Chapter 2
The Pebble Project

In 1988, Cominco America Inc. began investigating a low-grade copper-gold-molybdenum ore body on Alaska state land in a region within the Bristol Bay basin now known as the Pebble deposit. In 2001, Cominco sold its claims to Vancouver, B.C.-based Northern Dynasty Minerals, which further explored the prospect, found additional resources, and announced plans to mine the deposit. In 2007, a wholly-owned affiliate of Northern Dynasty joined a wholly-owned subsidiary of England's Anglo American PLC, one of the largest mining and natural resource corporations in the world, to create the Pebble Limited Partnership (PLP) and to mine the prospect.

One year prior to this merger, in support of water withdrawal permit applications that were subsequently suspended, Northern Dynasty submitted preliminary designs for a large-scale hard rock mine at the Pebble prospect. This initial concept, shown in Figures 2a and 6, proposed two large tailings storage facilities in addition to an open pit, process plant, road/pipeline corridor, port, and other infrastructure (Knight Piesold Consulting 2006a, 2006b). In early 2011, Wardrop Engineering Inc., working on behalf of Northern Dynasty, completed the "Preliminary Assessment of the Pebble Project" (Preliminary Assessment), which presented—among other scenarios—a short-term (25-year) development concept envisioning a single large tailings storage facility, shown in Figure 2b (Ghaffari et al. 2011). The Preliminary Assessment also called for a 378 MW on-site power plant.

The preliminary plans and designs described in these documents represent the most comprehensive and up-to-date scenarios available for consideration of a large-scale mining operation at the Pebble site. The authors of this report have used these preliminary plans to characterize the scope and extent of the scenarios most likely being considered to mine the Pebble deposit. The PLP is expected to release a formal Prefeasibility Study of the Pebble Mine and to initiate the permitting process in 2012. However, it is routine for numerous operating details to change after permits have been approved.

> *The Pebble Project will be a large industrial facility located within a vast region of Alaska notable for its undeveloped wilderness, isolated and sparsely populated communities, Alaska Native culture and traditional ways of life, significant salmon fisheries, and other fish and wildlife populations.*
>
> —"Preliminary Assessment of the Pebble Project" (Ghaffari et al. 2011)

2.1 *Pebble Mine Project Overview*

The Pebble Mine claim lies within the headwaters of the Nushagak and Kvichak watersheds, two of the world's largest sockeye salmon-producing rivers (Burgner 1991, Sands et al. 2008). The site includes currently productive salmon habitat (Woody and O'Neal 2010) and encompasses a transition zone between the largely unforested coastal lowlands and the forested interior uplands. In the watersheds' lower elevations, patches of willow and alder cover a gently rolling terrain studded with lakes, kettle ponds, sedge meadows, and wetlands. Further up the drainages, at the prospect site, the soils and vegetation are mostly hydric, indicating high connectivity between surface and groundwater. Intersecting this complex landscape, mainstem rivers meander through broad floodplains that support stands of spruce, birch, and balsam poplar (Viereck et al. 1992, Gallant et al. 1995, Nowacki et al. 2001).

The Pebble deposit is composed primarily of chalcopyrite ($CuFeS_2$) and bornite (Cu_5FeS_4) (NDM Ltd. 2007). Both deposits are referred to as *sulfide ores*, because copper is combined with iron and sulfur. Sulfide ores typically form sulfuric acid when exposed to oxygen and water.

Copper (Cu), gold (Au), and molybdenum (Mo) are the primary commercially valuable minerals that will be extracted from the Pebble Mine, although in similar porphyry copper deposits around the world, additional metals and metalloids are sometimes extracted, such as selenium, mercury, and uranium. Silver, rhenium, and palladium are expected to be extracted as accessory products (Ghaffari et al. 2011).

The region of copper-gold-molybdenum mineralization includes an area of roughly 5.3 square miles situated on a drainage divide, with the Upper Talarik Creek draining to the southeast, and the North and South forks of the Koktuli River draining to the west and southwest (Knight Piesold Consulting 2006a). The deposit reaches a depth of 2,000 feet in its western reach, known as *Pebble West*, and at least 5,000 feet in its eastern zone, *Pebble East* (Figure 3) (Ghaffari et al. 2011).

Commissioned by Northern Dynasty, the Preliminary Assessment provides three Pebble Mine "development cases", which consider mining operations under 25, 45, and 78-year time horizons. According to the

MINING AND MINERAL PROCESSING BASICS

Mineralized rock containing economically valuable mineral content is called ore. Ore is mined from either open pits or underground excavations using explosives and then transported to a processing plant using huge trucks or conveyer belts. Much of the rock removed from either an open pit or underground workings contains metal concentrations that are too low to be processed economically. This material, waste rock, is often discarded in huge piles somewhere near the pit perimeter.

At mines similar to the proposed Pebble operation, the ore is transported to a process plant where it is crushed. Massive quantities of process chemicals and water are added to the ore to extract the commercial metals. The resulting waste is often a mix of approximately 50% liquid and 50% solid particles, called tailings. This mix—a "chemical soup" containing literally hundreds of different potentially toxic compounds—is then discharged to a tailings impoundment, where the tailings are stored forever.

Figure 2a. Preliminary designs presented by Northern Dynasty in 2006 proposed two tailings storage facilities (TSFs) at Sites A and G (Knight Piesold Consulting 2006a, 2006b). Combined, these TSFs can store 2.5 billion tons of mine waste, less than a quarter of the estimated 10.8 billion tons of ore on site.

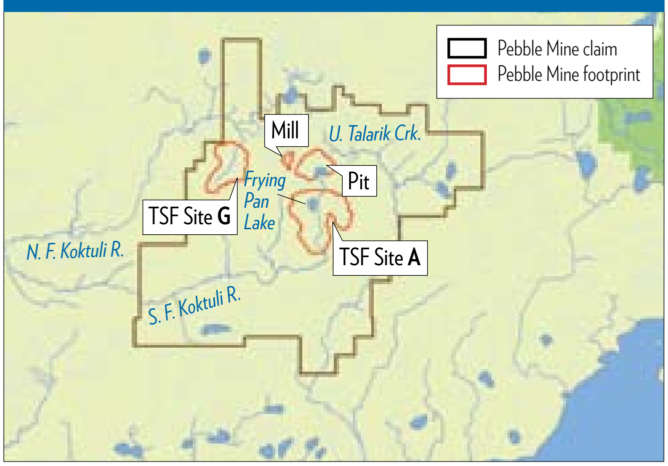
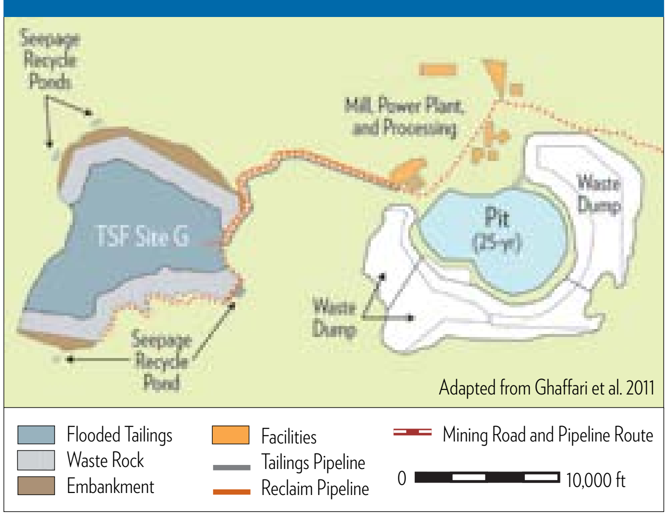


Figure 2b. An updated site plan contained in the Preliminary Assessment shows only a single TSF (site G), which could store two billion tons of waste under a 25 year operating scenario (Ghaffari et al. 2011). The Preliminary Assessment considers revenue potential associated with longer term scenarios (45 and 78 years) but does not describe how or where additional waste would be stored.



Preliminary Assessment, mine development is likely to begin with excavation of an open pit to access the minerals closest to the surface in both Pebble East and West. When the minerals in the shallower Pebble West deposit have been exploited, excavation will continue in Pebble East. Various stream diversion channels, wells, and other infrastructure will dewater the pit and extract all ground and surface water within the mine area to support mine processes (Ghaffari et al. 2011).

Figure 3 shows a cross section of the Pebble deposit and potential open pit dimensions according to the three development scenarios. In order to process the 1.8 billion metric tons of ore projected in the Preliminary Assessment's 25-year scenario, the open pit would need to be roughly 2,500 feet deep and 12,000 feet (approximately 2.3 miles) wide. Under the longer-term designs, the pit would be approximately 2,800 feet deep and 14,000 feet wide (45-year scenario), and 4,000 feet deep and 17,000 feet wide (78-year scenario). These scenarios process 32% and 55% of the total estimated Pebble mineral resource, respectively. While initial short and mid-term (25 and 45-year) development scenarios propose open pit mining, underground "block-caving" techniques may be used during these phases and ultimately mine Pebble East to a depth of 5,000 feet (Ghaffari et al. 2011).

2.2 Mine Waste Facilities

The Pebble mineral deposit that is accessible by both open pit and underground mining is estimated to include 10.8 billion metric tons of ore, yielding roughly 40.3 million tons of copper, 2.8 million tons of molybdenum, and 3,400 tons of gold (Ghaffari et al. 2011). Thus, over 99% of the ore mined would become tailings (rock that has been processed to remove valuable metals) and waste rock (rock that does not contain economic concentrations of metal). These waste materials would remain on-site forever.

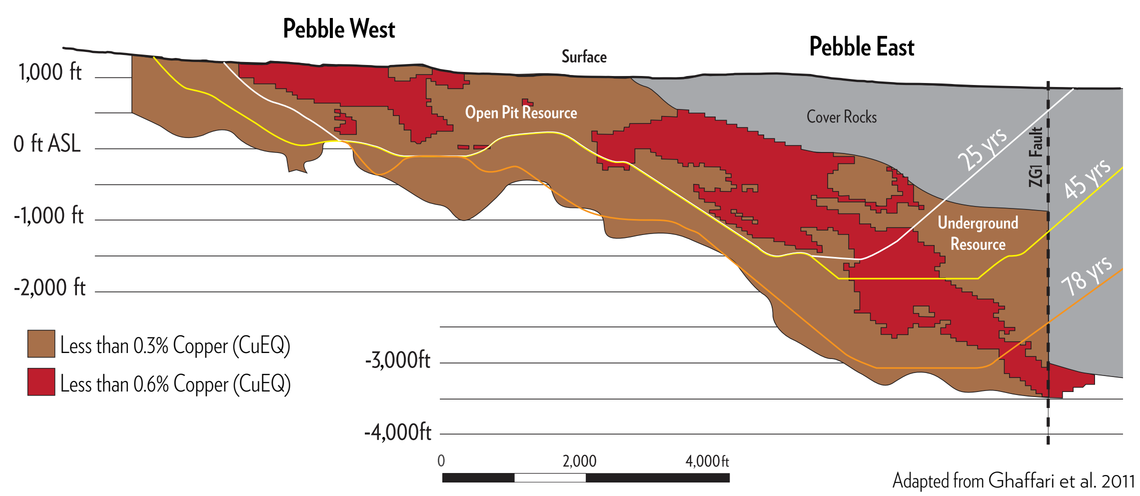
According to the applications submitted by Northern Dynasty in 2006, the mine waste (tailings and waste rock) would be stored in two tailings storage facilities (TSFs), "TSF A" and "TSF G," shown in Figures 2a and 6. Tailings embankments (essentially dams), illustrated in Figure 5a, would be constructed with mine waste rock and progressively raised in a series of staged expansions (Knight Piesold Consulting 2006a). The embankments would cut across currently productive salmon rivers (Woody and O'Neal 2010) and would produce storage reservoirs with a combined surface area of over 10 square miles (Ecology and Environment, Inc. 2010).

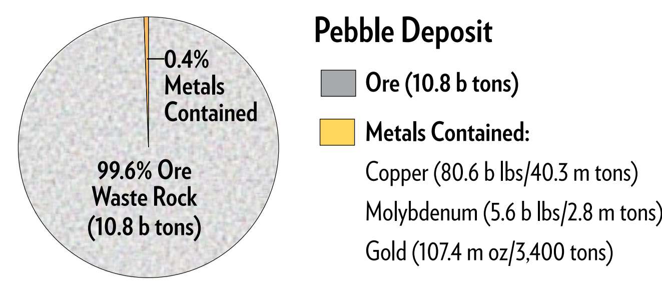
TSF A would store approximately 2 billion tons of waste and would incorporate three embankment structures situated in the headwaters of the South Fork

The Pebble Project Site

The Pebble Mine claim lies within the headwaters of the Nushagak and Kvichak watersheds, two of the world's largest sockeye salmon producing rivers (Burgner 1991, Sands et al. 2008). The region of copper-gold-molybdenum mineralization includes an area of roughly 5.3 square miles situated on a drainage divide, with the Upper Talarik Creek watershed draining to the southeast, and the North and South Forks of the Koktuli River draining to the west and southwest, respectively (Knight Piesold Consulting 2006a) (see Figure 6 map). Frying Pan Lake and much of the Upper Talarik Creek valley pictured here would be lost to development of the open pit, tailings storage facilities, and other mine infrastructure (photos by Erin McKittrick).

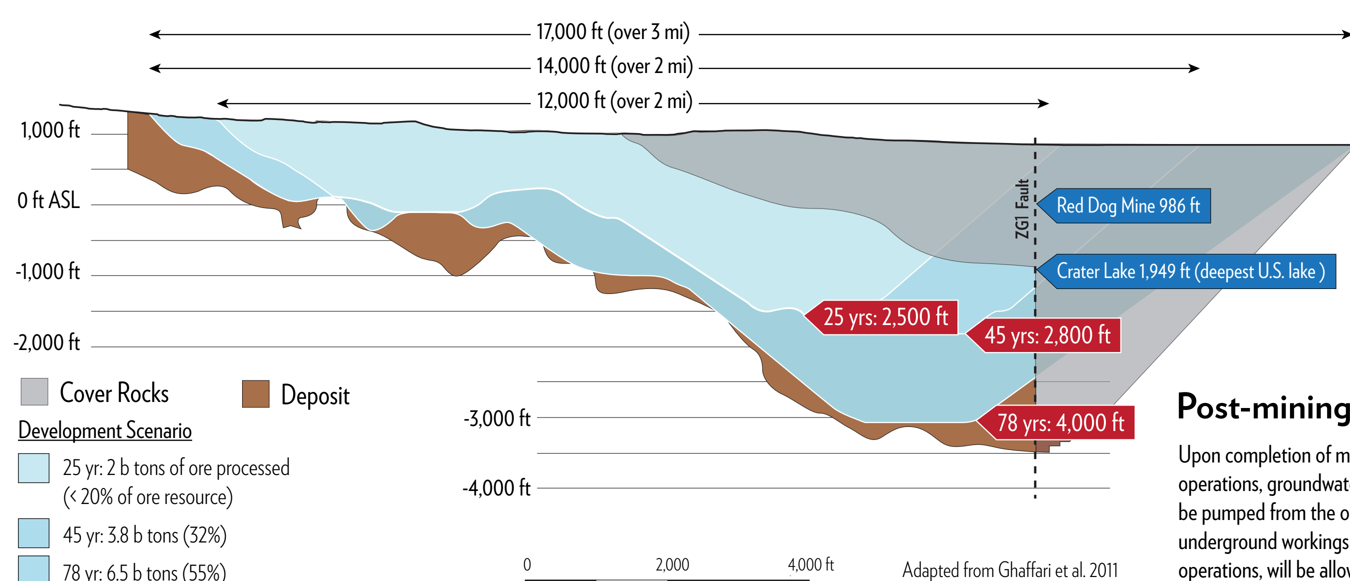
Figure 3. Pebble Deposit Cross Section. The Pebble deposit reaches a depth of 2,000 feet in its western reach, known as Pebble West, and at least 5,000 feet in Pebble East (Ghaffari et al. 2011). Mine waste, including tailings and waste rock, comprises roughly 99% of the approximately 10.8 billion metric tons of ore on site (Knight Piesold Consulting 2006a, 2006b).





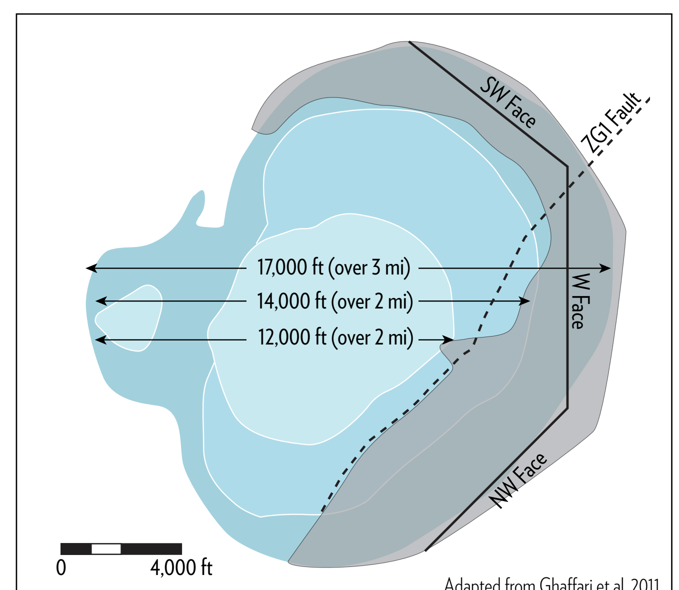
How much is 10.8 billion tons? If PLP used rail cars capable of carrying 100 tons each to transport the roughly 10.8 billion tons of ore, the effort would require 108 million rail cars. With standard 65-foot-long hopper rail cars, the train would measure 1.33 million miles, long enough to circle the Earth at its equator over 50 times.

Figure 4. Pebble Pit. Although operations are likely to also include underground mining ("block caving"), the Preliminary Assessment presents design scenarios for an open pit under three "development cases", which include 25, 45, and 78 year time horizons (Ghaffari et al. 2011).



Post-mining Pit Lake

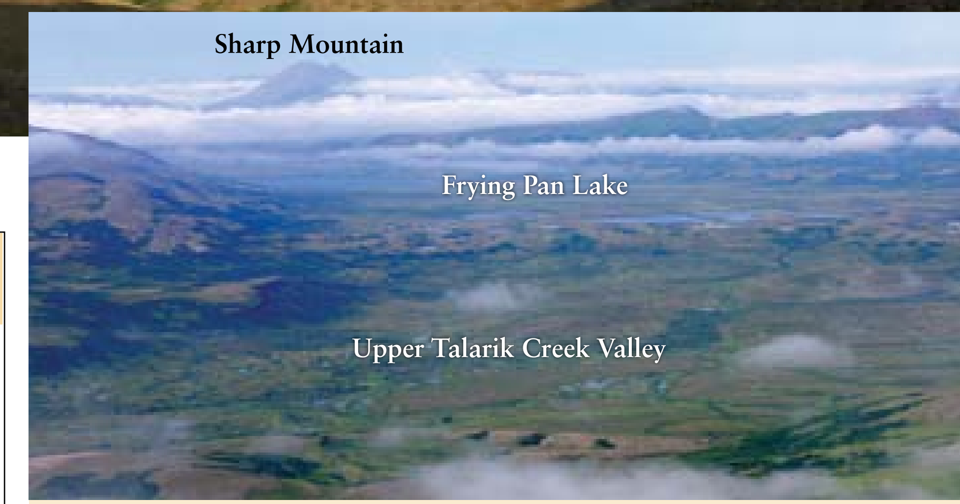
Upon completion of mining operations, groundwater which will be pumped from the open pit and underground workings during mining operations, will be allowed to fill these areas, forming a post-mining pit lake.



Pebble Mine Deposit

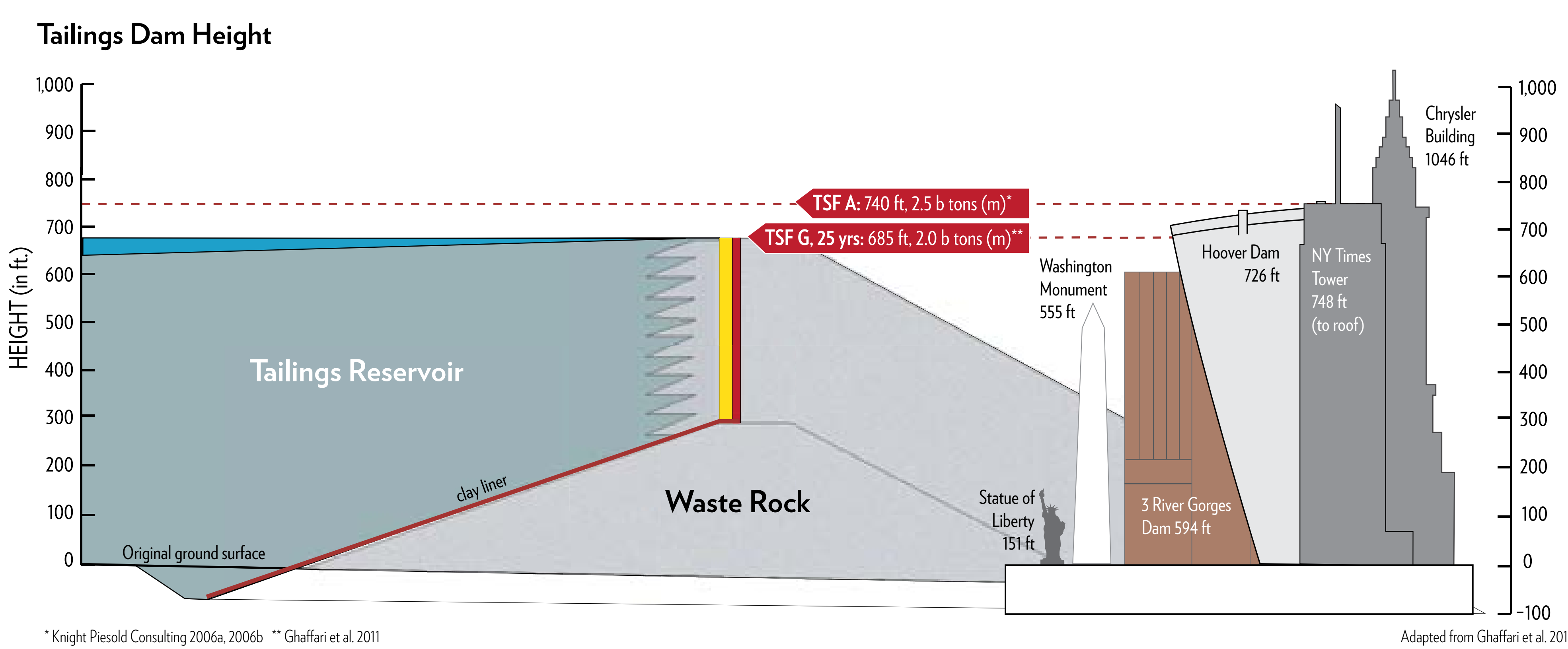
To process the roughly 2 billion metric tons of ore projected in the Preliminary Assessment's 25-year scenario, the open pit would need to be roughly 2,500 feet deep and 12,000 feet wide. Under the longer-term designs, the pit would be approximately 2,800 feet deep and 14,000 feet wide (45-year scenario), and 4,000 feet deep and 17,000 feet wide (78-year). Because Pebble East lies under a wedge of unmineralized overburden that is too thick to mine economically by open pit method, it will most likely be mined by underground block caving. While the final proposed open pit dimensions will probably resemble the 25 year scenario, block caving could facilitate mining to a depth of 5,000 feet or more (Ghaffari et al. 2011).

Following mining, the open pit and underground workings will be flooded forming a pit lake (Ghaffari et al. 2011). Pit water will be impacted by the composition of the rock remaining in the pit walls, especially that material which has been further exposed by fracturing and crushing. If the hydrology of the site is such that water from the pit can migrate down gradient to ground and surface waters, there could be long-term impacts to water off of the mine site. Because the Pebble Mine sits atop a watershed divide in a region with extensive hydrologic connection, management of contaminated pit water should be a key consideration in review of the Pebble Mine proposal.



Above: View of the Pebble Mine claim area facing northeast towards Groundhog Mountain and Lake Iliamna. Right: Facing south/southwest toward Sharp Mountain. Frying Pan Lake (pictured on the right) and much of the Upper Talarik Creek valley would be lost to development of the proposed mine pit and tailings reservoirs (photos by Erin McKittrick).

Figure 5a. Pebble Tailings Dam. The height of the proposed Pebble Mine tailings dams (Sites A and G) compared to well-known existing dams and landmarks (Knight Piesold Consulting 2006a, 2006b; Ghaffari et al. 2011). Waste rock will be used to build massive dams that will contain reservoirs of flooded pyritic tailings (acid-generating rock) and processing reagents that will need to be stored permanently.

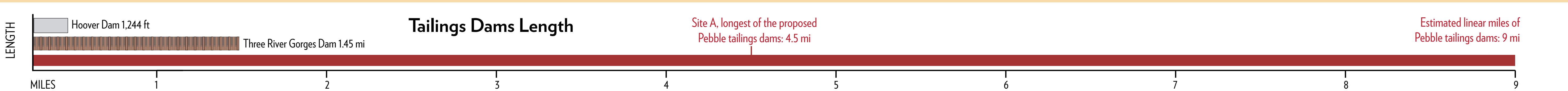


Pebble Mine Waste

According to applications submitted by Northern Dynasty in 2006 (Knight Piesold Consulting 2006a, 2006b), mine waste would be stored in two tailings storage facilities (TSFs). TSF A would store approximately 2 billion tons of waste behind three embankments that would be constructed in stages, ultimately reaching heights ranging from 700 to 740 feet. If constructed according to these preliminary plans, the longest dam (at 4.5 miles) would be the largest dam in North America. The TSF G described in the 2006 applications would provide storage for an additional 500 million tons of waste. The Preliminary Assessment uses Site G as the primary TSF, proposing 2 billion tons of storage over a 25 year development scenario (Ghaffari et al. 2011).

It is important to note that the estimated 10.8 billion metric tons of waste rock associated with the Pebble mineral resource far exceeds the total proposed storage capacity of the two preliminarily described TSFs. This strongly implies that the required waste storage space for the mine will have to be several times larger than indicated in either the Tailings Impoundment Applications made by Northern Dynasty in 2006 or considered in the Preliminary Assessment completed in 2011. It's unknown where additional waste-storage capacity would be located and what additional non-mine resources would be affected. Project developers will likely seek permits to store a small amount of waste (relative to the size of the deposit), and once operations are underway, return to seek additional permits for storage space that currently cannot be defined.

Figure 5b. Pebble Tailings Dam Length. The length of the proposed Pebble Mine tailings dams at Site A compared to existing dams (Knight Piesold Consulting 2006a).



Koktuli River. These embankments would be among the tallest dams in the world. The north embankment would ultimately reach a height of 700 feet, and the southeast and southwest embankments would attain heights of 710 feet and 740 feet, respectively. The taller of these two structures would rise higher than the Colorado River's 726-foot Hoover Dam. If this dam reaches 4.5 miles in length, as conceived in submitted documents (Knight Piesold Consulting 2006a), it would be the largest dam in North America (Figure 5b).

TSF G would provide storage for approximately 500 million tons of tailings and waste rock. The design includes a main embankment along the outlet of an unnamed tributary to the North Fork Koktuli River, as well as a smaller saddle dam constructed during staged expansions of the tailings impoundment. The main dam would reach an ultimate height of 450 feet, and the saddle dam a height of 175 feet (Knight Piesold Consulting 2006b).

The storage scenario presented in the recently completed Preliminary Assessment indicates a preference to begin operations using TSF G to store tailings and waste rock. Under the 25-year operating life scenario, TSF G would utilize three embankments, with the north structure ultimately rising to a height of 685 feet and extending roughly three miles.

Although PLP has not yet applied for permits, several statements in the Preliminary Assessment indicate that it will likely seek approval for a project under this short-term scenario. First, the Preliminary Assessment states "phases of development beyond 25 years will require separate permitting and development decisions to be made in the future." Second, the 25-year scenario is indicated as the case "upon which a decision to initiate mine permitting, construction and operations may be based." Finally, the 25-year scenario has been the most "comprehensively engineered" (Ghaffari et al. 2011). Although initial permit applications may present a short-term development scenario, it is important to note that the 25-year case presented in the Preliminary Assessment processes less than 20% of the total estimated mineral resource present at the Pebble site (Figure 4). Therefore, the actual mine life may extend well beyond the development case presented in the initial development proposal that is used to secure permits. In fact, since the 78-year scenario processes only 55% of the mineral present at Pebble (and 6.5 billion metric tons of ore), if permitted it is likely that the mine will remain operational well into the 22nd century.

This potential for inconsistency between the development scenario presented in PLP's impending permit applications relative to the enormous size of the Pebble

Pebble Mine drill rig (photo by Steve Baird).

mineral deposit should be carefully considered in evaluating the Pebble Mine concept. The estimated 10.8 billion metric tons of waste rock associated with the Pebble mineral resource far exceeds the total proposed storage capacity of the TSF designs presented in both the initial permit applications—2.5 billion tons (Knight Piesold Consulting 2006a, 2006b)—and the 25-year scenario presented in the more recent Preliminary Assessment—2 billion tons (Ghaffari et al. 2011). The need for perpetual storage of wastes generated beyond a 25-year timeline raises important technical questions that have not yet been answered. In short, it is unknown where additional waste-storage capacity would be located and what additional non-mine resources would be affected.

2.3 Chemicals Used and Tailings Produced

After being blasted from the open pit or underground, ore from the Pebble deposit will be moved from the mine to the mill, and waste rock will be either dumped in the tailings reservoir or used to construct the embankments. At the mill, the ore will be physically and chemically processed to separate copper, gold, and molybdenum from the source rock, in what is known as the *flotation process*. At mines similar to the proposed Pebble operation, the flotation process relies heavily on chemicals—called *reagents*—that are added to the ore to extract the metals. These chemicals are mixed with the crushed ore and water in various complex stages to extract the desired metals. The resulting waste—called *tailings*—is discharged to a tailings impoundment (the TSFs described earlier). Because of the massive quantities of ore that will be processed at Pebble, tremendous amounts of reagents will be used and tailings produced.

The ore at Pebble will be processed to create several metal concentrates, including (but not limited to) a copper-gold concentrate and a molybdenum concentrate, which will be shipped off-site for final processing (Ghaffari et al. 2011). Generally, this process begins with rock being crushed to pieces that are approximately 6 inches or less, which are then ground

SOURCES OF ADDITIONAL CHEMICAL CONTAMINANTS

Fuels/Oils and Greases/Antifreeze. Modern mine operations are highly mechanized, employing trucks and equipment that require immense quantities of fuels (diesel, gasoline, kerosene), oils and greases, and antifreeze compounds, all of which are stored and used on-site. These organic compounds frequently leak from their storage containers or are spilled during normal use or in accidents. All may be highly toxic to aquatic organisms.

Explosives. Constructing underground mine workings, open pits, roads, etc., requires tremendous quantities of blasting compounds. When exploded, they leave soluble residues (organic compounds, nitrate, ammonia) on the rock surfaces, which wash off into the environment after rainstorms. One of these residues, ammonia, is roughly as toxic to fish as free cyanide.

Water Treatment, Sewage Facilities, Laboratories. All similar mines must operate facilities for their workers, which includes constructing camps with water treatment and sewage facilities. In addition, they maintain laboratories. All such functions use chemicals and often release chemical and bacteriologic wastes into the environment.

Miscellaneous Operations. Depending on the physical environment, many mines use significant quantities of herbicides, pesticides, and road-deicing compounds—all of which can be toxic to organisms.

FLOTATION PROCESS CHEMICALS

Collecting Agents. Collectors induce specific minerals to adhere to froth bubbles. Modifying agents may be used with collecting agents to induce or depress adhesion of specific minerals to the bubbles. The collectors are organic molecules or ions that are absorbed selectively on certain surfaces to make them hydrophobic (or insoluble in water). Collecting agents are the most important of all the flotation process agents. Typical flotation agents include ethyl, butyl, propyl, and amyl xanthates (e.g., potassium amyl xanthate).

Frothing Agents. Frothers are organic surfactants that are absorbed at the air/water interfaces (bubbles), creating suds that allow the minerals bonded with xanthates to attach themselves to air bubbles in the froth. The two main functions of frothers (e.g., methyl isobutyl carbinol [MIBC], pine oil, and cresylic acid) are to ensure the dispersion of fine bubbles in the ore pulp and to maintain an adequate stability of the froth on top of the pulp.

Activators. Activators are generally soluble salts that ionize (dissolve) in water. The ions in solution react with the mineral surfaces to favor the absorption of a collector. Activators are used when collectors and frothers cannot adequately float the concentrate.

Depressors. Depressors are inorganic compounds that selectively cover the mineral surfaces to make them hydrophilic (increasing their affinity for water while decreasing their affinity for collectors). The use of depressors increases the selectivity of flotation by preventing flotation of undesirable molecules such as cyanide. While cyanide is primarily used to dissolve gold from ore concentrate, it is sometimes used in small amounts in base metal flotation operations to keep pyrite from being collected in the flotation cells.

Flocculants. Flocculants are used to collect suspended particles to help separate water and solids. Flocculants are polymers, essentially water-in-oil emulsions. Flocculants are found in tailings, but they generally adhere to particles and are not typically mobile in the soil.

Lime. Lime is used primarily to raise the alkalinity of the processing solution to the desired level.

Acid. Acid might be added at the end of the water-treatment process to reduce the alkalinity of the discharge water to meet water quality standards, as waste water may have an elevated pH due to the addition of lime.

Figure 6. The Pebble Project. Geography and terrain of the site of the proposed Pebble Mine and Mining District, as well as facilities required to support mineral extraction and distribution, including an extensive road system, pipelines, and a deep water port (Ghaffari et al. 2011) (photos by Erin McKittrick).

1 Upper Koktuli valley and Sharp Mountain, from the ridge between Upper Talarik Creek and the mine site.

2 Looking across Upper Talarik Creek valley to the Newhalen River valley and Lake Iliamna.

3 Overlooking Frying Pan Lake, from a ridge that would be underneath the tailings reservoir.

4 Upper Talarik Creek valley and Groundhog Mountain, from a high peak over the mine site.

5 Looking over the headwaters of Upper Talarik Creek from Groundhog Mountain, with the mine site, Frying Pan Lake, and Sharp Mountain in background.

6 Thunderstorm approaching the mine site from Koktuli Mountain.

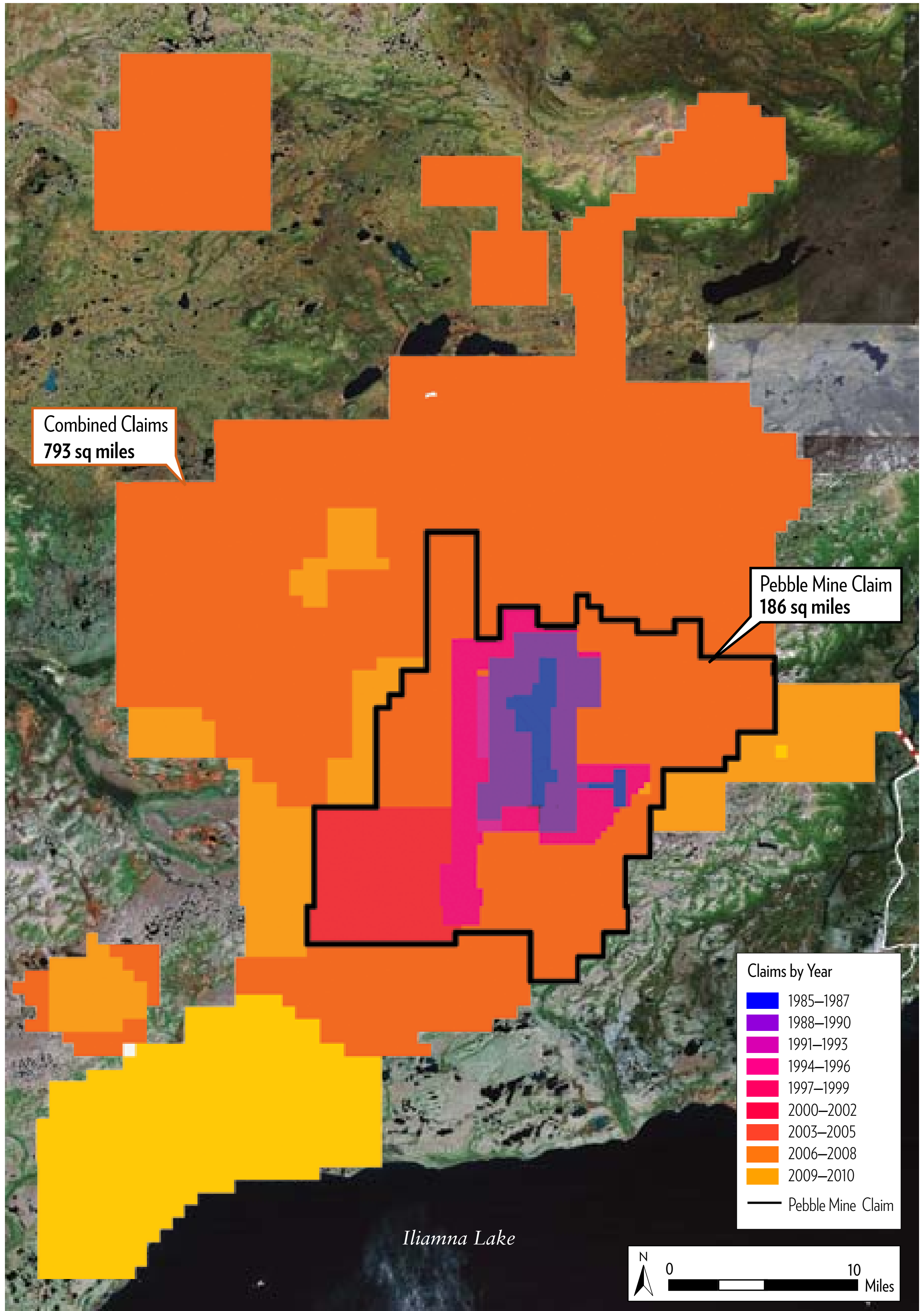
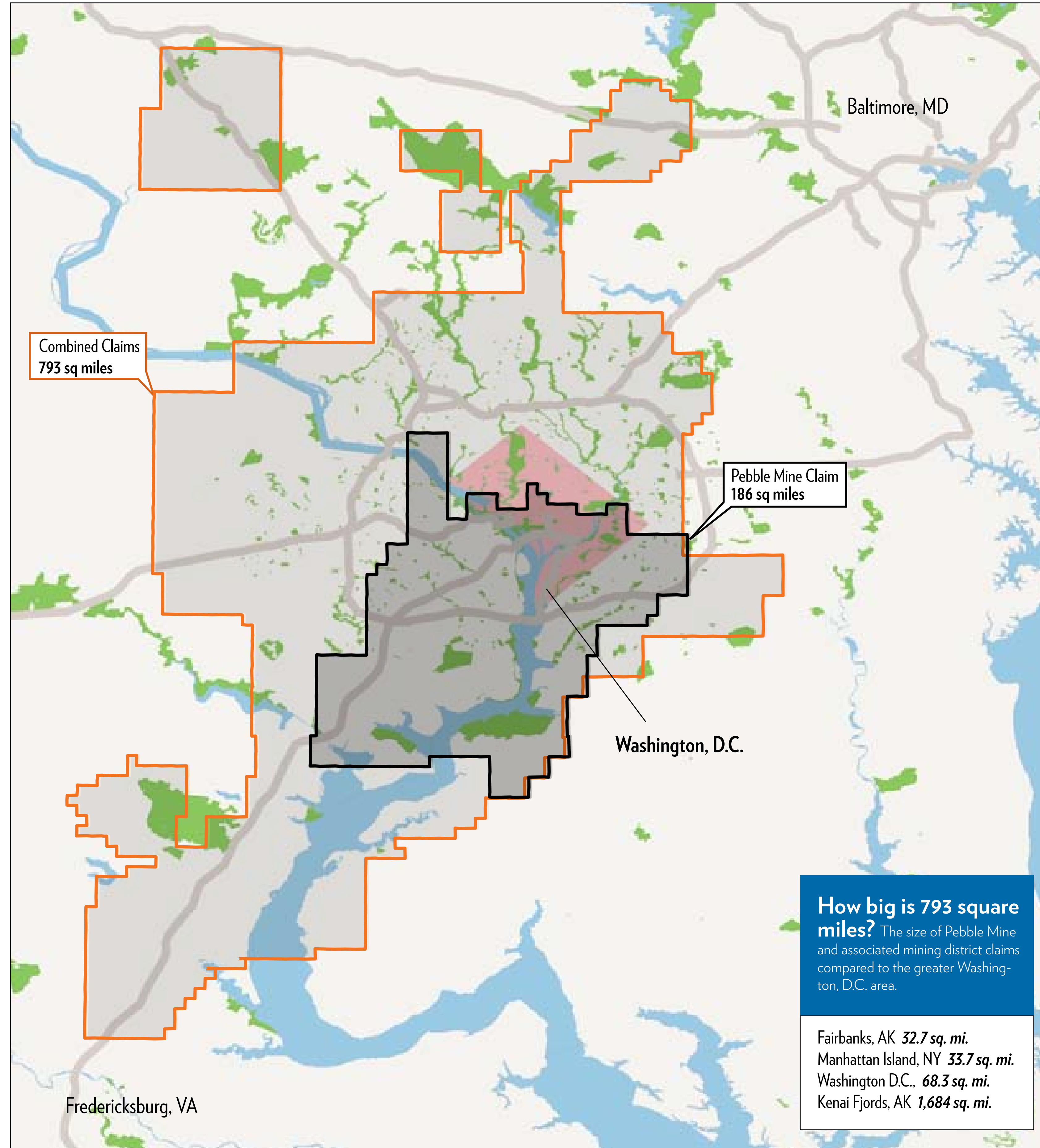


Figure 7. Growth of the Mining District. Mining claims by Northern Dynasty and other developers. Since PLP's establishment, seven different operators have established claims and initiated leases covering 793 square miles (ADNR 2010a).



How big is 793 square miles? The size of Pebble Mine and associated mining district claims compared to the greater Washington, D.C. area.

Fairbanks, AK *32.7 sq. mi.*
Manhattan Island, NY *33.7 sq. mi.*
Washington D.C., *68.3 sq. mi.*
Kenai Fjords, AK *1,684 sq. mi.*

Upper Talarik Creek, site of the proposed Pebble pit (photo by Erin McKittrick).

to the consistency of clayey sand. After it is ground, the ore goes to flotation tanks, where chemicals are added to separate the sulfide minerals from the non-sulfide host rock.

Over 90% of the tailings will be created at the first stage of flotation. These *bulk tailings* have a relatively low sulfide content, since the objective of the flotation process is to recover as much of the copper and molybdenum sulfide mineralization as possible. After the first flotation operation separates the sulfide minerals from the non-sulfide host rock, another series of flotation cells is used to further separate the initial sulfide float into concentrates of copper and molybdenum. A third flotation product is a pyrite concentrate that will be stored in the tailings reservoirs (see chapter 3). This material is highly reactive and must remain permanently underwater to inhibit the creation of sulfuric acid and to minimize the chances of acid mine drainage occurring.

The left-hand column of Table 1 presents a summary of the flotation reagents typically used in copper milling. To illustrate the enormous quantities of reagents that are likely to be used in processing the Pebble deposit, Table 1 projects the reagent quantities that would be used at three copper mills—Brunswick Mine & Smelting (Canada), Lornex (Canada), and Pyhasalai (Finland)—if these mills processed ore at the rate anticipated for the Pebble mill. While these copper mills differ in ore composition from one another and from the Pebble ore bodies, the reagent quantities shown are based on actual usage described in Ayres et al. (2002) and are likely to be representative of quantities used at the Pebble mill per unit of ore processed.

Under the 78-year development case, the Pebble project will process up to 6.5 billion metric tons of ore, which equates to a processing volume of almost 230,000 tons of ore per day, or just over 80 million tons per year, assuming 350 days of mine operation per year (Ghaffari et al. 2011). If the three copper mills in Table 1 also processed 80 million tons of ore per year, operators would have to use and safely dispose of enormous quantities of processing reagents. For example, at Pebble's processing rate, the Finnish site would have annually used almost 441,000 tons of sulfuric acid and over 127,000 tons of zinc sulfate. Given the significant gold concentrations in the Pebble ores, it is possible that sodium cyanide may also be used in processing the ore. At the Pebble Mine's processing rate, the Pyhasalai mill would have used 2,469 tons per year of sodium cyanide, which is the most toxic of the process chemicals shown in Table 1.

Table 1. Estimated consumption of reagents at copper mills (measured in tons/year) based on the processing rate projected at the Pebble Mine (under a 78-year development case). Table adapted from Ayres et al. (2002).

Reagents (tons/yr)	Brunswick	Lornex	Pyhasalai
Acids			
Sulfuric Acid			440,916
Alkalis			
Lime	220,458	96,607	277,777
Sodium Carbonate	291,004		
Modifiers			
Copper Sulfate	71,868		29,100
Sodium Cyanide			2,469
Zinc Sulfate			127,865
Sulfur Dioxide	61,728		
Starch	8,818		
Collectors			
x-Amyl Xanthate	23,809	3,086	19,400
x-Isopropyl Xanthate		2,645	
Frothers			
Dowfroth 250		1,234	
Pine Oil		1,763	

2.4 The Pebble Mine and the Emergence of the Bristol Bay Mining District

Once mining operations are complete, the Pebble Mine will have produced, at the very least, massive physical alterations to the headwaters of the Nushagak and Kvichak watersheds. Major permanent changes could include a flooded open pit measuring three miles long and 4,000 feet deep (based on a 78-year development scenario), and nine miles of tailings dams measuring up to 740 feet high to impound toxic tailings waste and chemicals within 10 square miles of contaminated reservoirs (based on preliminary permit applications).

These massive developments represent just a part of the imprint that the Pebble Mine will leave on the Bristol Bay landscape. First, PLP will construct a deep-water port on Iniskin Bay on the west side of Cook Inlet to ship the mineral concentrate to off-shore smelters and other processors. The port will also enable delivery of equipment, supplies, labor, diesel fuel, and other resources, including natural gas. According to the Preliminary Assessment, "natural gas will fire a new 378 MW natural gas turbine plant, which will be constructed at the mine site to serve the Pebble Mine's power needs. Natural gas will be sourced from other regions of Alaska or imported as liquefied natural gas (LNG) and transported by pipeline across Cook Inlet via a sea-bottom line to the port, and along the transportation corridor to the mine site" (Ghaffari et al. 2011).

The Preliminary Assessment describes the transportation corridor as follows: "[A]n 86-mile transportation corridor will be developed to link the Pebble Mine to [the] deep-water port on Cook Inlet, 66 miles to the east [of the mine]. About 80% of the transportation corridor is on private land owned by various Alaska Native Village Corporations, with which [PLP] has existing commercial partnerships. The balance of the transportation corridor is on land owned by the State of Alaska. The transportation corridor will include a two-lane, all-weather permanent access road. The primary purpose of the road will be to transport freight by conventional highway tractors and trailers, although critical elements of the design will be dictated by specific oversize and overweight loads associated with project construction." The Preliminary Assessment further states that "[t]he transportation corridor will also include four buried, parallel pipelines, including:

- a copper-gold concentrate slurry pipeline from the mine site to the port;
- a return water pipeline from the port site to the mine;
- a natural gas pipeline from the port site to the mine…; and
- a diesel fuel pipeline from the port site to the mine" (Ghaffari et al. 2011).

While the potential impacts on Bristol Bay's wild salmon ecosystems resulting from these developments are substantial (as described in chapter 3), of equal and perhaps even greater long-term consequence is the opportunity that this infrastructure creates for further mineral exploration within the Bristol Bay region. Since PLP's establishment, seven different operators have established claims and initiated leases covering 793 square miles of the Bristol Bay basin (Figure 7). The proposed development of the Pebble Mine and its supporting infrastructure—including its roads, pipelines, power-generating facilities, and port—will leverage the initiation of numerous additional proposals for mining operations in the Bristol Bay watershed. The majority of these claims cannot be exploited without development of the Pebble Mine infrastructure. Therefore, the total impact of the Pebble proposal on the Bristol Bay watershed may be far greater than those directly associated with the initial mine's development and operation.

Figure 8. Mine Density and Intolerance of Fish. Proportion of the fish assemblage composed of individuals that are intolerant of anthropogenic disturbance versus catchment mine density (Peter Esselman, Michigan State University, unpublished report).

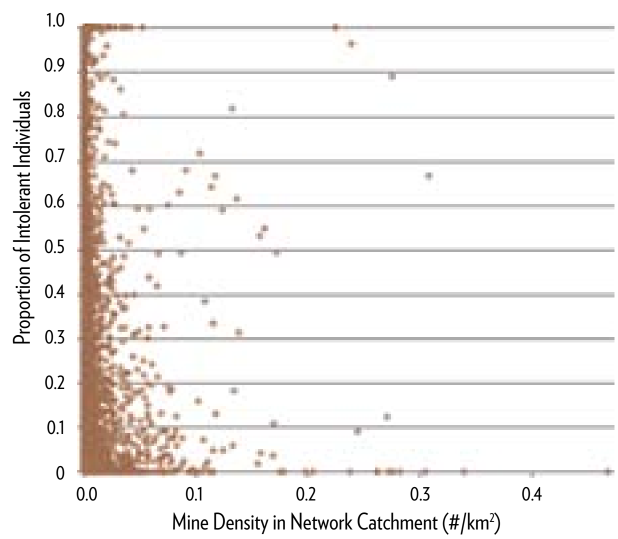


Figure 8 shows the potential impact of increased mine densities in a watershed. Once a metal mine is developed in a watershed, fish that are intolerant of anthropogenic disturbance, such as salmon and trout, do not generally persist in sustainable numbers. As shown in Figure 8, a very low incidence of mines in a catchment or near a stream sampling site is associated with reduced proportions of intolerant individuals in fish assemblages. With only four exceptions, once catchment mine density exceeds one mine per five square kilometers, the proportion of intolerant fish in the assemblage is less than 0.15. This indicates that significant reductions in salmon populations are likely to result from the increase in mine development brought about by the Pebble Mine. It also underscores the threat posed by the development of a mining district in the most productive sockeye salmon nursery in the world.

In evaluating the Pebble concept, it should be carefully considezred, therefore, that development of this district is only made possible through the construction of the Pebble Mine and its sprawling infrastructure.

Bristol Bay salmon (photo by Ben Knight).