheries in Bristol Bay are likely to have a cascading effect on local economies. A study by B. Watson et al. (2021) found that increases in commercially exploited fish stocks led to additional hiring of fishing and processing crew and additional value from processed harvests. For example, a $1 million increase in resident catch or local landings was found to result in 3.4 and 1.36 additional local fishing and processing crew hires, respectively (B. Watson et al., 2021). The study also found evidence of employment spillovers from commercial fishing into non-fishing sectors; a 10 percent increase in annual fishery earnings led to a 0.3 percent increase in employment (or 7.12 jobs gained for every million dollars of fishery earnings; B. Watson et al., 2021). Lastly, a $1 increase in fisheries earnings was found to increase total income for all residents in a borough by $1.54, primarily through the earnings of local commercial-fishing permit owners (B. Watson et al., 2021).

Commercial fisheries in Alaska also generate significant tax revenue via two primary fisheries-related taxes. Although taxes represent transfer payments and do not represent a net increase in economic value on their own, they do produce income distribution impacts (Section 3.2). Transfer payments refer to money exchanging hands without the offering of goods and services in return. The production of additional goods and services in an economy represents economic growth and improvements in societal welfare. Changes to societal welfare are tracked in cost-benefit analyses and from a national perspective

[25] Combined totals of Sockeye, Coho, and Chinook salmon.

represents the most important metrics for determining the overall impact of an Agency's actions. Looking beyond the total societal welfare impacts, distributional impacts within an economy are also important. For example the fishery related tax revenue, in this case, is important to local communities since it is shared with the community or borough where seafood is landed or processed (McKinley Research Group, 2021), and these funds may be used to provide public goods, like policing and health services, to underserved community members. The first tax is a Fisheries Business Tax, and the second is a Fishery Resource Landings Tax. The Fisheries Business Tax is a 1 to 5 percent tax on the ex-vessel value of seafood landed in Alaska within state waters. The Fishery Landings Tax is a 1 to 3 percent tax levied on the ex-vessel value of seafood processed at sea, outside state waters, but moved through Alaska ports for transshipment (McKinley Research Group, 2021). Fisheries taxes collected by the state of Alaska generated more than $5.4 million in annual revenues, on average, from 2018 to 2020 (McKinley Research Group, 2021). Because fisheries taxes from seafood landed or processed in the Bristol Bay region are distributed to municipalities in that region, shared fishery tax receipts are an important source of revenue for Bristol Bay communities. In 2019, these receipts contributed one-third of Bristol Bay Borough's total revenues (McKinley Research Group, 2021). Additionally, raw fish taxes also generate significant revenue for the Bristol Bay region. The Raw Fish Tax Program shares back to municipalities half of the state fisheries business tax collected from fish processors operating inside municipal boundaries.[26] Over $6.1 million in annual revenues, on average, was generated in the Bristol Bay region from 2018 to 2020 (McKinley Research Group, 2021).

In addition to being the most important economic sector in the region, the Bristol Bay commercial fishery has substantial economic impacts on other U.S. states beyond Alaska. As of 2013, Washington residents owned approximately 1,000 boats participating in the Alaska commercial fishery (McDowell Group, 2015). Many commercial fishing vessels that bring Alaska salmon to market use Seattle ports and facilities for maintenance, repair, and loading/offloading. In the Puget Sound region of Washington in the year 2013, Alaska-related commercial fishing generated 10,150 jobs and $600 million ($701 million in 2021$) in total labor earnings, while Alaska-related seafood processing created an additional 13,100 jobs and $690 million ($806 million in 2021$) in total labor earnings (McDowell Group, 2015). Thus, potential impacts to the Bristol Bay commercial fisheries under the 2020 Mine Plan could have far-reaching economic impacts well beyond the state of Alaska.

Projected commercial fishery impacts of construction and operation of the 2020 Mine Plan are detailed in Section 4.6 of the FEIS (USACE, 2020a). The FEIS analysis considered two types of commercial fishery impacts: (1) decline in total fishery harvest due to destruction of fish habitat, including spawning and rearing habitat from the placement of fill or changes in habitat quality (i.e., habitat fragmentation, loss of stream miles, changes in wetland types, loss or degradation of ecosystem functions), and (2) change in habitat quality affecting market reception of Bristol Bay fish.

Destruction and degradation of salmon habitat that would result from the construction and operation of the 2020 Mine Plan would erode both habitat complexity and biocomplexity in fishery areas. Habitat

[26] This information is taken from Alaska's Department of Community and Regional Affairs.

complexity and biocomplexity are key to the abundance and stability of salmon populations within the Bristol Bay region.[27] As a result, the loss of even a small, discrete population within the Bristol Bay watershed's overall salmon populations may have significant effects on fish abundance and stability, due to associated decreases in biocomplexity (U.S. EPA, 2022; Section 3.3.3). Simulations have shown that loss of headwater salmon populations can reverberate throughout the river network, resulting in reduced fish population stability (i.e., greater vulnerability to adverse environmental conditions) and, as a result, increased variability in harvest at most downstream locations (Moore, 2015). In other watersheds with previously robust salmon fisheries, such as the Sacramento River's Chinook salmon fishery, losses of biocomplexity have contributed to overall salmon population declines (Lindley et al., 2009). Loss of accessible floodplains and headwater streams and wetlands also can be a significant driver of salmon declines, as illustrated in Canada's Lower Fraser River (Finn, 2021). Section 3.3.3 in U.S. EPA (2022) provides additional details about habitat complexity and biodiversity effects on commercial salmon fisheries in the Bristol Bay region. Section 5.5 discusses the population stabilizing effect of diverse fish populations (i.e., the "portfolio effect") within the Bristol Bay watershed and how potential impacts from construction and operation of the 2020 Mine Plan may weaken the salmon portfolio that stabilizes fishery yield, and therefore commercial fishing benefits over time (Section 3 and Appendix B in U.S. EPA, 2022). Additionally, Table 5-2 summarizes projected commercial fishery impacts under the 2020 Mine Plan.

[27] For example, the Bristol Bay watershed includes a complex of different Sockeye salmon populations—that is, a combination of hundreds of genetically distinct, wild populations, each adapted to specific, localized environmental conditions. Under any given set of environmental conditions, some discrete Sockeye salmon populations will perform well while others perform less well. Thus, maintaining this biocomplexity stabilizes fish population over time (U.S. EPA, 2022; Section 3.3.3).

Table 5-2. Summary of Commercial Fishery Impacts under the 2020 Mine Plan	
Project Component	**Projected Impacts**
Mine Site	The mine site would result in loss of fish habitat (i.e., spawning and rearing habitat) in the upper North and South Fork Koktuli rivers. The mine site area is not connected to the Togiak, Ugashik, Naknek, and Egegik watersheds and is not expected to affect fish populations or harvests from these watersheds. The mine site is not expected to affect Cook Inlet commercial fisheries.
Transportation Corridor	This corridor would intersect with Upper Talarik Creek, the Newhalen River, Chekok Creek, Canyon Creek, Knutson Creek, the Pile River, and the Iliamna River. These intersections would result in small losses of fish habitat, including spawning and rearing habitat.
Port Site	The Diamond Point port site is near a Chum salmon (*O. keta*) fishery, which does not experience harvest every year. Permit holders and ADF&G have expressed concern that the presence of the port would interfere with tidal seine operations during years when there is harvest and that operations could impact juvenile rearing areas.
Pipeline Route	On the western side of Cook Inlet and in the Bristol Bay watershed, the natural gas pipeline would not directly interact with the Bristol Bay salmon fishery after construction. Construction activities would be timed to minimize effects on anadromous salmon streams. The pipeline would cross waters fished by the Cook Inlet salmon fishery and Cook Inlet groundfish fisheries. The pipeline would not directly interact with the drift net salmon fishery, given that the salmon fishery occurs in the top 30 feet of the water column. Seine gear in the Chenik subdistrict could be impacted by the pipeline. The 2020 Mine Plan avoids disturbing the northern Kamishak Bay weathervane scallop bed. The transportation corridor of the 2020 Mine Plan would intersect with Brown's Peak Creek, which has a sustainable escapement goal for Pink salmon (*O. gorbuscha*). Comments from ADF&G indicate that this creek is periodically targeted by commercial fisheries.

*Notes: ADF&G = Alaska Department of Fish and Game; Source: Pebble Project FEIS, Chapter 4, Section 4.6 (*USACE, 2020a*).*

The FEIS analysis found that potential mine impacts under the 2020 Mine Plan are unlikely to affect the market price of Bristol Bay fish since prices for Bristol Bay salmon reflect both the market for wild-caught Alaska salmon products and the broader market for all salmon products, including farmed salmon (USACE, 2020a). However, there is a potential for real or perceived quality changes in Bristol Bay salmon associated with operation of the 2020 Mine Plan to negatively affect the price of commercial salmon sourced from this area. Research has shown that consumers are willing to pay a price premium for wild-caught Alaskan salmon primarily because they believe wild-caught fish are healthier and lower in chemicals than farm-raised fish (Alaska Seafood Marketing Institute, 2019). Consumers have paid approximately $4 more per pound of wild-caught Sockeye salmon compared to farmed Atlantic salmon (Bristol Bay Regional Seafood Development Association, 2022b), which amounts to a substantial total price premium for the Bristol Bay fishery. Based on a 20-year average annual Sockeye salmon catch of nearly 157 million pounds, the total price premium for Bristol Bay salmon, on average, is $626 million per year.[28] Given increasing catches in recent years in the Bristol Bay area (e.g., over 200 million pounds of Sockeye salmon caught in 2020; Tiernan et al., 2021), commercial fishery revenue from the price premium may continue to grow in future years (Alaska Seafood Marketing Institute, 2019). The price premium for wild-caught fish relative to farmed fish also exists for other Alaskan fish species, including

[28] To obtain the 20-year annual average Sockeye salmon catch by weight (pounds), EPA Region 10 multiplied the 20-year average number of Sockeye salmon caught (27.0 million) by the average round weight of Sockeye salmon during the 2000-2020 timeframe (5.8 pounds; Table A.22 in Tiernan et al. (2021)), which equals to 156.6 million pounds.

Artic char (Yang et al., 2020). The existence of a large copper mine in the Bristol Bay headwaters could reduce consumers' confidence in the safety of fish caught in areas potentially affected by 2020 Mine Plan operations and, thus, their willingness to pay a price premium for wild-caught fish from the Bristol Bay region, reducing the stability of the region's commercial fishery.[29] Additionally, the 2020 Mine Plan could also have negative impacts on consumers' demand for fish caught beyond the Bristol Bay region if consumers had imperfect information about the extent of mine impacts on fish safety or if consumers preferred to avoid all related products (e.g., other Alaskan seafood) and seek alternatives instead of spending time researching the extent of mine impacts on seafood safety. Research documenting spillover effects in seafood markets outside of the impacted areas (Dedah et al., 2011; S. Sha et al., 2015; Wessells et al., 1995) indicates that if the 2020 Mine Plan generated negative media coverage related to seafood safety, consumer demand for fish caught beyond the Bristol Bay region may also be affected.

5.2. Subsistence

Construction and operation of the 2020 Mine Plan would likely adversely affect access to subsistence harvest areas, as well as the availability, abundance, and quality of subsistence resources, due to impacts on fishing and hunting areas (Sections 4.2 and 6.1.1 in U.S. EPA, 2022). For example, tribal members and subsistence hunters have anecdotally reported to EPA that noise during the exploration phase of the Pebble deposit has already disturbed moose populations and altered caribou migration patterns (Section 6 in U.S. EPA, 2022). Some of the adverse impacts on harvest areas could endure long beyond mine closure (Section 4.9 in USACE, 2020a; Section 6.3 in U.S. EPA, 2022), such as: (1) water treatment and maintenance of mine waste facilities would continue in perpetuity, which may cause Alaska Natives to avoid these areas, (2) closure period mine site features like the pit lake, unless fenced and continually managed, would be unattractive habitat to subsistence species, and (3) subsistence users may have permanently moved, discontinued practices, or passed without transferring knowledge and skills to the next generation.

Alaska Natives comprise the majority population in the Bristol Bay region,[30] and although subsistence use varies throughout the region in terms of the assortment of subsistence resources used and the per capita amount of subsistence harvest, subsistence harvests have provided the traditional diet for Alaska Native communities in the Bristol Bay region since time immemorial.

Salmon are harvested throughout the Nushagak and Kvichak River watersheds and provide the largest portion of subsistence harvests in Bristol Bay communities, accounting for between 29 percent to 82 percent of subsistence harvests. In 2017, subsistence fishers harvested 503,890 pounds of usable salmon in Bristol Bay (David Binder Research, 2020). In addition to salmon, Alaska Natives in the Bristol Bay region rely on non-salmon fishes (e.g., Northern Pike, Dolly Varden, Arctic Char, and Arctic Grayling)

[29] Since the retail price premium for Sockeye salmon is approximately equal to the ex-vessel price paid to commercial fishers, loss of the price premium for wild-caught Sockeye salmon would harm local fishers and reduce the stability of Bristol Bay's commercial fishery (Bristol Bay Regional Seafood Development Association, 2022a).

[30] Non-Alaska Natives also practice subsistence, with salmon constituting a large portion of their diet.

that could be adversely affected by the construction and operation of the 2020 Mine Plan. These non-salmon fishes fill an important seasonal component of the subsistence cycle, especially in spring and fall when salmon and other resources are less available. Non-fish resources also comprise a significant portion of subsistence use (Table 5-3). On average, non-fish resources, such as moose, caribou, waterfowl, plants, and other organisms, represent 34 percent of subsistence harvests by local communities in the Nushagak and Kvichak River watersheds, totaling over half a million pounds annually (Table 5-3).[31]

Subsistence harvests reduce transaction costs by supporting social cohesion and trust. Harvests can also act as insurance against income and food price volatility, further strengthened by the culture of sharing it cultivates. While harvests may reduce local spending on food, subsistence households will purchase equipment and materials related to subsistence fishing, hunting, and gathering, and will likely spend more on other goods and services, providing valuable economic contributions while maintaining their traditional way of life.

The replacement value of Bristol Bay subsistence salmon would be over $2.5 million for its protein content alone and over $10 million for its approximate nutritional content (McKinley Research Group, 2021).[32] Another study by Duffield et al. (2013) notes that using the market replacement cost to value subsistence fishery resources is likely to produce a lower value of these resources compared to the values implied by the wage compensating differential model of subsistence harvest.[33] Based on this model, the per pound value of subsistence harvest ranges from $75.0 to $107.2 (2021$), and the total value of the subsistence fishery in Bristol Bay ranges from $192.3 million to $274.8 million (2021$).

Despite the likely tens of millions of dollars in intrinsic value of harvests as highly nutritious food sources, the true value of the subsistence harvest is unquantifiable. The monetization of subsistence resources shows a measure of its importance to the economy but does not – and cannot – reflect that many Alaska Natives of the Bristol Bay region unanimously reject replacing their traditional subsistence food with imported replacements. Many Alaska Native subsistence users would incur high costs to replace these food resources with foods of similar quality and quantity (tribal members have noted, "It is very hard out here in the bush. We have to pay double for every food we get...") and view replacement resources as providing inadequate nutrition, stating that "salmon is a really important part of our diet. I think it has things that meat [domestic beef, for example] does not have" (Boraas et al., 2013). Modern science has documented the traditional understanding, recognizing that subsistence has been practiced for so long that the Yup'iks people of the Bristol Bay region have become biologically adapted to the salmon (Boraas et al., 2013).

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[31] 34 percent is the harvest-weighted average non-fish percentage of per capita subsistence harvest in pounds for communities in the Nushagak and Kvichak River watersheds.

[32] David Binder Research (2020) estimate households in Bristol Bay would have to pay at least $5/lb to replace subsistence salmon's protein content or $20/lb to approximate subsistence salmon's nutritional quality, based on calls to Bristol Bay groceries and suppliers.

[33] Duffield (1997) estimated the value per pound of Alaskan subsistence harvest through the use of a cross-sectional hedonic model of community-specific harvest per capita and community per capita income levels.

Subsistence activities and food resources are also profoundly important to the customs, traditions, values, beliefs, and identity of many people of the Bristol Bay region at the individual, family, and community levels. As one of the last intact salmon-based cultures in the world (U.S. EPA, 2022), the Indigenous peoples of the Bristol Bay region are unique, whole, and deeply rooted to their environment. Subsistence in the Bristol Bay region is inextricably linked to cultural practices, social and family structures, language, mental and physical health, traditional ecological knowledge, and other aspects of culture and lifestyle (see Section 6 in U.S. EPA, 2022). It provides the mechanism by which many Alaska Native peoples have created purpose, trust, communion, and tradition within their communities.

Subsistence has remained at the core of all practices in the Bristol Bay villages throughout time. It is an ingrained connection to the environment, and one that reaches through time to those ancestors that have taught each successive generation how to subsist. Gratitude and giving are the systemic values by which a person develops their merit. It establishes an understanding of how to be a cared for and caring member of the community. It is a firmly held opinion that "you are a very rich person if you share. If you don't share, you are nobody" (Boraas et al., 2013). The sharing of salmon is practiced as an act of communion – because of this custom, the reverence for salmon predominates. After so many generations and so much change, it is understood that the devotion to the salmon and what it represents will continue to be honored by future generations.

The recommended determination, if affirmed, would prevent loss and degradation to salmon habitat and associated death and displacement of salmon under the 2020 Mine Plan. Section 4.9 of the FEIS (USACE, 2020a) also acknowledges that, under the 2020 Mine Plan, moose, caribou, brown and black bears, gray wolves, small land mammals, grouse, and ptarmigan would be displaced from the mine site. In turn, the recommended determination would, if affirmed, prevent an increase in the time and expense required to harvest subsistence resources; reduce concerns about fugitive dust and other pollution from the 2020 Mine Plan contaminating waterfowl, fish, berries, and other vegetation; and result in fewer wildlife fatalities and reduced transportation time and costs for subsistence activities in the absence of mine-related traffic (USACE, 2020a; Section 4.9). The recommended determination would also, if affirmed, prevent mine-related road and pipeline construction from impeding access to subsistence resources, although there could be some benefits due to improved access. In some communities, subsistence households may have less income available to invest in subsistence activities without mine-related job opportunities during the 2020 Mine Plan's construction and operation periods.

Additionally, the recommended determination, if affirmed, would provide subsistence users a sense of certainty that their subsistence lifestyle is protected from a certain level of impacts associated with mining the Pebble Deposit. The adverse impacts on the mental and physical health of subsistence users in the Bristol Bay watershed, not only from the potential impacts from construction and operation of the 2020 Mine Plan but from living with the uncertainty about the stability of their life practices, are, in their own words, incalculable. Members and leaders of various Bristol Bay Tribes have stated: "We can't even fathom somebody hurting the salmon"; "We can't live without salmon"; "Salmon is very important to us. I don't think we could live without fish" (Boraas et al., 2013).

A summary of subsistence impacts is provided in Table 5-3.

Table 5-3. Summary of Subsistence Impacts under the 2020 Mine Plan

Issue	Projected Impacts
Availability of subsistence resources	Reduced availability of subsistence resources through habitat loss, disturbance and displacement of resources, fugitive dust deposits on resources, and increased costs and time for traveling to harvest areas.
Access to subsistence resources	Road and pipeline construction would interrupt or impede overland travel by subsistence users. PLP would put measures in place to minimize impacts, such as trail marking and crossings.
Competition for resources	There would be some availability to access other areas for harvest of resources, especially with the overland pipeline ROW and road paralleling it, which could increase competition in some areas by providing additional access for local residents.
Sociocultural dimensions of subsistence	Beneficial effects from new income to invest in subsistence activities. Adverse effects from out-migration, particularly if high-harvesting households leave.

Notes: PLP = Pebble Limited Partnership, ROW = right-of-way; Source: Pebble Project FEIS, Chapter 4, Section 4.9 (USACE, 2020a).

5.3. Recreational Use

The recommended determination, if affirmed, would prevent the physical destruction and loss of traditional character and use of various recreational resources in the region, including trails, traplines, campgrounds, areas for fishing, trapping, caribou and moose hunting, and wildlife viewing that would result from the construction and operation of the 2020 Mine Plan.

5.3.1. Recreational Fishing

The Bristol Bay region is renowned for its productive Chinook and Sockeye salmon fisheries as well as its ability to provide a fishing experience in a remote and pristine environment (USACE, 2020a). In addition to the five Pacific salmon species, the Bristol Bay region is home to numerous resident fish species such as Rainbow Trout, Dolly Varden, Arctic Char, Arctic Grayling, Humpback Whitefish, Northern Pike, and Lake Trout, which are typically targeted by recreational and subsistent anglers, as well as numerous other species that are not typically harvested. These fish species are found throughout the watershed, including headwater streams, rivers, off-channel habitats, wetlands, and lakes. For example, Chinook and Sockeye salmon can be found in the Aushagak, Iguigig, Iliamna, Koliganek, Kvichak, Levelok, Mulchatna, and Wood Rivers of the Nushagak and Kvichak watersheds (See Section 3 in U.S. EPA (2022) for species distribution maps).

In addition to the numerous fishes available for recreational fishing, the uncrowded, pristine wilderness setting of the Bristol Bay watershed attracts recreational anglers, with Bristol Bay anglers rating aesthetic qualities as most important in selecting fishing locations (U.S. EPA, 2022; Section 3.3.7). More than 20,000 sportfishermen per year are estimated to have fished in Bristol Bay in the past five years (McKinley Research Group, 2021). Sports fishing in the Bristol Bay watershed accounts for approximately $69.3 million (2021$) in expenditures and employs over 800 full- and part-time workers (U.S. EPA, 2022; Section 3.3.7). Recreational fishing in the Bristol Bay region also generates over 600 “multiplier jobs” in transportation, accommodation, and trade sectors of the economy (Duffield et al., 2013). The total estimated payroll attributable to sport fishing activities in the Bristol Bay region, including direct and multiplier jobs, is approximately $39.3 million (2021$; Duffield et al., 2013). The majority of sports fishes harvested are Sockeye, Chinook, and Coho salmon. The Nushagak River watershed alone accounted for more than 50 percent of the annual average sport harvest of Chinook salmon (an estimated harvest of 6,467 fish) between 2004 and 2017 (U.S. EPA, 2022; Section 3.3.7).

In addition to the importance of recreational fishing in the Bristol Bay area within the regional economy, there is a substantial net economic value attached to the trips these anglers take to the region (i.e., the amount anglers are willing to pay over and above the costs of their recreational fishing trips). Although there is a large amount of economic literature on estimating the value of recreational fishing,[34] the number of studies focused on the Bristol Bay area of Alaska is limited. Below we summarize most relevant studies of willingness-to-pay (WTP)[35] for salmon fishing in Alaska. For example, a stated preference study by Lew et al. (2012) estimated the value of saltwater fishing trips off the coast of Alaska and the added value for increases in catch and creel limits for Coho and Chinook salmon for Alaskan and non-Alaskan resident recreational saltwater anglers. These values are summarized in Table 5-4. Overall, Lew et al. (2012) finds non-Alaskan residents to have significantly larger (by an order of magnitude) WTP for single-day saltwater fishing trips to catch Chinook and Coho salmon compared to Alaskan residents. Alaskan resident WTP for Chinook and Coho salmon fishing trips range from $333 to $341 (2021$) and from $314 to $378 (2021$) for a single day trip, depending on fishing locations. [36] Non-Alaskan resident WTP for Chinook and Coho salmon fishing trips range between $3,257-$3,313 (2021$) and $2,564-$2,696 (2021$), respectively. Lastly, the study also found that Alaskan and non-Alaskan residents value increases in Chinook and Coho salmon fish catch and creel limits. As shown in Table 5-4, non-Alaskan residents held the greatest value for one fish increases in fish catch and creel limits at $70.29 (2021$) and $84.64 (2021$) for Chinook salmon and $45.12 (2021$) and $87.88 (2021$) for Coho salmon, respectively.

Based on a stated preference study by Duffield et al. (2013), the aggregate net WTP for recreational fishing in the Bristol Bay region is approximately $15.2 million (2021$).[37] Duffield et al. (2013) used data from the 2005 Bristol Bay angler survey to elicit WTP values per salmon fishing trip for resident and non-resident anglers. The estimated net WTP values ranged from $440 to $626 (2021$) for residents and non-residents, respectively. The total nonmarket value of recreational fishing in the Bristol Bay region was estimated by multiplying the estimated WTP per fishing trip ($440 and $626

[34] The literature uses a range of nonmarket valuation methods, including travel cost and stated preference. The travel cost method takes the costs people pay to visit recreational areas as an expression of its recreational value. Stated preference methods (such as choice experiments or contingent valuation surveys) are used for estimating the value of changes in nonmarket goods or services. These methods use survey data to determine people's willingness to pay to obtain this change (Hanley et al., 2019).

[35] WTP is the most common measure (or theoretical construct) used to quantify economic values for both market and nonmarket goods that benefit individuals or households.

[36] These ranges depend on whether the fishing was done in Southeast or South-Central Alaska (Lew et al., 2012).

[37] Bristol Bay anglers were asked a series of questions relating to what they spent on their fishing trip, and how much, if any, more they would have been willing to spend to have the same experience (Duffield et al., 2013).

(2021$) for residents and non-residents, respectively) by the estimated average annual number of trips for residents (16,903) and non-residents (12,464) in 2005. Based on the Duffield et al. (2013) analysis, the recreational fishery represents between 3.4 percent and 5.1 percent of the total value of ecosystem services provided by the Bristol Bay region. Recreational fishing trends in Southcentral Alaska suggest that recreational fishing in Bristol Bay (and thus, the total nonmarket value of the Bristol Bay recreational fishery) has remained stable since 2005. According to the Alaska Department of Fish and Game, the number of recreational anglers in Southcentral Alaska decreased by only 1.4 percent between 2005 and 2021 (342,580 anglers in 2005 to 337,709 in 2021; Alaska Department of Fish and Game, 2022).

Table 5-4. The Value of Coho and Chinook Salmon for Recreational Fishing in Alaska (2021$)

Study	Type of Angler	Species Caught	Mean WTP for single-day saltwater fishing trips	WTP for one-fish catch increases	WTP for one-fish creel limit increases
Lew et al. (2012)	Southeastern Alaskan Residents	Chinook salmon	$341	$0.31[a]	-
		Coho salmon	$314	$1.05[a]	-
	South-central Alaskan Residents	Chinook salmon	$333	$6.67	-
		Coho salmon	$378	$0.17[a]	$6.40
	Non-Alaskan Residents	Chinook salmon	$3,257 - $3,313[b]	$70.29	$84.64
		Coho salmon	$2,564 - $2,696[b]	$45.12	$87.88

Notes: [a] These values are based on statistically insignificant results.
[b] This range depends on whether the fishing is done in Southeast or South-central Alaska.

Given the iconic status of salmon species, salmon sportfishing has been a focus of recreational surveys and resource valuation studies since the 1980s. Earlier studies primarily relied on travel cost or a combination of travel cost and contingent behavior approaches. These approaches are focused on estimating use value of salmon fishing which is likely to underestimate the total value of this species (see Section 5.9 for a discussion of non-use values). Moreover, nonmarket valuation best practices have advanced significantly in recent decades, improving the accuracy of revealed preference methods (Bateman et al., 2020). Therefore, although results from earlier studies demonstrate significant nonmarket value for the resource, they should be interpreted with caution. EPA summarizes results from earlier studies to underscore the importance of the fishery resources in Alaska. For example, a study by Layman et al. (1996), which used a blended travel cost model/contingent behavior model, found a doubling of the Chinook salmon harvest rate and a doubling of the creel limit to be valued at $65.07 (2021$) and $61.71 (2021$) for Alaskan resident anglers fishing in the Gulkana River.[38] Additionally, a travel cost study of sportfishing in the Southcentral region of Alaska (R. T. Carson et al., 2009) estimated the average value Alaskan resident anglers held to ensure the option of fishing for salmon at various fishing sites using data on the sports fishing activities of 1,063 respondents collected

[38] These estimates are based on mean reported travel costs and 30 percent of the wage applied to the value of recreational time.

in 1986. The estimated values ranged from $0.64 (2021$) in the Russian River (for Red salmon) to $12.11 (2021$) in the Kenai River (for early run Chinook salmon species).

As described in the FEIS (USACE, 2020a), the 2020 Mine Plan infrastructure would cross a number of waterbodies with active recreational fishing, including the Pile and Iliamna Rivers. Development of the transportation corridor and onshore portions of the natural gas pipeline would remove 5.7 miles of streambed habitat. Additionally, mine site construction would remove approximately 99 miles of streambed habitat in the NFK and SFK watersheds. Permanent loss of these streams would directly result in the mortality, injury, and/or displacement of fish, including Coho, Chinook, and Sockeye salmon. Most of these losses would occur in the NFK watershed, where 72.4 miles of additional streams would be permanently lost (in addition to 8.5 miles of anadromous fish stream losses). Permanent additional stream losses in the SFK and UTC watersheds would be 18.8 miles and 0.02 miles, respectively (U.S. EPA, 2022; Section 4.2.1.3). Mortality or displacement of salmon species resulting from permanent loss of stream habitat in the NFK and SFK watersheds could also have indirect effects on other fish species in the NFK and SFK watersheds as well as in downstream watersheds. For example, sculpins, Dolly Varden, and Rainbow Trout are well-known predators of salmon eggs and emergent fry, and Northern Pike can be effective predators of juvenile salmon and other fish species. Given the complex and extensive migratory behavior of the species dependent on salmon eggs and emergent fry that are frequently sought after by recreational and subsistence anglers (e.g., Dolly Varden and Rainbow Trout), losses of salmon habitat and impacts on salmon spawning and rearing locations are likely to have broader impacts on recreationally important species throughout the Bristol Bay watershed (U.S. EPA, 2022; Section 3.3.1).

The aesthetics related to the recreational fishing experience would also be adversely affected by the discharge of dredge and fill material, as well as the increase in noise and light levels from ongoing activity at the mining site. Although recreational fishing in these areas may not be restricted, anglers may find them less desirable (e.g., due to the detrimental impact on fish populations and therefore, fish catch, and the adverse effect on aesthetic appearance). These factors may have a negative impact on recreational fishing for watershed resident and non-watershed resident anglers, including other Alaskans and out-of-state anglers. The recommended determination, if affirmed, would help protect access to recreational fishing sites in the Bristol Bay area, thus benefitting recreational anglers and helping to sustain the economically important recreational fishery. Projected recreational fishery impacts of the 2020 Mine Plan construction and operation are detailed in Section 4.6 of the FEIS (USACE, 2020a).

Table 5-5 summarizes projected recreation fishery impacts under the 2020 Mine Plan. The mine site is expected to affect the upper portions of the North and South Fork Koktuli rivers, displacing some number of fishing days that occur within the project area. Similarly, the transportation corridor and pipeline route are expected to displace fishing that occurs in portions intersecting the Newhalen and Iliamna Rivers, as well as other waterbodies. The presence of a continuous road would likely increase fishing pressure on freshwater waterbodies because of the additional access provided by the road. Additionally, the pipeline route may displace some fishing days for groundfish anglers who fish at the

Cook Inlet. These impacts would be long-term, lasting throughout the length of the project, and potentially, beyond. For example, the impacts from the transportation corridor would be long-term, lasting until the roads are decommissioned and reclaimed, which may not happen at the completion of the production phase of the project. The 2020 Mine Plan includes reclamation of the road system, but the roads would be retained as long as required for the transport of bulk supplies needed for long-term post-closure water treatment and monitoring. No impacts to recreational fishing areas are expected from the port site since no recreational fishing occurs in the area. Overall, given the aesthetic impairments and potential decrease in recreational fish abundance resulting from the construction and operation of the 2020 Mine Plan, recreational fishing may be displaced, potentially leading to an increase in recreation travel costs, a reduction in the number of fishing days (to the extent that recreational anglers choose not to relocate to other substitute sites for fishing), and a reduction in the value that anglers may hold for a recreational day at a site intersecting the proposed project area. Additionally, the erosion of both habitat complexity and biocomplexity in fishery areas, as discussed in Section 5.1, could reduce recreational fish catch and further reduce the value of recreational fishing trips.

Table 5-5. Summary of Recreational Fishery Impacts under the 2020 Mine Plan

Project Component	Projected Impacts
Mine Site	The Koktuli River does not appear in some ADF&G SWHS publications because not enough survey respondents report fishing on the river. The river also does not appear in ADF&G Guide Logbook data for 2011 through 2014. The unpublished ADF&G SWHS estimates for the entire Koktuli River for 2007 through 2016 average 285 angler days per year. Some of these days would be displaced if they occurred in the project area.
Transportation Corridor	The Newhalen River drainage and the Iliamna River are the most frequently fished waterbodies along this route. The Newhalen River drainage and the Iliamna River support 1,900 and 1,000 angler days per year, respectively. Transportation activity may disrupt fishing effort where the corridor intersects with these creeks and other waterbodies, but this effort would be redistributed along the waterbodies. Overall effects are expected to be low in magnitude, but higher-magnitude localized effects where transportation corridors cross the river are possible.
Port Site	There are no recreational fishing resources of note near the Diamond Point port site. The closest waterbody with measurable fishing effort is the Iliamna River.
Pipeline Route: Effects to freshwater recreational fisheries	The pipeline would follow the transportation corridor and would not be expected to affect recreational fishing resources (including salmon species) beyond those affected by the transportation corridor. Cook Inlet and Anchor River fishing opportunities would be unaffected.
Pipeline Route: Effects to Cook Inlet saltwater recreational fisheries	The pipeline would cross waters used by Cook Inlet salmon and groundfish anglers. Salmon in saltwater are traditionally caught by trolling in the upper parts of the water column. Because the pipeline would lie on the seabed, salmon anglers are unlikely to be affected by it. Groundfish anglers traditionally target Pacific halibut by placing baited and weighted hooks on or just above the seabed. They may need to avoid the pipeline route or may be affected by the disruption of traditional halibut "holes" and the potential for changes in local halibut abundance.

Notes: ADF&G = Alaska Department of Fish and Game; Statewide Harvest Survey = SWHS; Source: Pebble Project FEIS, Chapter 4, Section 4.6 (USACE, 2020a).

5.3.2. Other Recreational Uses

Wildlife viewing together with sport fishing discussed in the preceding section generates the second largest portion of jobs and income from tourist spending dependent on Bristol Bay salmon resources (Duffield et al., 2013). Of particular significance is the recreational and commercial value from brown bear viewing. Southcentral Alaska supports the world's largest concentration of brown bears (Young, 2019), attracting a large number of tourists. For example, a report by the McKinley Research Group (2021) estimated that between 40,000 to 50,000 people visited the Bristol Bay region in 2019, most commonly for bear viewing and sportfishing. Bear viewing in the Bristol Bay region is concentrated in two areas, the Katmai National Park and Lake Clark National Park and Preserve; in 2019, an estimated 20,000 people participated in bear viewing during trips to these two locations, with total spending on these trips estimated at $20 million ($21.1 million in 2021$) (McKinley Research Group, 2021). The same report found that Bristol Bay visitors spend nearly $1,000 per trip for a day of bear viewing.

People's recreational value from brown bear viewing depends on the quality of the experience (i.e., whether bear cubs are spotted or whether bears can be seen fishing for salmon) (Young, 2019). A survey of permit lottery applicants of the McNeil River State Game Sanctuary, which supports the largest concentration of brown bears on Earth located in Kenai Borough, found that they would pay $110.96 (2021$) to see bear cubs and $146.40 (2021$) to guarantee viewing bears fishing for salmon over foraging for vegetation (Young, 2019). Another study found that tourists are willing to pay more to view brown bears than any other Alaskan wildlife (as cited in Penteriani et al., 2017).

Substantial economic activity is associated with brown bear viewing. This includes economic activity from lodge and hotel stays, transportation including air taxi trips, guided wildlife viewing, food service and other activities. More than 90 lodges, primarily catering to bear viewing and sportfishing, operate in the Bristol Bay region (McKinley Research Group, 2021).

Sport hunting for caribou, moose, brown bear, and other species also play a significant role in the local economy of Bristol Bay. In recent years, approximately 1,323 non-residents and 1,319 non-local residents of Alaska traveled to the region to hunt, spending approximately $6,395 (2021$) and $1,631 (2021$), respectively (Section 6 in U.S. EPA, 2022). These hunting activities generated an estimated $10 million per year (2021$) in direct hunting-related expenditures (Section 6 in U.S. EPA, 2022).

Because numerous wildlife species depend on salmon (McKinley Research Group, 2021), there may be additional recreational impacts from the construction and operation of the 2020 Mine Plan beyond recreational fishing. The size of these impacts may be substantial, as approximately 41 thousand non-consumptive recreational visitors to the Bristol Bay region were found to spend $104.4 million in 2009 ($130.1 in 2021$; Duffield et al., 2013). A summary of the potential impacts are detailed in Section 4.5 of the FEIS (USACE, 2020a). Table 5-6 summarizes additional recreational impacts under the 2020 Mine Plan, as discussed in Sections 4.11, 4.12, and 4.19 of the FEIS (USACE, 2020a). Most notably, all components of the 2020 Mine Plan would result in a combined permanent loss of 10,132 acres of space (including uplands as well as streams, wetlands, and other waters) used for recreation.[39] Combined with this loss of recreational space is the potential reduction in quality of recreational experiences due to noise and aesthetic impairments, as well as the displacement of wildlife.

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[39] An additional 2 acres would be lost from the Concentration Pipeline Variant (see Table 4.23-2 of the FEIS; USACE, 2020a).

The discharge of dredged or fill material can adversely affect the particular features, traits, or characteristics of recreational areas. Increased noise and light levels due to construction and operations at the project site can negatively impact the visual landscape (night sky impacts could reach up to 20 miles from the mine site) and auditory soundscape (USACE, 2020a; Attachment B8). This would affect hunting, wildlife viewing, boating, camping, backpacking, beach combing, clamming, and picnicking activities.

Additional impacts include (1) the displacement of recreationists participating in hunting, wildlife viewing, boating, camping, backpacking, beach combing, and picnicking; (2) adverse effects to recreation experiences for visitors flying over the FEIS analysis area because construction would be visible by plane; (3) increased access to recreational areas from the construction of the transportation corridor; and (4) alterations to recreational settings (e.g., the adverse impact on views, and noise pollution) (USACE, 2020a). Overall, the 2020 Mine Plan would have an adverse effect on recreation at a local level.

Table 5-6. Summary of Additional Recreational Impacts under the 2020 Mine Plan

Category	Projected Impacts
Permanent loss of area available for recreation	Would lead to a loss of 10,130 acres for recreation due to impacts from the mine site, transportation corridor, port, and natural gas pipeline.
Recreation experience	Project-related noise and activities lasting from construction through operations and closure may adversely affect recreation experiences for recreationists by changing the recreation setting and displacing wildlife and fish throughout the FEIS analysis area. Would particularly affect visitors to lodges in the Pedro Bay area. Recreation experiences for visitors to the Lake Clark Park unit would be more impacted due to the increased sight of human-made development from construction of the pipeline. Impacts would last for the duration of the project.
Recreational setting	Recreationists flying over project components would be adversely impacted, as the project would be visible from planes. Views may be impacted in some areas of the Alaska Maritime National Refuge. There would be no impacts to recreation on Iliamna Lake. There would be changes to the recreational setting for visitors to Roadhouse Mountain. Impacts would last for the duration of the project.
Recreation activities	Poses adverse effects on wildlife viewing, and hunting opportunities and experiences from displacement of wildlife. Impacts would last for the duration of the project.
Recreational use	Potential for increase in recreational use due to increase in full-time resident population.

*Source: Pebble Project FEIS, Chapter 4, Section 4.5 (*USACE, 2020a*).*

5.4. Cultural Resources

The recommended determination, if affirmed, would benefit cultural resources that are inherently difficult to quantify by avoiding the impacts of construction and operation of the 2020 Mine Plan (USACE, 2020a; Section 4.7). Specifically, it would reduce disruption of archeological sites such as historical shipwrecks, village remains, and hunting camps. It would also help prevent the physical destruction and loss of traditional character and use of various cultural resources in the region, including traditional trails, traplines, campgrounds, and harvest areas for fishing, trapping, and caribou and moose hunting near Sharp Mountain, Koktuli River headwaters, Frying Pan Lake, and Groundhog Mountain.

In addition, the recommended determination, if affirmed, would prevent impacts to fish habitats and the disruption and displacement of subsistence salmon harvests, which are central to Yup'ik and Dena'ina cultural practice and identity and to traditional ecological knowledge sharing (Section 6.3.2 in U.S. EPA, 2022) that cannot be assigned a monetary value. The Yup'ik and Dena'ina peoples respect animals as kin, other esteemed members within the sacred web of life stating that "All the animals have souls. They are sensitive, very sensitive." (Boraas et al., 2013). This understanding emphasizes the careful and non-wasteful use of the animals, meant to ensure the animals' continued willingness to give themselves to the hunters and fishermen in the future. In this cycle of reciprocity, it is well understood that each animal's life is a gift, and to be taken with profound appreciation. The Dena'ina peoples' story of "Three People in Search of the Truth" explains that a successful hunter used the phrase *Chadaka, k'usht'a nhu'izdeyeshdle*, which translates as "Great Old Man, I am not equal to you," to make clear his humility toward the bear he was hunting (Boraas et al., 2013).

The Yup'ik have ceremonial masks that are *agayuliyararput*, "our way of making prayer", that symbolize both the high regard of the Yup'ik for the animals and the importance of their roles in Yup'ik culture (Boraas et al., 2013). The Yup'ik and Dena'ina peoples' festivals, ceremonies, art, songs, and dances revolve around respect and cooperation – between their hunters and fishermen and their harvests or within and between villages (Boraas et al., 2013).

As other spiritual beliefs have been introduced, traditional practices have been interwoven with those of Russian Orthodox and other Christian churches to create a new spiritual system. Two key tenets have remained, the reverence for nature and animals and the importance of sharing food with family, friends, and other communities in need. The "Blessing of the Waters" and the "First Salmon Ceremony" are spiritual practices that show the blending of these belief systems (Boraas et al., 2013). The "Blessing of the Waters" annually reaffirms the villages' understanding that the natural world is sacred and needs to be treated with care and reverence (Boraas et al., 2013). The condition of the ecosystems that support the salmon, both riverine and lacustrine, are nearly pristine, due to the long-term sustainable stewardship practiced by the Alaska Native communities that thrive on these resources.

Table 5-7 below lists the non-subsistence cultural impacts of the 2020 Mine Plan, based on Alaska Heritage Resources Survey locations, interview-identified cultural resources, and the place name database (USACE, 2020a; Section 4.7).

Table 5-7. Summary of Key Issues for Cultural Resources under the 2020 Mine Plan

Resource	Projected Impacts
Mine Site	
Known AHRS locations (identified to date)	2 known sites in the footprint would be destroyed due to facilities construction. 12 known sites would be subject to indirect impacts.
Place names	1 known place name would be subject to direct and indirect impacts. 4 known place names would be subject to visual, night sky, auditory, olfactory, and atmospheric changes that may alter the character, setting, and use of these resources.
Interview-identified cultural resources	19 interview–identified cultural resources in the mine site analysis area would be subject to indirect impacts. 6 sites would be subject to direct and indirect impacts. Direct impacts could occur from disruption to resource gathering cycles, access, routes, and trails. Indirect impacts from new visual,

	night sky, auditory, olfactory, and atmospheric changes may affect character, setting, and use of resources like Frying Pan Lake and Groundhog Mountain. Mining activities would create concern for culturally important elements of the environment such as salmon, and the waters and aquatic habitat that support them.
Transportation Corridor	
Known AHRS locations (identified to date)	3 known sites would be subject to direct and indirect impacts. 32 known sites would be subject to indirect impacts.
Place names	15 place names would be subject to direct and indirect impacts. 43 place names would be subject to indirect impacts.
Interview-identified cultural resources	90 features would be subject to indirect impacts, including 37 features that would be subject to direct impacts.
Known Historic Properties	1 known historic property would be subject to direct and indirect impacts.
Diamond Point Port	
Known AHRS locations (identified to date)	3 known sites would be subject to indirect impacts.
Place names	10 place names in the footprint would be subject to direct and indirect impacts. 1 place name would be subject to indirect impacts.
Interview-identified cultural resources	5 sites would be subject to indirect impacts.
Natural Gas Pipeline	
Known AHRS locations (identified to date)	Same as transportation corridor, plus: 3 known sites would be subject to indirect impacts.
Place names	17 place names would be subject to direct and indirect impacts.
	45 place names would be subject to indirect impacts.
Interview-identified cultural resources	91 features would be subject to indirect impacts, including 38 features that would be subject to direct impacts.
Known Historic Properties	Same as the transportation corridor.

*Note: AHRS = Alaska Heritage Resources Survey; Source: Pebble Project FEIS, Chapter 4, Section 4.7 (*USACE, 2020a*).*

5.5. Salmon-based Ecosystem

The Bristol Bay watershed's pristine streams, rivers, wetlands, and other waters provide spawning and rearing habitat for five Pacific salmon species, including Sockeye salmon, Chinook salmon, and Coho salmon. These waters also support other fish species important to subsistence, recreational and commercial fisheries (e.g., Rainbow Trout, Northern Pike, Dolly Varden, Arctic Char, and Arctic Grayling). In addition to fish, the Bristol Bay watershed provides habitat for a diversity of wildlife, including brown bears, wolves, moose, caribou, waterfowl, and migratory birds (USACE, 2020a; Section 4.23). Returning salmon are the keystone for a rich ecosystem that transfers marine nutrients into upstream watersheds to fuel dependent animals ranging from small microorganisms to 1,500-pound brown bears (McKinley Research Group, 2021). The magnitude of these effects is significant; in 2022, a total of 79.0 million Sockeye salmon returned to Bristol Bay—the largest inshore Sockeye salmon run ever recorded in the region (Alaska Department of Fish and Game, 2022b).

Studies have shown that people place a substantial value on preserving/improving salmon habitats (Jordan et al., 2012; J. B. Loomis et al., 1996). For example, California households were willing to pay between $108.27 and $311.06 (2021$) annually[40] to augment flows and improve riverine habitat in the San Joaquin River that would increase the population of Chinook salmon from less than 100 to 15,000, annually (J. B. Loomis et al., 1996). Additionally, Jordan et al. (2012) estimated the WTP for preservation of major habitats of Chinook salmon in Yaquina Bay, Oregon. Major habitats included streams and rivers (for salmon spawning and migration), the water column (for juvenile rearing and migration), and salt marsh (for juvenile rearing). The estimates were based on WTP of $203/year/household[41] (2021$) to avoid the loss of salmon that was then aggregated across households at different spatial scales (e.g., over the total number of households in Lincoln County, the state of Oregon, and the Pacific Northwest). These values were then applied to each major habitat, where WTP was assumed to be homogenously distributed across the size of the habitat (i.e., divided by the number of acres). When aggregated across 3,605,121 households in the Pacific Northwest and assuming the entire WTP applied to all habitat types, the WTP/acre/year for stream and river habitats was $4,549 (2021$), for water column habitat was $128,951 (2021$), and for Yaquina Bay salt marsh habitat was $423,697 (2021$).[42] Although to some degree these estimates may reflect the scarcity of salmon on the continental west coast of the U.S. they demonstrate a significant WTP to preserve and improve salmon habitats.

Construction and operation of the 2020 Mine Plan may have a detrimental effect on ecosystem services provided by fish and wildlife that reside near or depend on impacted streams, wetlands, and other waters, both via direct impacts to habitat and via effects on biodiversity. The “portfolio effect” is a feature of ecological communities (or species) by which variance is dampened due to the complementary or independent dynamics among species that perform similar ecosystem service functions. This portfolio effect has been recognized in Bristol Bay’s Sockeye salmon populations, emerging from the diversity of life history forms and run timings (Schindler et al., 2010). The Bristol Bay watershed’s habitat diversity supports the evolution of significant genetic diversity within Sockeye salmon and other salmon species that originate in the watershed. Research has identified several hundred discrete populations of salmon within the Bristol Bay watershed (U.S. EPA, 2022; Section 3). Project modeling has shown that the construction and operation of the 2020 Mine Plan may hinder the local portfolio effect given the extensive destruction and degradation of salmon habitat estimated to occur (USACE, 2020a; Attachment B8). Schindler et al. (2010) examined 50 years of data from Sockeye salmon in Bristol Bay to quantify portfolio effects. Key findings of the study include: (1) a reduction in the variability of annual salmon runs by a factor of 2.2 when compared to a similar system with a

[40] The range is based on the valuation scenario. The lower value for salmon population increases is based on the scenario that asked respondents to value multiple ecosystem service improvements (including the salmon program, wetland acreage increase, and reduction in wetland contamination from agricultural drainage). The higher value is based on the scenario that considered the salmon program alone, highlighting the need for taking an ecosystem approach to valuation, rather than a species-by-species approach.

[41] The value is based on coastal Oregon and Washington residents’ (within 30 miles of five Pacific Northwest estuaries) WTP for the enhancement of local Coho salmon stocks (Bell et al., 2003).

[42] The value for stream and river habitats was estimated at the ocean basin spatial scale (4.5 billion acres), the value for water column habitat was estimated at the estuary spatial scale (5,683 acres), and the value of salt marsh habitat was estimated at the sub-estuary spatial scale (1,730 acres). Acreage estimates were estimated using GIS and georeferenced salmon migration data from the published literature (Jordan et al., 2012).

homogenous salmon population, and (2) a reduction in the frequency of fishery closures by a factor of 10. Furthermore, portfolio effects from the variation of salmon species run timing support watershed food webs by providing predators (e.g., bears, wolves) prolonged seasonal access to salmon resources across the diverse Bristol Bay landscape. Thus, robust salmon populations result in additional benefits to the extent that these predators are valued by Alaskans and non-Alaskan hunters, recreators, and non-users (i.e., through existence values; see Section 5.9). The benefits that salmon provide to wildlife, other fish species, and the ecosystem as a whole are likely to be dampened by impacts under the 2020 Mine Plan.

Projected wildlife impacts from construction and operation of the 2020 Mine Plan are described in Section 4.23 of the FEIS (USACE, 2020a). The FEIS assessment accounted for projected behavioral disturbance, injury and mortality, and habitat changes to birds, terrestrial wildlife, and marine mammals resulting from impacts to streams, wetlands, other waters, and vegetation. The FEIS analysis area for wildlife impacts included the project footprint under the 2020 Mine Plan and the extended geographic area where impacts to wildlife are considered for the life of the project (e.g., 10-mile radius buffer around the mine site). The expected impacts under the 2020 Mine Plan are based on the estimated loss of 10,132 acres of habitat for a variety of wildlife species.[43] The duration of impacts would extend for the life of the project and longer, depending on the post-construction use of the transportation corridor. Although the extent is associated with a great deal of uncertainty (e.g., regarding the accuracy of the selected radii that was used to determine the assessment area) it may include the footprint of all project components (including the transportation corridor). Table 5-8 summarizes projected impacts on wildlife species other than fish under the 2020 Mine Plan. Fish species impacts are described in Table 5-2 and Table 5-5.

The recommended determination, if affirmed, would help protect habitat against impacts resulting from construction and operation of the 2020 Mine Plan for a wide range of terrestrial, avian, and marine mammal species and help ensure existence of healthy wildlife populations in the Bristol Bay region. Although no threatened and endangered species have been documented in the terrestrial portions of the 2020 Mine Plan, marine components of the 2020 Mine Plan could have impacts to threatened and endangered marine mammals in Cook Inlet (e.g., Cook Inlet beluga whale), the Gulf of Alaska, along the Aleutian Islands, and the Bering Sea (USACE, 2020a; Section 4.25). Therefore, the recommended determination, if affirmed, would support the preservation of existing biodiversity within the Bristol Bay region.

[43] An additional 2 acres would be lost from the Concentration Pipeline Variant (see Table 4.23-2; USACE, 2020a).

Table 5-8. Summary of Wildlife Impacts under the 2020 Mine Plan	
Impact Category	**Projected Impacts**
Mine Site	
Behavioral Changes	Avoidance of the mine site by terrestrial wildlife and bird species during construction, operations, and closure. Some species may return to formerly used and newly created habitats during and after various components have been reclaimed. There would be no behavioral changes from any of the variants under the 2020 Mine Plan at the mine site. This impact does not apply to marine mammal species because they do not occur in the mine site.
Injury and Mortality	During construction, operations, and closure, direct mortality to some terrestrial wildlife and bird species may occur through vegetation clearing and collisions with vehicles, equipment, and structures. Some bears may be killed in defense of life and property. Additional mortality may occur due to altered predator and prey relationships. There would be no additional injury or mortality from any of the variants under the 2020 Mine Plan at the mine site. This impact does not apply to marine mammal species because they do not occur in the mine site.
Habitat Changes	Loss of 8,392 acres of habitat. Indirect loss of additional habitat surrounding the mine site due to behavioral avoidance from project-related noise, lighting, fugitive dust (estimated as a 330-foot buffer around the mine site), etc.
Transportation Corridor	
Behavioral Changes	Traffic volumes, at 35 round-trip truck trips per 24-hour day (approximately one vehicle passing in one direction every 21 minutes if evenly spaced running 24 hours) would be anticipated to disturb wildlife while vehicles are passing. Vehicles may travel in groups, therefore, intervals between vehicles may be greater. There would be additional light vehicle traffic (i.e., vehicles other than large trucks transporting concentrate, fuel, and consumables) along the transportation corridor, which would add an unknown number of additional daily vehicle trips. Terrestrial wildlife would avoid the project components due to increased noise, vehicle, fugitive dust, and human presence. In particular, brown bears may den farther away from the transportation corridor, especially the port access road. Physical presence of vessels over 28 miles of travel, and aircraft, may displace harbor seals that inhabit Iliamna Lake.
Injury and Mortality	Potential terrestrial wildlife collisions with vehicles across 83 miles of road. There would be no impact to harbor seals that inhabit Iliamna Lake due to lack of a ferry.
Habitat Changes	Loss of 1,641 acres (inclusive of 604 acres from material sites) of terrestrial wildlife and bird habitat. Additional terrestrial wildlife avoidance of surrounding habitat.
Port Site	
Behavioral Changes	Terrestrial wildlife avoidance of area. Underwater noise from construction, operations, and closure may exceed disturbance thresholds for marine mammals as defined by the U.S. Fish and Wildlife Service (FWS) and National Marine Fisheries Service (NMFS). Physical presence of vessels and aircraft (mainly during construction) may displace marine species, including disturbances to harbor seal mother and pup pairs. Maintenance dredging of the navigation channel would cause disturbance to nearby marine mammals during dredging activities.
Injury and Mortality	Potential for terrestrial wildlife to be killed in defense of life and property at the port. Potential for bird species to collide with port infrastructure (e.g., communications tower) and vessels. Potential for vessels to collide with marine mammals. Potential for disturbance to harbor seal mother and pup pairs, which can lead to pup abandonment and death of the pup.
Habitat Changes	Loss of 32 acres of terrestrial wildlife habitat and 79 acres of benthic marine foraging habitat. Maintenance dredging approximately every 5 years of the navigation channel would cause habitat disturbance.
Pipeline Route	
Behavioral Changes	Avoidance of 164 miles during construction for wildlife species. Physical presence of vessels and aircraft may displace marine species.
Injury and Mortality	Potential for wildlife to collide with vessels and equipment during construction and pipeline installation. During construction, underwater noise levels (which would vary with different dredging technologies) may exceed the disturbance thresholds as defined by FWS and NMFS.
Habitat Changes	Loss of 13 acres of permanent habitat (from compressor station and material sites) plus temporary impacts during pipeline trenching.

Source: Pebble Project FEIS, Chapter 4, Section 4.23 (USACE, 2020a*). Note: Impacted acres in the table do not sum to the total direct impact footprint reported in the FEIS (10,132 acres for the concentrate pipeline variant), likely due to overlap in the estimated affected areas across project components.*

5.6. Regulation of Ecosystems

Streams and wetlands provide a variety of regulating ecosystem services such as carbon sequestration, flood protection, groundwater recharge, nutrient cycling, and sediment retention. Construction and operation of the 2020 Mine Plan may negatively affect these services. For example, construction activities, including the discharge of dredged or fill material would increase suspended sediments in wetlands (and other waters) and potentially lead to fragmentation that would alter drainage characteristics (USACE, 2020a; Attachment B8) and hinder ecological connectivity. Based on the description of the regulating functions of wetlands presented in the ecological literature, potential benefits associated with an avoided loss of 3,829 acres of wetland area (3,018 acres impacted by mining construction and operations and 811 acres impacted by the transportation corridor) and preservation of regulating services are likely to be substantial.[44]

Carbon sequestration.[45] Waterbodies (such as lakes and reservoirs) and wetlands have been shown to play an important role in carbon sequestration. The burial of organic carbon (OC) in sediments removes it from the short-term atmospheric carbon cycle, preventing GHG production. The magnitude of OC burial in lakes and reservoirs in Alaska has been estimated to range between 0.01 to 0.61 g $C/m^2/y$ (Mendonça et al., 2017). Wetlands both emit and sequester carbon (and other greenhouse gases (GHGs) such as methane) with net sequestration depending on wetland characteristics (Nag et al., 2017; Nahlik et al., 2016; Tangen et al., 2020). For example, wetland GHG emission rates have been found to vary depending on the conditions present in the wetlands such as vegetation development (C. Sha et al., 2011), salinity level (M. J. Loomis et al., 2010), and whether the wetland is permanently or temporarily inundated (Altor et al., 2006). Nearly two-thirds of wetlands typically found in Alaska are palustrine wetlands (Hall et al., 1994). Studies that have examined palustrine wetlands in the U.S. found carbon sequestration rates to vary between 0.48 and 4.03 Mg/ha/y (Bridgham et al., 2006; Tangen et al., 2020). The 2020 Mine Plan would not only lead to an increase in GHG due to the elimination of wetlands but would also directly contribute to an increase in GHG during all phases of construction, operations, and closure (USACE, 2020a; Attachment B8). Appendix K4.20 of FEIS stated that the 2020 Mine Plan would result in 411,748 tons of CO_2 per year from project site construction, 1,240,477 tons of CO_2 per year from project site operation, and 664,753 tons of CO_2 per year from project site closure, and 126,823 tons of CO_2 per year from transportation corridor construction, and 30,126 tons of CO_2 per year from transportation corridor operations (USACE, 2020a).[46, 47]

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[44] The USACE determined that compensatory mitigation would not offset the significant degradation resulting from the 2020 Mine Plan (USACE, 2020a; Attachment B8).

[45] Wetlands may also emit other GHGs, such as methane and nitrous oxide (Nag et al., 2017; Mitsch et al., 2013), which would need to be considered in determining whether they are GHG sources or sinks.

[46] The analysis presented in the FEIS was not specific to a proposed action alternative, but instead, was representative of several action alternatives. "Because the action alternatives would have similar emission sources and locations of stationary emissions (except for the location of the port and transportation corridor), emissions estimates and air dispersion modeling for the analyzed representative project provide a proxy for all action alternatives." (USACE, 2020a, p. K4.20-1).

[47] The GHG analysis presented in the FEIS was specific to the 2020 Mine Plan geographic location and did not consider indirect impacts to GHG emissions associated from changes to the geographic location of source minerals being supplied/transported to industrial sites nor how produced minerals may be used in other industries.

Flood protection. Numerous studies of ecological functions provided by wetlands demonstrated that wetlands and nearby streams provide significant flood protection benefits. Flood protection benefits have been shown to increase with wetland size (Ameli et al., 2019; Evenson et al., 2018; Martinez-Martinez et al., 2014; Tang et al., 2020; Wu et al., 2008) and vary depending on their location relative to nearby streams (Ameli et al., 2019; Evenson et al., 2018; Tang et al., 2020). For example, wetland flood protection benefits have been found to increase when wetlands are closer to the mainstream network (Ameli et al., 2019), further away from streams (Evenson et al., 2018),[48] and upstream in the watershed (Tang et al., 2020). For example, in the Prairie Pothole region, peakflow reduction per hectare of wetland has been found to be 165 times larger for wetlands located within 100 m of a mainstream network (268 m^3/day) compared to wetlands located more than 4,000-m away (1.61 m^3/day) (Ameli et al., 2019). The economic value of flood protection benefits provided by wetlands is site-specific and is likely to vary depending on the type of wetland and the number and value of nearby properties (Lawrence et al., 2019; K. B. Watson et al., 2016). Using an avoided damages approach, Lawrence et al. (2019) estimated the value of flood protection from wetlands along a perennial stream in Northern Virginia to be $86/ha/y or $35/acre/y. Given that the Bristol Bay region is generally sparsely populated with no structures within a 100-year floodplain where the project would be constructed (USACE, 2020a; Attachment B8), avoided damages to built infrastructure resulting from wetland preservation are likely to be small (USACE, 2020a; Attachment B8).

Groundwater recharge and instream flow preservation. Groundwater recharge plays a significant role in the Bristol Bay watershed's aquatic habitats. Areas of groundwater recharge create high quality salmon habitat because salmon rely on clean, cold water flowing over and through porous gravel for spawning and rearing (U.S. EPA, 2022; Section 3.2.1). For example, beach-spawning Sockeye salmon in the Wood River watershed have been found to have the highest densities at sites with strong groundwater upwelling and not found at sites with no upwelling (U.S. EPA, 2022; Section 3.2.1).

Groundwater contributions to streamflow, along with the influence of run-of-the-river lakes, support flows in the region's streams and rivers that are more stable than those typically observed in many other salmon streams (e.g., in the Pacific Northwest or southeastern Alaska). This results in more moderated streamflow regimes (i.e., lower peak flows and higher baseflows), creating a less temporally variable hydraulic environment (U.S. EPA, 2022; Section 3.2.1).

Based on information presented in the FEIS, EPA Region 10 has estimated that construction and operation of the 2020 Mine Plan would either increase or decrease average monthly stream flows by greater than 20 percent in at least 29 miles of anadromous fish streams downstream of the mine site.[49] The most notable streamflow reductions downstream of the mine site would occur in the 2.8-mile reach

[48] The results from Ameli et al. (2019) and Evenson et al. (2018) who both study wetlands in the Prairie Pothole Region of the U.S. seem to be contradictory. This may be related to the latter study's focus on depressional wetlands.

[49] Streamflow reductions exceeding 20 percent of average monthly streamflow would occur in at least 1 month per year in at least 13.1 miles. Additionally, 25.7 stream miles would have an increase in monthly average streamflow (for additional details, see Section 4.2.4.3 of U.S. EPA, 2022).

of anadromous fish habitat in the SFK mainstem leading to Frying Pan Lake (average monthly streamflow would be reduced by between 32 and 53 percent from the baseline average monthly streamflow in every month of the year) (see Section 4.2.4.4 in U.S. EPA (2022) for additional detail). This would reduce natural inflows to Frying Pan Lake which provides rearing habitat for juvenile Coho and Sockeye salmon, as well as other resident fishes (such as Arctic Grayling, Northern Pike, whitefish, stickleback, and sculpin). Additionally, the construction and operation of the 2020 Mine Plan may potentially decrease stream flows due to a loss of wetlands (which regulate stream flow) (Evenson et al., 2018), and hence negatively affect resident fishes.[50]

Preservation of instream flow to support salmon, steelhead, and other anadromous fish runs is likely to provide significant benefits to both recreational users and non-users of these resources. In a study from Douglas et al. (1999), the average WTP[51] for a recreational user for augmenting instream flows and preserving anadromous fish runs in Northern California ranged from $14.68 for the preservation of instream flows measuring 120,000 acre-feet per annum and 9,000 fish to $405.05 for the preservation of instream flows measuring 840,000 acre-feet per annum and 105,000 fish. For non-users, the estimated WTP ranged from $11.98 to $90.20 for the same valuation scenarios. Similarly, in a study from J. B. Loomis (2012), households in Colorado had a WTP of $298.99 per year for maintaining instream flows for an urban perennial river.

Water quality regulation. Streams draining the Pebble deposit area are undisturbed, with low conductivity, alkalinity, dissolved solids, suspended solids, and dissolved organic carbon (U.S. EPA, 2022; Section 3.2.1). However, the presence of a metalliferous site such as that being proposed in the 2020 Mine Plan would result in elevated levels of sulfate and other metals (such as copper, molybdenum, nickel, and zinc), particularly in the SFK watershed (U.S. EPA, 2022; Section 3.2.1). In general, direct and indirect adverse effects on water quality would result from alteration of mined rock and its interaction with air and water, the discharge of treated effluent, project-related fugitive dust, seepage from mine site facilities, potential sedimentation, and the loss of wetlands (USACE, 2020a; Attachment B). Moreover, the loss of wetlands may make these streams more vulnerable to pollution from the construction of the transportation corridor and the mine site (e.g., fugitive dust and toxic metals) as wetlands provide sediment retention and prevent runoff which can lead to improvements in water quality (Arp, 2004; Hopkins et al., 2018).[52] Headwater streams, which make up approximately 65 percent of assessed stream length in the SFK, NFK, and UTC watersheds, play a significant role in nutrient cycling because they can have high instream rates of nutrient processing and storage, which influences downstream water chemistry,[53] and provide key habitats to numerous fish species (including

[50] Existing studies found that wetlands provide groundwater recharge ranging from 3.29 to 12 cm/day, depending on wetland location and wetland type such as isolated and riverine (e.g., Williams et al., 2015; Harvey et al., 2004).

[51] WTP is the maximum amount of money an individual would voluntarily pay to obtain an improvement (National Center for Environmental Economics, 2010).

[52] For example, Hopkins et al. (2018) found floodplains and wetlands to prevent the runoff of nitrogen.

[53] Headwater streams and wetlands also contribute nutrients downstream to higher-order streams in the watershed (U.S. EPA, 2022; Section 3.2.4).

Coho, Chinook, and Sockeye salmon) which assist in nutrient recycling (U.S. EPA, 2022; Arp, 2004; Hopkins et al., 2018). When adult salmon return to their natal freshwater habitats to spawn, they import "marine derived nutrients" (MDN), which assists nutrient recycling. MDN contributions play a significant role in the Bristol Bay watershed, which tends to have aquatic systems that are nutrient poor. For example, Sockeye salmon are estimated to import 55 tons of phosphorus and 438 tons of nitrogen into the Kvichak River system annually (U.S. EPA, 2022; Section 3.3.4). The FEIS indicated that approximately 20 percent of available stream habitat in the Headwaters Koktuli watershed would be lost to the 2020 Mine Plan (USACE, 2020a; Section 4.24). The loss of headwater streams would most heavily affect reaches immediately downstream (given the potential loss of inputs from upstream habitats) with additional dampened effects occurring further downstream the river network (U.S. EPA, 2022; Appendix B.1.1). Components of the 2020 Mine Plan would also adversely affect water quality through its effect on water chemistry (i.e., via land runoff, fugitive dust, and treated water discharges which would substantially increase concentrations of chloride, magnesium, and other substances) (U.S. EPA, 2022; Appendix B.5.1). The loss of headwater streams and reduction in water quality would alter fish habitat with likely negative consequences. This has been observed to occur in Oregon's Columbia River basin where prolonged depression of salmon stocks resulted in chronic nutrient deficiency (which hindered the recovery of endangered and threatened Pacific salmon stocks) (U.S. EPA, 2022; Section 3.3.4).

5.7. Health and Safety

The recommended determination, if affirmed, would have both beneficial and adverse impacts on regional health and safety that are difficult to quantify due to a lack of data (USACE, 2020a; Section 4.10). One health benefit from the recommended determination, if affirmed, would be the reduced risk of exposure to hazardous chemicals in air (e.g., lead and benzene), soil (e.g., beryllium and cadmium), groundwater (e.g. aluminum and arsenic), surface water (e.g., cobalt and nickel), sediment (e.g., arsenic and copper), and bioaccumulated compounds in subsistence foods (e.g., arsenic and cadmium) around the mine site.[54] Alaska Native populations would also avoid the mental health issues associated with the potential degredation or loss of cultural significant sites and resources. Without the project and its attendant traffic, morbidity and mortality rates from injury would be lower. Infectious disease rates would be lower without the increase in proximity and interaction within surrounding communities when the mine's transportation corridor and pipeline would have been constructed. Access to

[54] The mine would increase the risk of exposure to copper-gold and molybdenum concentrates that contain sulfide minerals and other metals, criteria air pollutants (carbon monoxide, nitrogen oxide, particulate matter, sulfur dioxide, volatile organic compounds, and lead), metals hazardous air pollutants (antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, mercury, nickel, and selenium), organic hazardous air pollutants (acetaldehyde, benzene, formaldehyde, hexane, hydrochloric acid, and toluene), chemicals in groundwater (aluminum, antimony, arsenic, barium, beryllium, bismuth, boron, cadmium, chromium, cobalt, copper, lead, manganese, mercury, molybdenum, nickel, selenium, silver, thallium, silicon, tin, vanadium, zinc, and bioaccumulative compounds), surface water, soil, sediment, and bioaccumulative compounds in subsistence foods. These chemicals can cause lung, liver, kidney, bladder, and skin cancers as well various developmental, hematological, nephrological, renal, thyroid, pulmonary effects, reproductive, and central nervous system effects. See Appendix K Section 4.10 of the Pebble Project FEIS for more information.

healthcare and safety services would improve because emergency situations overwhelming capacity would be less likely. The recommended determination, if affirmed, has the potential to result in adverse health outcomes associated with lower average real incomes in the absence of the mine's construction and operation, but would also prevent adverse health outcomes from economic dislocation at the mine's closure. Table 5-9 below lists projected health and safety impacts of the 2020 Mine Plan, as discussed in the FEIS (USACE, 2020a; Section 4.10).[55]

Table 5-9. Summary of Key Issues for Health and Safety under the 2020 Mine Plan

Direction of Impact	Projected Impacts
Increase in Health and Safety	• Health improvement associated with mine economic activity (e.g., increase in incomes from mine and decrease in transportation costs improving access to food, healthcare) (likely)
Decrease in Health and Safety	• Increase in risk of exposure to hazardous chemicals (unlikely) • Increase in transportation-related accidents (unlikely) • Increase in suicide (very unlikely) • Increase in infectious disease transmission, morbidity, and mortality (about as likely as not) • Decrease in access to healthcare and safety services due to emergency situations overwhelming local and regional capacities depending on adequacy of emergency planning and preparedness (very unlikely) • Decrease in employment and income at mine closure (likely)
Ambiguous Change in Health and Safety	• Increase and decrease in stress (psychosocial and familial) (about as likely as not) • Increase and decrease in injury unrelated to transportation (very unlikely) • Increase and decrease in access to, quantity of, and quality of subsistence resources (about as likely as not) • Increase or decrease in food security (about as likely as not) • Increase or decrease in morbidity and mortality rates from changes to diet, nutrition, and physical activity (about as likely as not)

Source: Pebble Project FEIS, Chapter 4, Section 4.10 (USACE, 2020a). The likelihood of each impact is presented in parentheses for each potential impact.

5.8. Quality of Life

The recommended determination, if affirmed, would result in beneficial impacts to aesthetics, noise, and traffic that are difficult to quantify (USACE, 2020a; Sections 4.11, 4.12, and 4.19). The recommended determination, if affirmed, would preserve the visual continuity of the landscape, prevent mine-related lighting from disrupting dark sky views, and prevent mine-related noise from disturbing the soundscape for residents, workers, and visitors in the region. Without the project, residents, workers, and visitors would spend less time waiting in traffic, particularly in the communities of Pedro Bay, Iliamna, and Newhalen. The recommended determination, if affirmed, would also reduce the risk of air, water, and surface traffic accidents by preventing new structures in navigable areas. Table 5-10 below lists the

[55] The FEIS considered these categories in more detail, with directionality estimates, in Chapter 4, which presents impacts of the mine (USACE, 2020a). The recommended determination, if affirmed, would prevent the impacts of the project.

aesthetic, noise, and traffic impacts of the 2020 Mine Plan, as discussed in the FEIS (USACE, 2020a; Sections 4.11, 4.12, and 4.19).[56]

Table 5-10. Summary of Key Aesthetic, Noise, and Traffic Impacts from Mine Development and Operation under the 2020 Mine Plan

Issue	Projected Impacts
Aesthetics	Mine site: moderate to strong visual contrast would dominate landscape within short distance, lighting would affect night sky within 20mi, soundscape affected within 10mi
	Transportation corridor: weak to moderate visual contrast would be evident in landscape, soundscape affected within 0.5mi, Petro Bay affected
	Port: weak to moderate visual contrast would be evident in landscape up to 5mi, night sky affected within 13mi, soundscape affected within 2mi
Noise	Mine site: noise detectable within 10mi, disturb outdoor sleeping recreationists and subsistence hunters within 3mi, disturb rural indoor residents within 2mi
	Roads: disturb outdoor sleeping recreationists and subsistence hunters within 2mi, disturb rural indoor residents within 1mi, disturb developed area residents within 0.5mi
	Pile Bay airstrip takeoffs disturb outdoor sleeping recreationists and subsistence hunters within 6.5mi (4.5 approach) and rural indoor residents within 3.4mi (1.8mi approach)
	Port: disturb outdoor sleeping recreationists and subsistence hunters within 2mi and rural indoor residents within 1mi
	Pipeline construction: disturb outdoor sleeping recreationists and subsistence hunters within 4mi, rural indoor residents within 3mi, and developed area residents within 2mi
	Pipeline maintenance, closure, and reclamation: disturb outdoor sleeping recreationists and subsistence hunters within 2mi, rural indoor residents within 1mi, and developed area residents within 0.5mi
	Pipeline compressor station operation: disturb developed area residents within 0.5mi
Traffic	Increase road traffic volume in Pedro Bay, Iliamna, and Newhalen. 35 port-to-mine truck round trips/day through Pedro Bay.
	Increase air traffic at Pile Bay Airstrip or Pedro Bay airport by 10+ flights/week, requiring improved navigation systems and lighting.
	Increase risk of vessel allision from dredging and new structures in Cook Inlet, Newhalen River, Pile River, and Iliamna River.

Source: Pebble Project FEIS, Chapter 4, Sections 4.11, 4.12, and 4.19 (USACE, 2020a).

5.9. Non-use Value

Non-use values are values that are not associated with actual use of an ecosystem or its services. Non-use benefits from avoided project impacts to the Bristol Bay area include:

[56] The FEIS considered these categories in more detail, with directionality estimates, in Chapter 4, which presents impacts of the mine (USACE, 2020a). The recommended determination, if affirmed, would prevent the impacts of the project.

Existence benefits: value that individuals place on simply knowing that Bristol Bay streams, wetlands, other waters, and the ecosystem as a whole exist, as well as the existence of the Alaska Native cultural and subsistence lifestyle independent of any use;

Option benefits: value that individuals have for maintaining Bristol Bay streams, wetlands, other waters, and the ecosystem as a whole, as well as the culture it supports, even if there is little or no likelihood of using them because of uncertainty about future supply (the continued existence of Bristol Bay aquatic resources) and potential future demand (the possibility that they may someday use Bristol Bay aquatic resources); and

Bequest benefits: value that the current generation places on availability of Bristol Bay ecosystem and culture for future generations.

Given the high-profile nature of the project, EPA Region 10's recommended determination, if affirmed, would likely generate significant non-use benefits for Alaskan households, particularly households outside the Bristol Bay region, and other U.S. households. Even small non-use values held by a large number of households could lead to substantial aggregate values. For example, a study by Goldsmith et al. (1998), as cited in Duffield et al. (2013), estimated the non-use value (including existence and bequest) for the 26 wildlife refuges in Bristol Bay to be between $3.7 and $7.3 billion per year (2021$). The estimated value is based on the WTP for protecting large tracts of wilderness in other areas (e.g., Alberta and Colorado) from several studies (Adamowicz et al., 1991; Walsh et al., 1984; Walsh et al., 1985)[57] and the number of U.S. households estimated to hold values for protecting natural resources in Alaska based on a WTP study conducted by R. Carson et al. (1992).[58] Results from a contingent valuation survey found that Pacific Northwest nonusers with no probability of future use and nonusers with some probability of future use were willing to pay $47.72 (2021$) and $105.37 (2021$) annually to double Columbia River runs of Pacific salmon and Steelhead by the year 2000 (Olsen et al., 1991). These benefits may be substantial when considering the number of nonusers. When aggregating WTP estimates over 1,599,360 nonusers with no probability of future use and 304,640 nonusers with some probability of future use, total regional annual values amount to $76 million (2021$) and $32 million (2021$), respectively (Olsen et al., 1991).[59]

Opinion poll results and participation in public discourse on a topic can provide a general sense for the public's interest in and knowledge of the potential environmental issues associated with the 2020 Mine Plan. Although this information shows public preferences, it cannot be used to quantify the economic

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[57] The estimated per household WTP values ranged from $39.78 to $79.55 per year (2021$).

[58] The study was conducted by the State of Alaska Trustees in the Exxon Valdez oil spill case and served as basis for $1 billion settlement between the State and Exxon.

[59] Olsen et al. (1991) estimated the number of nonusers based on the number of households in the Pacific Northwest. The number of nonusers is split between nonusers with no probability of future use and nonusers with some probability of future use by applying the ratio from the sample. Estimated WTP values account for true zero-value bids but excluded protest bids.

value of the resource at interest. EPA presents a brief summary of the results of public opinion polls and public comment received by EPA below.

Polling has consistently found that the majority of Alaskans oppose development of mine at the Pebble deposit. A 2020 David Binder Research poll commissioned by the Bristol Bay Defense Fund indicated that 62 percent of Alaskan voters oppose the Pebble Mine, with 48 percent of respondents indicating that they “strongly oppose” the mine compared to only 15 percent who “strongly support” it (David Binder Research, 2020). A 2018 Hays Research Group poll commissioned by the United Tribes of Bristol Bay indicated that 77 percent of Bristol Bay residents oppose the Pebble Mine and 70 percent believe that the Pebble Mine and Bristol Bay salmon fishery cannot safely co-exist (Heimer, 2018). Bristol Bay Native Corporation (BBNC) polling has shown that the majority of Alaskans have consistently opposed the Pebble Mine from 2012 through 2020 (BBNC, n.d.). Additionally, in November 2014, Alaskan voters passed a ballot measure, 65 percent in favor versus 35 percent opposed, that would enable the Alaska Legislature to ban proposed mining in the Bristol Bay Watershed if lawmakers believe the project would endanger wild salmon stocks (Doogan, 2014). These polling and ballot initiatives show that Alaskan households are concerned about the impacts of development of a mine at the Pebble deposit. Public comment and tribal consultation on previous EPA Region 10 actions related to the Pebble Deposit area indicate that many Alaska residents hold both use and non-use values for protecting aquatic resources in the Bristol Bay area.

U.S. households, both within Alaska and within other U.S. states, demonstrated strong opposition to the development of a mine at the Pebble deposit. EPA Region 10 received more than 670,000 written comments from households across the United States during the public comment period for its 2014 proposed determination. More than 99 percent of these public comments supported the 2014 proposed determination, with many stating that the estimated economic benefits of the proposed project are outweighed by environmental costs.[60] Alternatively, commenters in support of the proposed project described a need to bring economic benefits to the region by developing infrastructure, creating job opportunities in an area with high rates of unemployment and poverty, and making the United States a leader in mineral extraction (instead of outsourcing to foreign countries with less environmentally sound mining practices) (USACE, 2020a; Attachment B). Similarly, EPA Region 10 received over 582,000 written comments from households across the United States during the public comment period for its 2022 proposed determination, 99 percent of which supported the 2022 proposed determination.[61] The large volume of comments supporting EPA Region 10’s determination indicates that a significant number of U.S. households, both within and outside of Alaska, hold non-use values for stream, wetland, and other aquatic resource protection in the Bristol Bay area.

[60] Docket No. EPA-R10-OW-2014-0505

[61] Docket No. EPA-R10-OW-2022-0418

5.10. Environmental Justice

The recommended determination, if affirmed, would result in environmental justice impacts (USACE, 2020a; Section 4.4).[62] Minority and low-income communities would experience benefits, including increased availability, abundance, and access of subsistence resources (see Section 5.2), and income and employment opportunities stemming from sustainable salmon fisheries (see Section 5.1). In addition, these communities may potentially benefit from reductions in traffic-related accidents, suicides, and exposure to hazardous chemicals. To the extent commercial and recreational harvests are protected by the recommended determination, employment in those sectors may be sustained. However, since PLP has stated that it would prioritize local hires for mine operation and construction jobs,[63] and assuming that local individuals currently possess or can be trained by PLP to have the necessary skills,[64] the recommended determination, if affirmed, may also reduce opportunities for steady income and employment during mine construction and operation in the communities closest to the proposed mine site, including Newhalen, Iliamna, Nondalton, and Pedro Bay. Table 5-11 below lists the environmental justice impacts of the 2020 Mine Plan, as discussed in the FEIS (USACE, 2020a; Section 4.4).[65]

Table 5-11. Summary of Key Issues for Environmental Justice under the 2020 Mine Plan

Environmental Justice Rating	Projected Impacts
Socioeconomics: no high or adverse impacts	Economic benefits to minority and low-income communities (especially Newhalen, Iliamna, Nondalton, and Pedro Bay) by increasing job opportunities, creating year-round employment, providing steady income, and cutting high cost of living (via lower transportation and energy costs).[1]
Subsistence: potential adverse impacts	Adverse changes in resource availability for minority and low-income communities. No high or adverse impacts to access of subsistence resource harvest areas for minority and low-income communities because of access to alternate subsistence resource areas. The transportation corridor would disrupt access to subsistence resource areas for Iliamna, Newhalen, Pedro Bay, and Nondalton residents. Employment opportunities could provide additional revenue to support subsistence activities.

[62] The Environmental Justice analysis in the FEIS considered the 2020 Mine Plan in the context of local social and economic conditions and trends. However, it considered no alternative economic development plans.

[63] According to the FEIS (USACE, 2020a; Section 4.3.3.1), mine operations jobs would prioritize Alaskan hires, with approximately 250 employees from surrounding communities and 600 employees from Anchorage or Kenai. For mine construction, up to 50 percent of non-Alaskan hires would be required to fill the anticipated 2,000 jobs.

[64] The FEIS (USACE, 2020a; Section 4.3) documented that, to date, PLP has supported training and education programs in Alaska (e.g., Alaska Native Science and Engineering Program, Teacher Industry Externship Program, Alaska Resource Education) and anticipated that such efforts would increase under the 2020 Mine Plan "as the needs of the workforce expand."

[65] The FEIS considered these categories in more detail, with directionality estimates, in Chapter 4, which presents impacts of the mine (USACE, 2020a). The recommended determination, if affirmed, would prevent the impacts of the project.

Table 5-11. Summary of Key Issues for Environmental Justice under the 2020 Mine Plan	
Environmental Justice Rating	Projected Impacts
Health and Safety: potential adverse impacts	Economic benefits and improvements to the overall health and well-being of residents, especially those in the Lake and Peninsula Borough. Beneficial impacts on minority and low-income communities from reduced psychosocial and family stress (e.g., increased funding for boroughs to maintain or improve community health services, increased financial security for community members employed by the project). Adverse impacts on minority and low-income communities from increased unintentional injuries (e.g., falls, poisoning) and psychosocial and family stress (e.g., fear of changes in lifestyle and cultural practices, depression and increased substance abuse, real or perceived impacts on food security). Beneficial and adverse impacts on minority and low-income communities related to access to and quantity of subsistence resources and food security. Adverse impacts from potential increased transportation/navigation accidents and potential increase in suicide rates. Potential for increased risk of exposure to hazardous chemicals in air, soil, groundwater, surface water, sediment, and bioaccumulative compounds would be low, and imperceptible from baseline. Real or perceived impacts could cause additional stress for local residents harvesting salmon for subsistence, commercial fishing, and recreational fishing purposes.

Source: Pebble Project FEIS, Chapter 4, Section 4.4 (USACE, 2020a).

1: According to the FEIS (USACE, 2020a; Section 4.3.3.1), mine operations jobs would prioritize Alaskan hires, with approximately 250 employees from surrounding communities and 600 employees from Anchorage or Kenai. For mine construction, up to 50 percent of non-Alaskan hires would be required to fill the anticipated 2,000 jobs. Local hires for mine operation and construction positions would depend upon: (1) local individuals already possessing the skills required or (2) PLP providing any training necessary for locals to develop required skills.

5.11. Potential Spill and Dam Failure Risks

The recommended determination, if affirmed, would eliminate the risks from potential spills or dam failures (USACE, 2020a; Section 4.27). There is a likelihood that some spills would occur over the life of the mining operation (U.S. EPA, 2022; Section 6). Spill risks over the life of the mining operation includes diesel fuel, natural gas, chemical reagents, copper-gold flotation concentrate, tailings, and untreated contact water (USACE, 2020a; Section 4.27). Failure of major infrastructure—such as concentrate and tailing pipelines, the water management facilities, or tailings storage facility dams—even if not likely, would result in severe impacts to aquatic resources in affected watersheds (U.S. EPA, 2022; Section 6). For example, a release of concentrate slurry into flowing waters would increase sedimentation to downstream waters, cause exceedances of water quality criteria for copper and other metals, and result in metal leaching to waters potentially as far downstream as Iliamna Lake (U.S. EPA, 2022; Section 6). A tailings release would cause exceedances in water quality criteria for total suspended solids and some metals, release mercury that could bioaccumulate in fish, and potentially cause lethal acute metal toxicity in aquatic species (U.S. EPA, 2022; Section 6). The USACE ROD (USACE, 2020b) also acknowledges that although the probability of a full tailings storage facility dam breach is low, the consequences would be high. A major infrastructure failure could have severe and irreversible impacts to subsistence, commercial, and recreational fisheries. USACE states, “In the event of human error and/or a catastrophic event, the commercial and/or subsistence resources would be irrevocably harmed, and there is no historical scientific information from other catastrophic events to support restoration of the fishery to its pre-impacted state” (USACE, 2020b: Attachment B3: Page B3-27). Table 5-12 presents a summary of the four spill or failure risk scenarios that EPA Region 10’s recommended determination stated were applicable to the 2020 Mine Plan (U.S. EPA, 2022; Section 6), along with the projected impacts of each spill scenario.

Recent research has also found that quantitative spill risk assessments in Environmental Impact Statements (EISs) for Alaskan mine projects have underestimated actual mine-related spills, based on spill and release records from the Alaska Department of Environmental Conservation (Lubetkin, 2022). For the five largest hardrock mines in Alaska (Pogo, Kensington, Greens Creek, Fort Knox/True North, and Red Dog), EIS quantitative spill risk analysis focused on truck accident spills using the N = RT model, where N is the number of predicted spills, T is the total miles traveled by hazardous materials, and R is the spill rate per truck mile. Actual truck accident spills related to the five mines (n=114) exceeded predictions by 26.5 times. The EIS analyses did not estimate the frequency of other transportation-related spills (e.g., unsecured cargo, overfilled tanks) or other on-site spills (e.g., spills of hazardous materials from the processing facilities) for the five mines, although spill records indicate that such spill incidents are common (n=890 and n=7,153, respectively). In total, spill and release records show more than 8,150 total spills between 1995 and 2020 across the five mines, or an average of more than 300 toxic spills each year, and these spills released more than 2.3 million gallons and 1.9 million pounds of hazardous materials into the ecosystem (Lubetkin, 2022). The Lubetkin (2022) analysis did not describe the response or remediation of spills that occurred or the resultant environmental impacts.

Each of the five mines included in the Lubetkin (2022) analysis is substantially smaller, both in terms of total deposit size and annual mining rates, than the 2020 Mine Plan. The large size of the 2020 Mine Plan combined with the remote and seismically active location of the Pebble deposit (USACE, 2020a; Section 4.15) could increase the risk of spills at the Pebble deposit.

Table 5-12. Summary of Applicable Spill and Dam Failure Risk Scenarios

Spill Scenario	Projected Impacts
Tailings Dam Failure	The FEIS determined that in the event of a tailings dam failure, in addition to those impacts outlined in the tailings release event (third row, below), more extensive stream flow increases could occur, more habitat and streamflow could be buried, downstream waters would experience increased water quality criteria exceedances, sedimentation and turbidity, fish and aquatic species could experience extensive smothering effects, and spawning habitat would be impaired, Extensive harm could occur to commercial, recreational, and subsistence fish resources (USACE, 2020a; Section 4.27)
Release of Concentrate Slurry from the Concentrate Pipeline	The FEIS determined that in the event of a concentrate spill, concentrate would be difficult to recover, would cause Total Suspended Solids (TSS) and metals water quality criteria exceedances to downstream waters, potentially impact fish populations, cause potential future metal leaching from concentrate solids in the streams, cause displacement of fishing efforts, and cause contamination concerns for subsistence users (USACE, 2020a; Section 4.27)
Tailings Release from tailings pipeline incident or partial dam incident	The FEIS determined that in the event of a partial tailings release, tailings would cause TSS downstream, additional erosion from the release flood, water quality criteria exceedances due to dissolved metal, impacts to commercial, recreational and subsistence fishing, and psychosocial stress for local populations. (USACE, 2020a; Section 4.27)
Untreated Contact Water Release	The FEIS determined that in the event of untreated contact water release, water quality criteria exceedance would occur downstream due to dissolved metals fish populations would be exposed to the same dissolved metals leading to impacts to fish, and commercial, recreational and subsistence fishing efforts may be disrupted. (USACE, 2020a; Section 4.27)

Source: U.S. EPA (2022); Section 6.

6. RESULTS OF THE COST ASSESSMENT

The recommended determination to prohibit and restrict the use of certain waters in the Bristol Bay watershed as disposal sites for the discharge of dredged or fill material associated with mining at the Pebble deposit could result in a broad range of potential costs, if affirmed. The costs associated with the forgone investments and revenue of the 2020 Mine Plan are described in Section 6.1, the forgone estimated mineral production and impact to commodity markets are discussed in Section 6.2, and impacts to Alaska Natives, Tribes, and ANCs are discussed in Section 6.3. The dollar values presented in Section 6 are imported directly from the PEA (Kalanchey et al., 2022) and the IHS Markit report (IHS Markit, 2022). Those values do not account for the significant uncertainties identified above in Section 4.2. The dollar year of the estimates are not reported in either source.

6.1. Potential Costs

The recommended determination to prohibit and restrict the use of certain waters in the Bristol Bay watershed as disposal sites for the discharge of dredged or fill material associated with mining at the Pebble deposit, if affirmed, could result in several potential costs associated with reducing investments from the mine and reducing revenues from mine production. EPA Region 10 presents estimated costs decomposed into categories related to: construction phase expenditures, operating and maintenance phase expenditures, revenues of the mine (Kalanchey et al., 2022). Transfer payments and other financing costs, apart from taxes, are not presented due to the lack of regional economic activity that they generate.

6.1.1. PEA Analysis

Under the PEA analysis, during the 4.5-year construction phase, the 2020 Mine Plan could have total direct capital expenditures of $4,188.7 million, $1,304 million of sustaining capital expenditures, and $1,860.6 million of indirect, owner's and contingency costs.[66] Details on the categories of direct expenditures, and amounts per category, are presented in Table 6-1. Indirect expenditures represent a total of 20.5 percent of direct costs (Kalanchey et al., 2022; Section 21.2.4) and are allocated across the following categories to enable and support the construction activities: engineering and procurement, construction management, construction indirect costs, freight and logistics, first fills, spares, start up and commissioning, and vendor representation at site (Kalanchey et al., 2022; Table 21-12).

[66] Table 6-1 presents the direct and indirect economic costs of the mine for the full capital case.

Table 6-1. Construction Phase Estimated Expenditures of the 2020 Mine Plan			
Category	Sub-Category	Initial Capital ($ millions)	Sustaining Capital ($ millions)
Site General			
	Site earthworks and general construction	$64.90	
	Access and haul roads	$38.40	
	Electrical power distribution	$12.70	
Power Supply			
	Mine site power generation plant	$521.90	
	Marine terminal site power generation plant	$10.50	
Natural Gas Line			
	Off-shore natural gas pipeline (sub-sea placements)	$169.40	
	On-shore natural gas pipeline (trenching in roads)	$77.00	
Open Pit Mining			
	Pre-production stripping	$66.20	
	Mine equipment capital	$156.60	$218.70
	Miscellaneous mine capital	6.30	
Ore Handling to Mill			
	Primary crushing and stockpile feed	$91.50	
Process Plant			
	Stockpile, grinding, pebble-crushing	$433.00	
	Copper and Molybdenum flotation, regrind, bulk & pyritic tailings thickeners	$190.70	
	Molybdenum flotation	$34.50	
	Thickening & Molybdenum concentrate filtration	$39.00	
	Water & air systems	$17.50	
	Reagents	$21.60	
Earthworks, Tailing and Water Management			
	Earthworks	$639.00	$967.90
	Mechanical equipment	$100.30	$117.40
	Mobile equipment purchase	$268.90	
Water Treatment Plants			
	Water Treatment Plant #1 open pit water management pond	$64.70	
	Water Treatment Plant #2 main water management pond	$205.00	
On-site Infrastructure			
	Site buildings	$73.50	
	Site services and utilities	$15.00	
	Plant mobile fleet (not including mining equipment)	$9.00	
	Temporary facilities for construction	$131.30	
Concentrate Pipeline			
	Slurry and return water pipeline supply and installation	$115.00	

Table 6-1. Construction Phase Estimated Expenditures of the 2020 Mine Plan			
Category	Sub-Category	Initial Capital ($ millions)	Sustaining Capital ($ millions)
	Pumping station supply and installation	$70.00	
	Fiber optic cable for pipeline system control	$3.50	
Marine Terminal Site			
	Site civil works and utilities	$12.80	
	Auxiliary buildings	$6.10	
	Fuel receiving and storage system	$9.50	
	Mobile equipment	$9.10	
	Concentrate filtration plant	$38.50	
	Concentrate handling, storage, and barge loading	$58.10	
	Power distribution, lighting, and controls system	$8.30	
	Marine infrastructure (including dredging and tug purchase)	$103.30	
External Access Roads			
	Permanent access road construction	$274.90	
	Temporary bridges	$14.70	
	Mobile equipment purchase	$6.50	
Total Direct Cost		$4,188.70	$1,304.00
Total Indirect Cost		$857.20	
Total Owner's Costs		$325.00	
Total Contingency Costs		$678.40	
Total Cost		$6,049.30	$1,304.00

Source: Kalanchey et al., 2022.

During the 20-year operating and maintenance phase, the 2020 Mine Plan would have average annual direct operating and maintenance expenditures of $527.37 million. Details on the categories of expenditures, and amounts per category, are presented in Table 6-2.

Table 6-2. O&M Estimated Expenditures of Proposed Mine			
Category	Sub-category	2% Gold and 6% Silver Royalty Scenario	
		Annual Cost ($ millions)	Unit Cost ($ millions /ton milled)
General and Administrative			
	Administration office	$3.33	$0.05
	Mine site services	$5.52	$0.09
	Materials & other directs	$7.60	$0.12
	Overheads	$28.83	$0.45
	Labor transportation	$11.44	$0.18
Open Pit Mining			
	Drilling	$2.11	$0.03
	Blasting	$14.15	$0.22
	Loading	$9.58	$0.15
	Hauling	$33.36	$0.52
	Dewatering	$3.35	$0.05
	Support	$11.40	$0.18
	Ancillary	$2.03	$0.03
	Labor transportation	$34.72	$0.54
	Other	$2.00	$0.03
Mineralized Material Handling & Process Plant			
	Power	$92.20	$1.43
	Operating consumables		
	Reagents	$53.60	$0.83
	Mill media	$64.70	$1.00
	Liners	$17.50	$0.27
	Filters, laboratory and miscellaneous	$3.90	$0.06
	Maintenance consumables	$12.50	$0.19
	Labor	$24.60	$0.38
Tailings		$10.00	$0.16
Water Treatment Plant			
	Water Treatment Plant # 1	$3.01	
	Water Treatment Plant # 2	$18.45	
Concentrate Pipeline		$1.90	$0.03
Marine Terminal			
	Electrical power	$1.00	$0.02
	Maintenance consumables	$1.40	$0.02
	Labor	$10.50	$0.16
	Transhipment	$2.80	$0.04
External Access Roads [1]		$27.80	$0.45
Consumables Freight Costs		$10.20	$0.16
Total Cost		$527.37	$7.84

Source: Kalanchey et al., 2022

1 The 2022 PEA cost estimates differ in small ways from the 2021 PEA cost estimates, which resulted in the cost of External Access Roads falling slightly.

Over the lifetime of the mine, five types of metals are expected to be produced: copper, gold, molybdenum, silver, and rhenium. The PEA uses long-term metal price forecasts to estimate total revenues to the mine (Kalanchey et al., 2022). The total revenue produced over the lifetime of the mine, netting out realization charges,[67] is estimated to be $31,733 million. Details on revenue produced by metal type are presented in Table 6-3.

Table 6-3. Life of Mine Revenue Estimates

Metal	Price	$/ton Milled	Value Over LOM ($ millions)
Copper	$3.50/lb	$16.69	$21,536
Gold	$1,600/oz	$7.04	$11,404
Molybdenum	$10/lb	$2.32	$2,995
Silver	$22/oz	$0.56	$724
Rhenium	$,1500/kg	$0.24	$312
Total			$34,652
Realization Charges			$2,919
Net Smelter Return			$31,733

Source: Kalanchey et al. (2022)

The FEIS suggested annual full-time equivalent employment would be 2,000 during the capital expenditure phase and average 850 jobs per year during the operation of the mine (USACE, 2020a; Section 4.3).[68] Employment opportunities during operations for the local community may amount to 250 employees and another 650 from Anchorage or Kenai (USACE, 2020a; Section 4.3). During construction, it is possible that 50 percent of the required 2,000 jobs would come from out of state (USACE, 2020a; Section 4.3). Based on the estimated $9,497 monthly salary for these mining jobs (ADOL, 2017), labor income during the capital expenditure phase is estimated to be $227.93 million annually, and $96.87 million annually during operation of the mine.[69] The FEIS (USACE, 2020a; Section 4.3) notes, but does not estimate, that some employment will be seasonal or short term. As a result, the annual labor income may be overestimated depending on the proportion of seasonal or short-term employees. The FEIS also discussed the potential for mine-related access and spur roads and port to reduce transportation costs and for a mine-related natural gas pipeline to reduce heating fuel costs, depending

[67] Realization charges refer to any costs associated with the shipping of metal concentrate to smelters, and the smelting charges to treat and refine metals.

[68] The FEIS analyzed employment for Alternative 1 and suggested that Alternative 3 would have the same level of employment during construction. However, the FEIS also stated that O&M employment for Alternative 3 would be less than Alternative 1 but not by how much (USACE, 2020a; Section 4.3).

[69] Calculation: 2,000 employees in capital expenditure phase * 12 months * $9,497 monthly salary = $227.93 million; 850 employees in O&M phase *12 months * $9,497 monthly salary = $96.87 million.

on arrangements for their public use, which could lower the cost of living in nearby communities of Pedro Bay, Iliamna, Newhalen, and Nondalton (USACE, 2020a; Section 4.3).

6.1.2. IHS Markit Analysis

The IHS Markit economic impact assessment (IHS Markit, 2022) presents results in three time periods: the initial capital phase (construction of the mine), Year 1 – Year 5 of operation, and Year 6 – Year 20. The detailed results, representing total impacts (direct, indirect, and induced), are presented in Table 6-4.[70]

[70] Definitions and further descriptions of the IMPLAN model are found in Section 3.2.

Table 6-4. IHS Markit Average Economic Impact Summary				
Metric	Region	Initial Capital (Total over 4.5 years)	Year 1 – Year 5 (Average Annual)	Year 6 – Year 20 (Average Annual)
Jobs	Alaska	6,166	4,087	4,018
	Washington, Oregon, and California	1,591	493	511
	Rest of US	4,811	1,117	1,138
	Total	**12,569**	**5,698**	**5,667**
Economic Activity (Output)[1]	Value of Production (accrues to Alaska)		$1,813.0M	$1,759.0M
	Supply Chain and Induced Activity			
	Alaska	$973.9M	$748.6M	$744.3M
	Washington, Oregon, and California	$392.0M	$159.5M	$165.5M
	Rest of US	$1,106.9M	$277.9M	$280.9M
	Total	**$2,472.8M**	**$2,999.0M**	**$2,949.7M**
Gross Domestic Product or Gross State Product (Value Added)[2]	From Mine Production (accrues to Alaska)		$1,249.6M	$1,171.3M
	Alaska	$513.3M	$422.1M	$419.4M
	Washington, Oregon, and California	$176.6M	$61.6M	$64.0M
	Rest of US	$510.1M	$124.8M	$126.5M
	Total	**$1,200.0M**	**$1,858.1M**	**$1,781.1M**
Labor Income[3]	Alaska	$456.9M	$335.4M	$330.9M
	Washington, Oregon, and California	$119.4M	$43.2M	$44.8M
	Rest of US	$339.8M	$84.0M	$85.5M
	Total	**$916.1M**	**$462.7M**	**$461.1M**
Taxes (from operations and supply chain activity)	State Taxes			
	Alaska	$29.6M	$24.7M	$72.6M
	Washington, Oregon, and California	$17.3M	$5.7M	$5.9M
	Rest of US	$38.5M	$9.6M	$9.7M
	Extraction Taxes and Royalties		$37.8M	$85.9M
	Federal Taxes	$170.5M	$65.2M	$153.3M
	Total	**$256.0M**	**$143.1M**	**$327.4M**

Source: IHS Markit, 2022

1 Output is the value of production by industry in a calendar year. It can also be described as annual revenues plus net inventory change. The Output for wholesale and retail Industries represents their margin only; it does not represent revenues (sales). (IMPLAN, 2022b).

2 GDP/GSP/Value Added is defined as the total market value of all final goods and services produced within a region in a given period of time (usually a quarter or year). It is the sum of value added at every stage of production (the intermediate stages) for all final goods and services produced within a region in a given period of time. (IMPLAN, 2020).

3 Labor Income includes all forms of employment income, including employee compensation (wages, salaries, and benefits) and Proprietor Income. (IMPLAN, 2022a).

The IHS Markit economic impact assessment estimates are larger than those presented in the FEIS. Section 3.2 discusses the details of the model IHS used, but the difference is in most part explained by the fact that these results include direct, indirect, and induced impacts while the FEIS only included direct impacts. Total employment estimates from the IHS report during the 4.5 year long initial capital phase of the project are estimated to be 12,569 full time equivalent jobs, with average annual employment during Year 1 – Year 5 being 5,698 full time equivalent jobs and 5,667 during Year 6 – Year 20. Value added through employment and expenditures during the same three periods are estimated to be $1,200.0 million, $1,858.1 million, and $1,781.1 million for the initial capital, Year 1 – Year 5, and

Year 6 – Year 20 respectively. Estimated tax revenue from operations and supply chain activity are $256.0 million, $143.1 million, and $327.4 million for the initial capital, Year 1 – Year 5, and Year 6 – Year 20 periods. Annual state tax revenue to the State of Alaska is estimated to be $29.6 million, $24.7 million, and $72.6 million during the initial capital, Year 1 – Year 5, and Year 6 – Year 20 periods. Extraction Taxes and Royalties (which includes the Alaska Mining License, Municipal Severance Tax, Alaska State Royalty Tax, and Borough Taxes) during the operation period of the mine are estimated to be $37.8 million and $85.9 million during the Year 1 – Year 5 and Year 6 – Year 20 periods. As discussed in Section 4.2, a significant portion of these economic impacts, particularly in the short-run, are likely transfers from other areas of the national economy.

6.2. Estimated Mineral Production and Impacts to Commodity Markets

EPA utilized three data sources to assess the potential impact of the mineral production from the Pebble mine as described in the 2020 Mine Plan: the PEA produced by Northern Dynasty Minerals Ltd. (Kalanchey et al., 2022), the IHS Markit report (IHS Markit, 2022), and The Pathway for Copper to 2030 produced by RFC Ambrian (Bird, 2022). As noted in Section 4.2, the PEA and IHS studies include inferred resources in their mineral resource estimates and assume that all estimated mineral resources will be found to accurately represent mineral reserves. The RFC Ambrian report presents a global picture of various mines that could be developed/expanded to meet growing copper demand and as a result does not specify differences in deposits between measured, indicated, and inferred resources. Table 6-5 presents the production and deposit estimates for the five minerals examined in the PEA. Due to the relatively lower production levels of gold, molybdenum, silver, and rhenium, EPA did not analyze market impacts for those minerals.

Table 6-5. IHS, PEA and RFC Mineral Production and Deposit Estimates (Metric Tons)					
Source	Copper	Gold	Molybdenum	Silver	Rhenium
Production Estimates					
Final Pebble PEA [1]	2,791,022 MT	202 MT	135,851 MT	933 MT	208 MT
IHS Markit – Economic Impact Assessment of Pebble 2020 Mine Plan[1]	2,907,073 MT	208 MT	136,032 MT	1,037 MT	231 MT
RFC Ambrian – The Pathway for Copper to 2030	2,630,835 MT				
Pebble Mine Deposits Estimates					
Final Pebble PEA (Measured)	1,737,258 MT	168 MT	95,254 MT	796 MT	167 MT
Final Pebble PEA (Indicated)	24,303,479 MT	1,837 MT	1,456,031 MT	8,969 MT	2,443 MT
Final Pebble PEA (Measured + Indicated)[2]	25,818,477 MT	2,000 MT	1,551,285 MT	9,769 MT	2,615 MT
Final Pebble PEA (Inferred)	11,131,156 MT	1014 MT	1,006,975 MT	4,830 MT	1,603 MT
RFC Ambrian – Copper Projects Review (Measured + Indicated + Inferred)	33,529,548 MT				
IHS Markit – Economic Impact Assessment of Pebble 2020 Mine Plan (Measured + Indicated) [1]	25,854,765 MT	2,013 MT	1,542,214 MT	9,781 MT	2,600 MT
IHS Markit – Economic Impact Assessment of Pebble 2020 Mine Plan (Inferred)	11,339,809 MT	1,020 MT	997,903 MT	4,819 MT	1,600 MT

Source: Kalanchey et al. (2022); IHS Markit (2022); Bird (2022)

1: The PEA and IHS reported weights in lbs, ozs, and kgs, but they were converted to MT in order to be consistent with other sources.

Sources estimate that approximately 25.8 million metric tons of measured and inferred copper ore exist within the Bristol Bay deposit. The IHS report and PEA letter have similar values due to the fact that the IHS estimated economic impacts from mine production use the PEA production values. Due to the limited measures on minerals other than copper, the actual deposit sizes apart from copper are more difficult to definitively state. The source for the RFC Ambrian report is internal company data that is not open to the public while the source for the IHS/PEA numbers is a study done by a Northern Dynasty geologist. EPA was unable to obtain any third-party estimates of deposit size or production estimates for the mine in order to corroborate estimates from IHS/PEA.

The 2020 Mine Plan estimates that the project could produce approximately 153 thousand tons (Kalanchey et al., 2022) of copper annually along with lesser amounts of other metals. Over the life of the mine, this would amount to roughly 2.8 million metric tons of copper, 202 metric tons of gold, 135,851 metric tons of molybdenum, 933 metric tons of silver, and 208 metric tons of rhenium (Kalanchey et al., 2022). With copper being the main purpose of the mine, and a central metal used in the renewable energy transition, this analysis will focus on contextualizing the impact of the 2020 Mine Plan's copper production.[71] To put these values in the context of national and global consumption, the

[71] The low production levels of gold, molybdenum, silver, and rhenium are unlikely to impact the commodity markets for which they are destined. This expectation is based on both their low quantities as well as research indicating supply shocks on metal commodity prices are less significant than demand shocks (discussed further in this section).

additional copper produced annually is equal to between 3.3 and 6.9 percent of forecasted U.S. copper production, and less than 1 percent of global copper production (Flanagan, 2022).[72]

Though EPA Region 10 is unable to quantify the impact that the recommended determination, if affirmed, might have on commodity prices, the expectation is that the impacts would be negligible. This expectation is based on past research that shows that supply related shocks on metal commodity prices are less significant than demand shocks. Research on commodity prices has found that demand shocks are stronger drivers of commodity prices than supply shocks for a variety of commodities including copper (Jacks et al., 2016) and that supply shock impacts on prices are transitory (Stuermer, 2018). Due to the necessity of copper in renewable energy products, the anticipated demand shock over the coming decade is forecasted to increase the price of copper under base scenarios to over $10,000 per ton (Lanton et al., 2021), and under bullish scenarios to between $12,000 and $15,000 per ton (Lanton et al., 2021; Snowdon et al., 2021)[73] with prices remaining elevated due to the surge originating from demand increases. Demand for copper is relatively inelastic with an own-price elasticity[74] of demand of -0.4 (Stuermer, 2018). Therefore, to a limited extent (because of the inelasticity), as prices rise, demand for copper will decrease.

The 2020 Mine Plan could play a role in meeting U.S. demand for copper, but the extent of that role is uncertain in part due to the PEA's production estimate, which relies on indicated deposits to account for more than one-third of total estimated production (Table 6-5). Additional uncertainty comes from the likelihood that all of the copper extracted from the Pebble deposit will be exported to Asia and Europe (Kalanchey et al., 2022),[75] so this analysis considers the impacts on the global copper market, and the contribution to the U.S. based on the U.S.'s share of global copper demand. One reason for the oversees outsourcing of smelting is the current lack of domestic smelting capacity for production (Flanagan, 2022). The PEA outlines that during the 21st century, most new smelting capacity has been developed in Asia and Europe, and specifically references China, Japan, India, and Korea, and Europe as potential markets for the copper concentrate produced by the mine, with 50%, 20%, 20%, 5%, and 5% of the copper concentrate ending up in each of those markets respectively (Kalanchey et al., 2022). Table 6-6 presents forecasted demand and supply for 2030 and 2040 as those were the most common scenarios that aligned roughly with the estimated production period of the mine. Estimates are based on a variety of publicly available sources, and range in their anticipation of demand increases resulting from the renewable energy development. Global copper demand forecasts have significant variation over the 2030, and 2040 period ranging from 28.6 to 40.0 million metric tons in 2030 and 31.7 to 48.0 million metric tons in 2040. Supply forecasts vary similarly, based on anticipated permitting and construction of

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72 Based on 2021 U.S. Geological Survey Data, U.S. copper production amounted to 1.2 million metric tons and global copper production amounted to 21 million metric tons (Flanagan, 2022).

73 The price of copper is currently around $9,260 per ton (Flanagan, 2022)

74 Price elasticity of demand is the percent change in demand of an item from a 1% increase in the price.

75 "The copper-gold concentrate would be transported via buried pipeline from the mine site to the marine terminal where it would be filtered, loaded onto the lightering barges, and then unloaded directly into the holds of Handysize bulk carriers for shipment to smelter customers in Asia and Europe." (Kalanchey et al., 2022)

new mines, and varying adoption of recycling standards for copper. U.S. demand for copper comprises only 5.7% of global demand (Flanagan, 2022). If all the copper concentrate is exported to foreign refiners (as is stated in the PEA), then it is reasonable to assume the average U.S. proportion of global copper demand would return. The assumption that 5.7% of the mine's output would return to the domestic market represents approximately 0.2 to 0.3% of U.S. total copper demand (Table 6-6)[76]. Even this estimate could overstate the 2020 Mine Plan's contribution to domestic copper demand because 96 percent of U.S. refined copper imports come from South and North America (Chile (62%), Canada (23%), Mexico (11%)), and the U.S. imports only 4 percent of refined copper from other parts of the world (Flanagan, 2022). EPA did not conduct an analysis of the relative price differentials between refined copper outputs from North and South America versus Asia and Europe, but the quantities of 2020 Mine Plan copper concentrates being shipped to Asia and Europe are, as mentioned earlier in this section, unlikely to impact prices and therefore are unlikely to shift the distribution of refined copper imports between regions.

Table 6-6. Copper Market Analysis (Million Metric Tons)

	2020	2030	2040
Global Copper Demand[1,a,b,c,d,e]	25	28.6 - 40.0	31.7 - 48
"Ambitious" Global Copper Supply (Extraction)[2,a]	20.6	31.7	37.2
"Ambitious" Global Copper Supply (Recycling) [2,a]	3.9	7.7	11.2
"Rocky Road" Global Copper Supply (Extraction)[3,a]	20.6	28.1	36.8
"Rocky Road" Global Copper Supply (Recycling)[3,a]	3.9	5.8	7.6
Pebble Mine Contribution[4,f]	0	0.16	0.14
U.S. Demand Forecast[a,g,77]	2.2	3.0	3.5
Percent of U.S. Demand filled by Pebble Production[5]	-	0.3%	0.2%

Source: a: Bonakdarpour et al. (2022); b: Dominish et al. (2021); c: Bird (2022); d: IHS Markit (2022); e: IEA (2022); f: Kalanchey et al. (2022); g: He et al. (2022).

1: Global copper demand estimates were presented with fewer significant figures than the corresponding supply values.

2: In the "Rocky Road" scenario, mine utilization and recycling rates will not significantly change from what its average between 2012 and 2021 has been.

3: In the "Ambitious" scenario, mine utilization, the output as a percentage of total mine capacity, will rise from 84% to 96% by 2035 and recycling rates will increase.

4: These annual projection estimates assume construction on Pebble Mine begins in 2023, resulting in production commencing in 2027 after the four-and-a-half-year construction period.

5: U.S. proportions are based on reported mine production and the proportion of global demand represented by the U.S., assuming that the same proportion of Pebble deposit production would be supplied to meet global and U.S. demand respectively.

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[76] For 2030 estimate - 0.3% = (0.16 MMT (2020 Mine Plan average annual copper production) * 5.7% (Proportion of Global Demand Contributed by U.S.)/3.0 MMT (U.S. Copper Demand in 2030). For 2040 estimate – 0.2% = (0.14 MMT (2020 Mine Plan annual copper production in 2040) * 5.7% (Proportion of Global Demand Contributed by U.S.)/3.5 MMT (U.S. Copper Demand in 2040)

[77] Based on modeling by He et al. (2022) and Bonakdarpour et al. (2022), peak copper demand in the United States will occur near 2035 at roughly 4.3 million metric tons.

As noted in Table 6-6, recycling is an important aspect of the global copper supply to consider when forecasting growth scenarios, equaling 17% of copper demand under the "Rocky Road" scenario[78] and between 19.3% and 23.3% of global copper demand in the "Ambitious" scenario[79]. Current estimates of recycling rates for copper are around 17% of global demand and have the potential to reach 26% by mid-century (a 53% increase) as a result of increases to copper prices as demand rises (Bonakdarpour et al., 2022). Studies specifically focused on developing new recycling techniques to address the increased demand for lithium-ion batteries suggests that higher rates of recycling of copper could meet up to 55% of global copper demand in 2040 (Dominish et al., 2021)[80]. While that upper bound represents an ambitious forecast of recycling, the forecasted gap between extractive supply and the highest demand, in Table 6-6, of up to 11.9 million metric tons in 2030 and up to 11.2 million metric tons in 2040 under the "Rocky Road" scenario does not require such dramatic adoption of recycling. Under this scenario recycling would be required to meet 29.75% (11.9 million metric tons) of global demand in 2030, and 23.4% (11.2 million metric tons) in 2040 to satisfy shortfalls in extractive supply, and under the "Ambitious" scenario recycling would need to meet 20.75% (8.3 million metric tons) of global demand in 2030, and 22.5% (10.8 million metric tons) in 2040 (Bonakdarpour et al., 2022). These levels of recycling are achievable, as they all fall within the 26% upper bound estimate from Bonakdarpour et al. (2022), reinforcing the need to consider recycling as a key driver to meeting the increase in global and U.S. copper demand in the coming years.

Impacts to the U.S. copper industry from the production of the 2020 Mine Plan extend downstream to manufacturers who require refined copper for their inputs. The impacts to the U.S. copper market in terms of copper sales and supported jobs were also estimated by the IHS Markit in a separate economic impact analysis. The methodology used in the IHS report, detailed in Section 3.2, resulted in downstream estimated economics impacts of $350 million to $610 million and 850 to 1,500 full time equivalent jobs. These downstream economic impacts of the mine are based on the assumption that other sources of copper, either from mined ore concentrates, or manufacturing and post-consumer scrap will not take the place of the 2020 Mine Plan output. In addition, as discussed in Section 4.2 the estimated downstream impacts in the IHS report rely on the assumption that 100 percent of the 2020 Mine Plan production is consumed in the U.S., which as discussed in this section and based on Kalanchey et al. (2022), it is more likely that only 5.7% or less of the mine's production is consumed in the U.S. Table 6-7 shows recent copper production and refining amounts for the U.S. Based on this data it is likely that domestic copper production exceeds refining capacity. As a result, it is unlikely that marginal increases to U.S. copper production, such as those that would come from the 2020 Mine Plan's production, would be refined in the U.S.

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[78] In the "Rocky Road" scenario, mine utilization and recycling rates will not significantly change from what its average between 2012 and 2021 has been.

[79] In the "Ambitious" scenario, mine utilization, the output as a percentage of total mine capacity, will rise from 84% to 96% by 2035 and recycling rates will increase.

[80] Under that upper bound scenario, recycled copper production would be approximately between 17.4 and 26.4 million metric tons.

Table 6-7. U.S. Domestic Copper Production and Refining (Thousand Metric Tons)			
	2019	2020	2021
U.S. Copper Production	1,260	1,200	1,200
U.S. Copper Refining Capacity	985	874	950
U.S. Copper Ore Exports	353	383	360
U.S. Refined Copper Imports	663	676	920
U.S Refining Deficit (Production – Refining)	275	326	250

Source: Flanagan (2022)

Copper substitution effects may also alleviate any supply shortfalls. Copper substitutes are limited to materials with similar properties and must be produced in similarly large quantities. For copper, materials like aluminum, titanium, and plastics can be used as substitutes in applications like electrical appliances, heat exchangers, and plumbing appliances respectively (Dominish et al., 2021)[81]. For aluminum, sustained substitution of copper could be achieved due to consistent supply surplus (Bray, 2022), whereas titanium would be less achievable due to limited supply (Gambogi, 2022). Global demand values presented in Table 6-6 do not specify if substitution is considered in the forecasts. Higher copper prices will make marginal substitutions more economically feasible and would contribute towards meeting the copper demand that would otherwise have been met by the 2020 Mine Plan, reducing the necessity of developing the Pebble deposit.

6.3. Impacts to Alaska Natives, Tribes, and ANCs

The recommended determination, if affirmed, could reduce some economic opportunities for Alaska Natives, Tribes, and ANCs (see Section 5.2, 5.3, 5.4, 5.7, and 5.10 above for benefits). A portion of the economic activity supported by the 2020 Mine Plan as presented in Section 6.1 could accrue to the Alaskan Natives, Tribes, and ANCs in the Bristol Bay region. One possible avenue for this is the Pebble Performance Dividend payment. The PEA (Kalanchey et al., 2022) claims it would "distribute a 3 percent net profits royalty interest in the Pebble Project to adult residents of Bristol Bay villages that have subscribed as participants. The Pebble Performance Dividend will distribute a guaranteed minimum annual payment of $3 million each year the Pebble mine operates, beginning at the outset of Project construction." The PEA estimates this could amount to a total payment over the 24.5-year period of construction and operation of between $200 million to $240 million. However, as discussed in Section 4.2, there is significant uncertainty around the potential profits of the mine and therefore the ability of the mine to pay out more than the minimum annual payment in any given year.

In addition to the dividend payment, Alaska Natives, Tribes, and ANCs may be helped by the indirect and induced economic activity occurring as a result the 2020 Mine Plan through employment or income generated by economic activity generated by the mine. The extent to which job opportunities from this

[81] Dominish et al. (2021) and the USGS copper report (Flanagan, 2022) discuss the potential for plastic as a substitute for copper in plumbing applications, however neither source provides an estimate of the supply gap or surplus for plastics that would allow the Agency to determine the scope of the potential substitution.

economic activity would extend to Alaska Natives, Tribes, and ANCs depends on job specific requirements such as special skills, education level, and the location within Alaska of employment supported by the mine and supported economic activity in the supply chain.[82] During the exploration phase of the mine site, approximately 43 percent of workers were from Bristol Bay communities (Loeffler et al., 2017).[83] Employment opportunities physically on the mine site are likely to be a small portion of the overall economic impacts. For example, the PEA estimates that 158 mine site positions (Table 21-19; Kalanchey et al., 2022) would be staffed for processing and maintenance and 71 marine terminal positions (Kalanchey et al., 2022; Section 21.3.8) would be staffed for operation and maintenance of the terminal site; a total of 229 positions, compared to the annual average direct jobs of 850 O&M jobs in Alaska (USACE, 2020a; Section 4.3). Alaska Natives in the Bristol Bay region are more likely to have access to positions on the mine site than other employment opportunities across Alaska, and thus the jobs available to Alaska Natives would likely be limited.

The economic impacts to local communities are also likely limited, at least compared to the economic impacts estimated elsewhere (Section 6.1). In Section 6.1, the IHS Markit report estimates that 49% or 6,158 of the 12,569 created jobs will be filled by Alaskans. The majority of these jobs, potentially filled by Alaskans, would be primarily from individuals who live in other parts of the state that, unless they move to the region, will remit a portion of their income to other regions. This is because the adult population of the three counties surrounding the Pebble deposit is 5,077, which is lower than the number of estimated jobs filled by Alaskans (IHS Markit, 2022). It is estimated that population, employment, and income in communities near the project and its components may increase (USACE, 2020a, pg. 4.3-2). Given these population statistics, the estimated economic impact on the region may be less than or greater than anticipated.

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[82] According to PLP's CWA Section 404 permit application there would be "access agreements with Alaska Native Claims Settlement Act (ANCSA) Village Corporations include bidding and employment preferences, revenue sharing, and other benefits to enhance local employment and revenue generation." (Pebble Limited Partnership, 2020).

[83] The Loeffler et al. (2017) study found that approximately 125 jobs were annually held by individuals in communities less than 100 miles from the mine site. 19 percent of jobs held at any time by individuals from these communities had the title drill helpers, 10 percent skilled laborers, 9 percent kitchen assistants, and 12 percent bear guards. The remaining 50 percent of jobs were a variety of non-skilled and skilled positions.

7. REFERENCES

Adamowicz, W., Asapu-Adjaye, J., Boxall, P., & Phillips, W. (1991). Components of the Economic Value of Wildlife: An Alberta Case Study. *The Canadian Field Naturalist, V. 105, No. 3. pp. 423-429.*

ADOL. (2017). Preliminary Third Quarter Employment and Wages: July - September 2017.

Alaska Department of Fish and Game. (2022). Alaska Sport Fishing Survey database [Internet].

Alaska Department of Fish and Game. (2022b). *Bristol Bay Salmon Season Summary*.

Alaska Seafood Marketing Institute. (2019). Alaska Seafood at Food Service.

Altor, A. E., & Mitsch, W. J. (2006). Methane Flux from Created Riparian Marshes: Relationship to Intermittent Versus Continuous Inundation and Emergent Macrophytes. *Ecological Engineering,, 28(3), 224-234.*

Ameli, A. A., & Creed, I. F. (2019). Does Wetland Location Matter When Managing Wetlands for Watershed-Scale Flood and Drought Resilience? *JAWRA Journal of the American Water Resources Association, 55(3), 529-542.* .

Arp, C. D., & Cooper, D. J. (2004). . (2004). Analysis of Sediment Retention in Western Riverine Wetlands: The Yampa River Watershed, Colorado, USA. *Environmental Management,, 33(3), 318-330.* doi:doi:10.1007/s00267-004-0027-8

Bateman, I. J., & Kling, C. L. (2020). Revealed preference methods for nonmarket valuation: An introduction to best practices. *Review of Environmental Economics and Policy*.

Bell, K. P., Huppert, D., & Johnson, R. L. (2003). Willingness to pay for local coho salmon enhancement in coastal communities. *Marine Resource Economics, 18*(1), 15-31.

Bird, D. (2022). *The Pathway for Copper to 2030*.

Bjornn, T. C., & Reiser, D. W. (1991). *Habitat Requirements of Salmonids in Streams*. Retrieved from

Bonakdarpour, M., & Bailey, T. M. (2022). *The Future of Copper: Will the looming supply gap short-circuit the energy transition?* Retrieved from

Boraas, A., & Knott, C. (2013). *Traditional Ecological Knowledge and Characterization of the Indigenous Cultures of the Nushagak and Kvichak Watersheds, Alaska*. Anchorage, AK

Borden, R. (2021). *Subject: Review of the Pebble Mine Project Preliminary Economic Assessment.*

Bray, E. (2022). *Mineral Commodity Summaries 2022: Aluminum*.

Bridgham, S. D., Megonigal, J. P., Keller, J. K., Bliss, N. b., & Trettin, C. (2006). The Carbon Balance of North American Wetlands. *Wetlands, 26(4): 889-916.*

Bristol Bay Native Corporation. (n.d.). PEBBLE MINE POLLING UPDATE.

Bristol Bay Regional Seafood Development Association. (2022a). *Public Comment Letter Re: Docket ID No. EPA-R10-OW-2022-0418 (EPA Region 10's Revised Proposed Determination relating to the Pebble Deposit Area, Southwest Alaska)*. Retrieved from

Bristol Bay Regional Seafood Development Association. (2022b). Retail Promotional Prices for Sockeye & Atlantic Salmon, 2013-2022.

Carson, R., Mitchell, R., Hannemann, W., Presser, S., & Ruud. P. (1992). *A Contingent Valuation Study of Lost Passive Use Values Resulting from the Exxon Valdez Oil Spill*.

Carson, R. T., Hanemann, W. M., & Wegge, T. C. (2009). A Nested Logit Model of Recreational Fishing Demand in Alaska. *Marine Resource Economics, 24(2), 101-129*.

CIM Standing Committee on Reserve Definitions. (2014). CIM Definition Standards for Mineral Resources & Mineral Reserves.

David Binder Research. (2020). *Alaska Voters Strongly Oppose Pebble Mine and Would Support an EPA Veto*.

Dedah, C., Keithly Jr, W. R., & Kazmierczak Jr, R. F. (2011). An analysis of US oyster demand and the influence of labeling requirements. *Marine Resource Economics, 26*(1), 17-33.

Dominish, E., Florin, N., & Wakefield-Rann, R. (2021). *Reducing new mining for electric vehicle battery metals: responsible sourcing through demand reduction strategies and recycling*.

Doogan, S. (2014, May 11, 2016). Minimum Wage, Anti-Pebble Measures Pass Easily.

Douglas, A. J., & Taylor, J. G. (1999). The Economic Value of Trinity River Water. *International Journal of Water Resources Development, 15*(3), 309-322. doi:10.1080/07900629948835

Duffield, J. (1997). Nonmarket valuation and the courts: The case of the Exxon Valdez. *Contemporary Economic Policy, 15*(4), 98-110.

Duffield, J., Neher, C., Patterson, D., Knapp, G., Schwörer, T., Fay, G., & Goldsmith, O. S. (2013). Bristol Bay Wild Salmon Ecosystem: Baseline Levels of Economic Activity and Values. 224.

Evenson, G. R., Golden, H. E., Lane, C. R., McLaughlin, D. L., & D'Amico, E. (2018). Depressional Wetlands Affect Watershed Hydrological, Biogeochemical, and Ecological Functions. *Ecological Applications,, 28(4), 953-966.*

Figge, F. (2004). Bio-folio: applying portfolio theory to biodiversity. *Biodiversity & Conservation, 13*(4), 827-849. doi:10.1023/B:BIOC.0000011729.93889.34

Finn, R., J. R. . (2021). Quantifying lost and inaccessible habitat for Pacific salmon in Canada's Lower Fraser River. *Ecosphere, v. 12*(no. 7), pp. e03646--02021 v.03612 no.03647. doi:10.1002/ecs2.3646

Flanagan, D. M. (2022). *Mineral Commodity Summaries 2022: Copper*.

Gambogi, J. (2022). *TITANIUM MINERAL CONCENTRATES*.

Ghaffari, H., R. S. Morrison, M. A., d., A. Živković, T. Hantelmann, D. Ramsey, & Cowie, S. (2011). *Preliminary Assessment of the Pebble Project, Southwest Alaska*. Vancouver, B.C.: Prepared for NDML by WARDROP (a Tetra Tech Company)

Goldsmith, S., Hill, A., Hull, T., Markowski, M., & Unsworth, R. (1998). Economic Assessment of Bristol Bay Area National Wildlife Refuges: Alaska Peninsula/Becharof, Izembek, Togiak. *Report of the US Department of Interior, Fish and Wildlife Service*.

Griffiths, J. R., Schindler, D. E., Armstrong, J. B., Scheuerell, M. D., Whited, D. C., Clark, R. A., . . . Volk, E. C. (2014). Performance of salmon fishery portfolios across western North America. *The Journal of Applied Ecology, 51*, 1554 - 1563.

Hall, J. V., Frayer, W. E., & Wilen, B. O. (1994). Status of Arctic Coastal Plain PALUSTRINE OPEN WATER AND EMERGENT - FLOODED Alaska Wetlands.

Hanley, N., Shogren, J., & White, B. (2019). *Introduction to environmental economics*: Oxford University Press.

Harvey, J. W., Krupa, S. L., & Krest, J. M. (2004). Ground Water Recharge and Discharge in the Central Everglades. *Groundwater,, 42(7), 1090-1102.* doi:doi:10.1111/j.1745-6584.2004.tb02646.x

He, R., & Small, M. J. (2022). Forecast of the U.S. Copper Demand: a Framework Based on Scenario Analysis and Stock Dynamics. *Environmental Science & Technology, 56*(4), 2709-2717. doi:10.1021/acs.est.1c05080

Heimer, T. K. (2018). Poll Finds Overwhelming Local Opposition to the Pebble Mine.

Hopkins, K. G., Noe, G. B., Franco, F., Pindilli, E. J., Gordon, S., Metes, M. J., & Hogan, D. M. (2018). A Method to Quantify and Value Floodplain Sediment and Nutrient Retention Ecosystem Services. *Journal of Environmental Management,, 220, 65-76.*

IHS Markit. (2022). *Economic Contribution Assessment of the Proposed Pebble Project to the US National and State Economies*. Retrieved from

IMPLAN. (2020). Understanding IMPLAN: Measures of GDP.

Jacks, D., & Stuermer., M. (2016). *What Drives Commodity Price Booms and Busts?*

Jordan, S. J., O'Higgins, T., & Dittmar, J. A. (2012). Ecosystem Services of Coastal Habitats and Fisheries: Multiscale Ecological and Economic Models in Support of Ecosystem-Based Management. *Marine and Coastal Fisheries, 4*(1), 573-586. doi:10.1080/19425120.2012.703162

Kalanchey, R., Ghaffari, H., Hafez, S. A., Galbraith, L., Gaunt, J. D., Titley, E., . . . Lang, J. (2021). *Pebble Project Preliminary Economic Assessment NI 43-101 Technical Report*.

Kalanchey, R., Ghaffari, H., Hafez, S. A., Galbraith, L., Gaunt, J. D., Titley, E., . . . Lang, J. (2022). *Pebble Project Preliminary Economic Assessment NI 43-101 Technical Report Update*.

Lanton, M., Nugent, O., Liao, T. X., Morse, E. L., Doshi, A., Ravi, E., . . . Shang, J. (2021). *Copper Book: 2021-2030 Outlook; New framework predicts decarbonisation-led bull market*.

Lawrence, C. B., Pindilli, E. J., & Hogan, D. M. (2019). Valuation of the Flood Attenuation Ecosystem Service in Difficult Run, VA, USA. *Journal of Environmental Management,, 231, 1056-1064.*

Layman, R. C., Boyce, J. R., & Criddle, K. R. (1996). Economic valuation of the Chinook salmon sport fishery of the Gulkana River, Alaska, under current and alternate management plans. *Land Economics, 72*(1), 113-128. doi:10.2307/3147161

Lew, D. K., & Larson, D. M. (2012). Economic Values for Saltwater Sport Fishing in Alaska: A Stated Preference Analysis. *North American Journal of Fisheries Management, 32*(4), 745-759.

Lindley, S. T., Grimes, C. B., Mohr, M. S., Peterson, W. T., Stein, J. E., Anderson, J. J., . . . Williams, T. H. (2009). What caused the Sacramento River fall chinook stock collapse.

Loeffler, B., & Schmidt, J. (2017). Local Jobs and Income from Mineral Exploration A Case Study of the Pebble Exploration Project. *University of Alaska Anchorage*.

Loomis, J. B. (2012). Comparing households' total economic values and recreation value of instream flow in an urban river. *Journal of Environmental Economics and Policy, 1*(1), 5-17. doi:10.1080/21606544.2011.640855

Loomis, J. B., & White, D. S. (1996). Economic Values of Increasingly Rare and Endangered Fish. *Fisheries, 21*(11), 6-10.

Loomis, M. J., & Craft, C. B. (2010). Carbon Sequestration and Nutrient (Nitrogen, Phosphorus) Accumulation in River-Dominated Tidal Marshes, Georgia, USA. *Soil Science Society of America Journal, 74*(3), 1028-1036.

Lubetkin, S. (2022). *Alaska Mining Spills: A comparison of the predicted impacts described in permitting documents and spill records from five major operational hardrock mines*.

Martinez-Martinez, E., Nejadhashemi, A. P., Woznicki, S. A., & Love, B. J. (2014). Modeling the Hydrological Significance of Wetland Restoration Scenarios. *Journal of Environmental Management,, 133, 121-134.*

McDowell Group. (2015). *Ties that Bind: The Enduring Economic Impact of Alaska on the Puget Sound Region*.

McKinley Research Group. (2021). *The Economic Benefits of Bristol Bay Salmon*.

Mendonça, R., Müller, R. A., Clow, D., Verpoorter, C., Raymond, P., Tranvik, L. J., & Sobek, S. (2017). Organic carbon burial in global lakes and reservoirs. *Nature Communications, 8*(1), 1694. doi:10.1038/s41467-017-01789-6

Meyer, J. L., Strayer, D. L., Wallace, J. B., Eggert, S. L., Helfman, G. S., & Leonard, N. E. (2007). The Contribution of Headwater Streams to Biodiversity in River Networks1. *JAWRA Journal of the American Water Resources Association, 43*(1), 86-103.

Midgard Environmental Services LLC. (2021). Review of the Pebble Mine Project Preliminary Economic Assessment.

Mitsch, W. J., Bernal, B., Nahlik, A. M., Mander, Ü., Zhang, L., Anderson, C. J., & Brix, H. (2013). Wetlands, Carbon, and Climate Change. *Landscape Ecology,, 28(4), 583-597.* doi:doi:10.1007/s10980-012-9758-8

Moore, J. (2015). Bidirectional connectivity and implications for watershed stability and management. *Canadian Journal of Fisheries and Aquatic Sciences, 72*, 785-795. doi:10.1139/cjfas-2014-0478

Nag, S. K., Liu, R., & Lal, R. (2017). Emission of Greenhouse Gases and Soil Carbon Sequestration in a Riparian Marsh Wetland in Central Ohio. *Environ Monit Assess, 189(11), 580.* doi:doi:10.1007/s10661-017-6276-9

Nahlik, A. M., & Fennessy, M. S. (2016). Carbon Storage in US Wetlands. *Nature Communications, 7(1), 1-9*.

National Center for Environmental Economics. (2010). *Guidelines for Preparing Economic Analyses*.

Olsen, D., Richards, J., & Scott, R. D. (1991). Existence and Sport Values for Doubling the Size of the Columbia River Basin Salmon and Steelhead Runs. *Rivers, 2*(1), 44-56.

Pebble Limited Partnership. (2020). *Pebble Project Department of the Army Application for Permit* (POA-2017-271).

Penteriani, V., López-Bao, J. V., Bettega, C., Dalerum, F., del Mar Delgado, M., Jerina, K., . . . Ordiz, A. (2017). Consequences of brown bear viewing tourism: A review. *Biological Conservation, 206*, 169-180.

Powell, J. (2022). Chair Powell's Press Conference - January 26, 2022 [Press release].

Ruggerone, G. T., Peterman, R. M., Dorner, B., & Myers, K. W. (2010). Magnitude and Trends in Abundance of Hatchery and Wild Pink Salmon, Chum Salmon, and Sockeye Salmon in the North Pacific Ocean. *Marine and Coastal Fisheries, 2*(1), 306-328.

Schindler, D. E., Armstrong, J. B., & Reed, T. E. (2015). The portfolio concept in ecology and evolution. *Frontiers in Ecology and the Environment, 13*(5), 257-263.

Schindler, D. E., Hilborn, R., Chasco, B., Boatright, C. P., Quinn, T. P., Rogers, L. A., & Webster, M. S. (2010). Population diversity and the portfolio effect in an exploited species. *Nature, 465*(7298), 609-612. doi:10.1038/nature09060

Sha, C., Mitsch, W. J., Mander, Ü., Lu, J., Batson, J., Zhang, L., & He, W. (2011). Methane Emissions from Freshwater Riverine Wetlands. *Ecological Engineering,, 37(1), 16-24.*

Sha, S., Santos, J. I., Roheim, C. A., & Asche, F. (2015). Media coverage of PCB contamination of farmed salmon: The response of US import demand. *Aquaculture economics & management, 19*(3), 336-352.

Snowdon, N., Sharp, D., & Currie, J. (2021). Green Metals; Copper is the New Oil. *Goldman Sachs Commodities Research*.

Stuermer, M. (2018). 150 Years of Boom and Bust: What Drives Mineral Commodity Prices? *Macroeconomic Dynamics*(22 (3): 702-717.).

Tang, Y., Leon, A. S., & Kavvas, M. (2020). Impact of Size and Location of Wetlands on Watershed-Scale Flood Control. *Water Resources Management,, 34(5), 1693-1707.*

Tangen, B. A., & Bansal, S. (2020). Soil Organic Carbon Stocks and Sequestration Rates of Inland, Freshwater Wetlands: Sources of Variability and Uncertainty. *Science of The Total Environment, 749, 141444*.

Tiernan, A., Elison, T., Head, J., & Vega, S. (2021). *2020 Bristol Bay Area Annual Management Report*.

Tüzemen, D. (2022). *Labor Market May Remain Tight until Labor Demand Cools Further*.

U.S. Army Corps of Engineers. (2020a). Pebble Project EIS: Environmental Impact Statement.

U.S. Army Corps of Engineers. (2020b). *Record of Decision for Application Submitted by Pebble Limited Partnership*.

U.S. Bureau of Labor Statistics. (2020-2022). BLS Data Viewer.

U.S. Census Bureau. (2020). American Community Survey: Employment Status (S2301).

U.S. Environmental Protection Agency. (2009). *Environmental Impact and Benefits Assessment for Final Effluent Guidelines and Standards for the Construction and Development Category*. (EPA-HQ-OW-2008-0465; FRL-9086-4; 2040-AE91).

U.S. Environmental Protection Agency. (2010). *Guidelines for Preparing Economic Analyses*.

U.S. Environmental Protection Agency. (2015). *Benefit and Cost Analysis for the Effluent Limitations Guidelines and Standards for the Steam Electric Power Generating Point Source Category*. (EPA-821-R-15-005).

U.S. Environmental Protection Agency (2017). [SAB Advice on the Use of Economy-Wide Models in Evaluating the Social Costs, Benefits, and Economic Impacts of Air Regulations].

U.S. Environmental Protection Agency. (2022). *Recommended Determination of the U.S. Environmental Protection Agency Region 10 Pursuant to Section 404(c) of the Clean Water Act, Pebble Deposit Area, Southwest Alaska*.

U.S. Office of Management and Budget. (2003). *Circular A-4: Regulatory Analysis*.

Walsh, R., Bjonback, R., Rosenthal, D., & Aiken, R. (1985). Public Benefits of Programs to Protect Endangered Wildlife in Colorado, Symposium on Issues and Technology in Management of Impacted Western Wildlife. *Thorne Ecological Institute*.

Walsh, R., Loomis, J., & Gillman, R. (1984). Valuing Option, Existence, and Bequest Demands for Wilderness. *Land Economics, Vol. 60, No. 1, pp. 14-29.*

Watson, B., Reimer, M. N., Guettabi, M., & Haynie, A. (2021). Commercial fisheries & local economies. *Journal of Environmental Economics and Management, 106*, 102419.

Watson, K. B., Ricketts, T., Galford, G., Polasky, S., & O'Niel-Dunne, J. (2016). Quantifying Flood Mitigation Services: The Economic Value of Otter Creek Wetlands and Floodplains to Middlebury, VT. *Ecological Economics,, 130, 16-24.*

Wessells, C. R., Miller, C. J., & Brooks, P. M. (1995). Toxic algae contamination and demand for shellfish: a case study of demand for mussels in Montreal. *Marine Resource Economics, 10*(2), 143-159.

Williams, C., & Tufford, D. (2015). Groundwater Recharge Rates in Isolated and Riverine Wetlands: Influencing Factors. *Journal of South Carolina Water Resources,, 2(1).*

Wu, K., & A. Johnston, C. (2008). Hydrologic Comparison Between a Forested and a Wetland/Lake Dominated Watershed Using SWAT. *Hydrological Processes,, 22(10), 1431-1442.*

Yang, Y., Hobbs, J. E., & Natcher, D. C. (2020). Assessing consumer willingness to pay for Arctic food products. *Food Policy, 92*, 101846.

Young, T. B. (2019). *McNeil River State Game Sanctuary permit lottery applicant preferences and marginal willingness to pay for permit application: a best-worst discrete choice experiment*: University of Alaska Fairbanks.