Pebble Tailings Management

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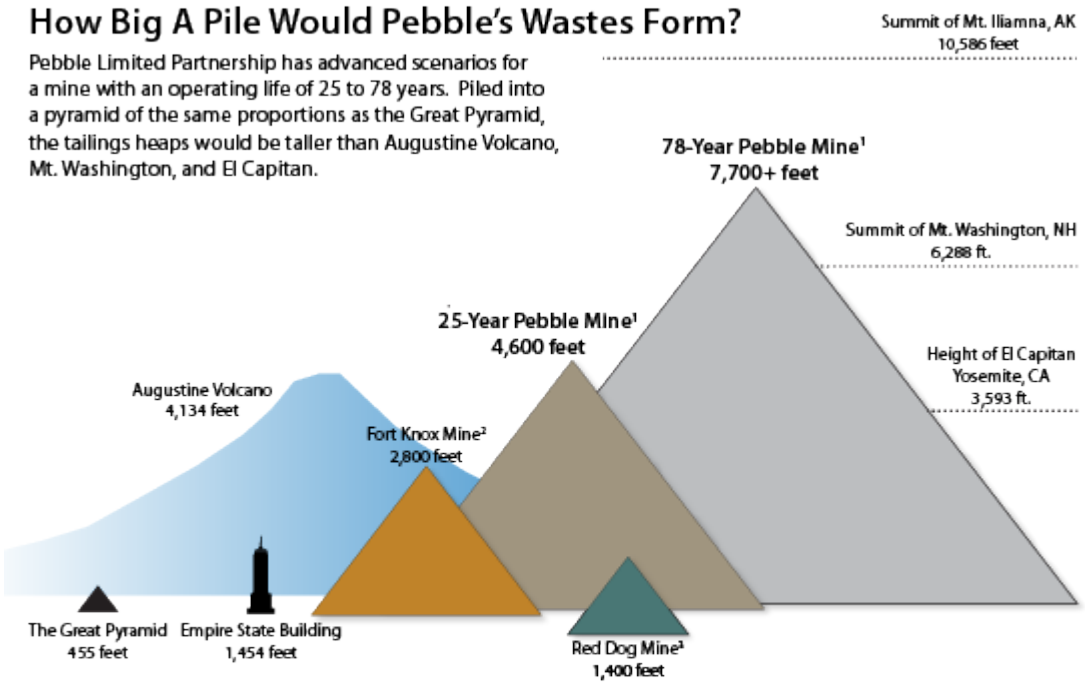
The proposed Pebble Mine (/Issues/MetalsMining/pebble-mine-gold-copper-prospect-alaska.html) could produce up to 10.7 billion tons (http://www.northerndynastyminerals.com/i/pdf/ndm/Pebble_Project_Preliminary%20Assessment%20Technical%20Report_Februa of tailings (/Issues/MetalsMining/MineTailings.html), a mud waste that results from processing ore to extract metals. For perspective, this amount would be up to 1000 times the mass of the Great Pyramid of Egypt. Tailings are produced by most mining operations, and the environmental risk they pose varies from mine to mine, primarily due to local geology, mining methods, and how well they are stored.

At Pebble, the tailings would be from sulfide ore. Sulphide ore tailings pose a major environmental hazard if not successfully contained and isolated from the environment, due to their acid generating potential (/Issues/MetalsMining/AcidMineDrainage.html). These tailings would need to be

stored perpetually (/Issues/OtherIssues/perpetual-waste-storage-perpetuity.html) in one or more massive storage facilities, most likely under an artificial lake contained by earthen dams. Pebble's impoundments would be some of the largest tailings facilities in the world (http://www.pbs.org/wgbh/pages/frontline/environment/alaska-gold/tailings-dams-where-mining-waste-is-stored-forever/).



PEBBLE'S TAILINGS (/figures/pebble-mine-tailings-pyramids/) — The relative quantity of Pebble's tailings, formed into pyramids similar to Egypts, and other natural and man-made objects.

Why Would Pebble's Tailings be Hazardous?

Pebble's ore contains a large fraction of iron pyrite, or "fool's gold." When exposed to water and oxygen, the ore releases sulfuric acid. This phenomenon, common in mines, is known as acid mine drainage (/Issues/MetalsMining/AcidMineDrainage.html). The acidic water leaches residual heavy metals and chemicals from the surrounding rock, and the resulting water is toxic.

The primary concern with Pebble's tailings (/Issues/MetalsMining/MineTailings.html) is whether they would be successfully contained. Due to their geochemistry, such tailings do not naturally stabilize or lithify (turn into rock) on human timescales, and must be isolated in perpetuity (/Issues/OtherIssues/perpetual-waste-storage-perpetuity.html) to prevent environmental harm. If such tailings can be totaly and permanently isolated from the environment, then theoretically they will cause no environmental harm. In practice, this can prove difficult, due to the immense volume of material to be isolated, the economic cost of maintaining the facilities, and the long timescale.

How Much Tailings Waste Would be Produced?

The Wardrop Report (see box, at bottom) estimates that 2 billion tons of tailings (~300 Great Pyramids) would be produced by a 25-year mine, along with 2.5 billion tons of discarded waste rock. A 78-year mine, characterized by higher

production rates, might produce more than 6.5 billion tons of tailings (~1000 Great Pyramids), along with an unknown quantity of unmilled waste rock.

Waste rock, unlike tailings, would be piled loose on the landscape around the mine facilities. An attempt would be made to separate the waste rock into piles of inert rock and potentially acid-generating rock. Historically, waste rock has itself been one of the largest sources of acid mind drainage which enters the environment, since waste rock is not usually isolated in secure impoundments. Once acid drainage is observed from waste rock piles, it may be prohibitively expensive or logistically infeasible to move the acid-generating rock into a tailings impoundment. This has occurred at Alaska's Red Dog Mine (/Issues/MetalsMining/RedDogMine.html), where acid runoff has been rerouted into the tailings impoundment, but the waste rock itself has not been moved. Pebble is forecast to produce 3 to 17 billion tons of waste rock.

How Would Tailings Be Stored at Pebble?

Tailings at Pebble would most likely be stored under an artificial lake. A valley at the headwaters of the North Fork Koktuli River would be blockaded with giant earthen dams and filled with tailings via a slurry pipeline. This variation of conventional impoundment (http://www.tailings.info/disposal/conventional.htm), known as valley impoundment (http://www.tailings.info/storage/containment.htm), was modeled in the Wardrop Report. The highly pyritic (and hence most heavily

acid-generating) fraction of the tailings would be separated during metal extraction and would likely be deposited in the center of the tailings impoundment(s).

Size of the Pebble Tailings Impoundment

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Tailings would be delivered via pipelines to the facility, at a rate of roughly 200,000 plus tons per day. At the end of 25 years, the minimum projected lifetime of the mine, the tailings impoundment might:

• Have dams nearly 700 feet high

• Have 8 miles or more of dams

• Hold roughly 2 billion tons of mine tailings

• Hold 200 million tons of potentially acid-generating iron pyrite* (derivation)

• Cost roughly $250 million dollars to build and operate

A mine operating for a longer period of time, or with higher productivity, would produce a much larger volume of tailings. These would probably be stored in multiple facilities of comparable size, scattered around the local landscape.

Conventional impoundment is less expensive than some other storage methods, but is also more likely to result in accidental contamination of water and surrounding areas. Given the low ore grade and remote location of Pebble, conventional impoundment using blockaded valleys may be the only financially feasible option.

What Sort of Accidents or Failures Could Happen?

Pebble's tailings dams could experience either gradual leakage or more dramatic dam failures. Worldwide, accidental discharges from tailings facilities occur periodically (http://www.infomine.com/library/publications/docs/Azam2010.pdf), including from behind recently constructed dams (http://www.csp2.org/reports/Long%20Term%20Risks%20of%20Tailings%20Dam%20Failure%20-%20Chambers%20&%20Higman%20Oct11.pdf).

Catastrophic or partial containment failure could occur in a variety of ways (http://www.csp2.org/files/reports/Long%20Term%20Risks%20of%20Tailings%20Dam%20Failure%20-%20Chambers%20%26%20Higman%20Oct11-2.pdf). For instance, the lake could overtop the dam during a rapid melt of heavy snowfall, erosion from flowing water could breach a dam, or an earthquake could suspend tailings in the water and slosh them over a spillway. At Pebble, dam failure could occur either during the life of the mine or after mine closure. An failure which releases reactive tailings into downstream rivers and floodplains could create long-term damages. Once introduced

into the environment, tailings are usually difficult or impossible to clean up, and can continue to release acid and metals for years or even centuries.

Perhaps most relevant to Pebble, the Mount Polley Mine tailings impoundment in British Columbia suffered a catastrophic breach (http://en.wikipedia.org/wiki/Mount_Polley_mine_disaster) in summer of 2014. The Mount Polley facility used the same construction method proposed for Pebble, and was engineered by Knight-Piesold, the same firm retained to engineer the Pebble dams. Knight-Piesold was not in charge of engineering oversight for the dam at the time of the breach, and the dam may have failed for reasons unrelated to the underlying engineering. Investigation into the causes of the Mount Polley breach is ongoing.

Although it is possible that Pebble's dams could catastrophically fail, leakage may be a more likely problem. During leakage, contaminated water slowly escapes into the landscape from behind the dams, typically by moving underground. Since the area of the Pebble prospect has a complex groundwater regime (/Issues/MetalsMining/pebble-mine-water-impacts-hydrology.html) including local artesian springs, it may be difficult to contain underground leakage, if the clay lining of the impoundment is not 100% effective. Leakage from Pebble's tailings facility is a particular concern due to the very large size of the impoundments. Leakage could contaminate rivers or groundwater. At long distances from the mine itself, dilute pollutants could still have negative impacts. For instance, very

low copper concentrations have been shown to disrupt the navigation of spawning salmon (http://pebblescience.org/copper-and-salmon.html).

Can Pebble's Tailings Be Made Safer?

In theory there are many options that would reduce the potential for pollution leaking from the tailings storage facilities. These include separating the heavily acid-generating minerals (pyrite) from the tailings and exporting them, cementing or buffering the tailings, and using underground mining techniques to target only the richest ore, thus creating fewer tailings. We outline these and other options in detail in our related article on alternatives to conventional tailings storage at Pebble (/Issues/MetalsMining/pebble-mine-alternative-tailings-storage-management-options.html).

These alternative approaches are very unlikely to be economical at current metal prices. Northern Dynasty Minerals asserts that the first step to safe tailings storage is to make the tailings as "clean" as possible (http://www.northerndynastyminerals.com/i/pdf/NDM_Backgrounder_Sep05.pdf) by extracting a high percentage of copper and other metals, and recovering processing chemicals. This is true from the standpoint of reducing the dissolved metals load, although it does not address the acid-generating potential of the material. Current techologies cannot extract metals from ore to the point where there are not significant amounts of metal still chemically available in them.

Given the fundamental uncertainty of perpetual tailings storage (/Issues/OtherIssues/perpetual-waste-storage-perpetuity.html) and the general rates of failure observed (http://ofmpub.epa.gov/eims/eimscomm.getfile?p_download_id=513583) in tailings dams, it's unlikely that Pebble's tailings can be stored in conventional impoundments without substantial risk the downstream environment.

"The Wardrop Report": Preliminary Assessment Technical Report of the Pebble Copper-Gold-Molybdenum Project

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The "Wardrop Report" (http://www.northerndynastyminerals.com/i/pdf/ndm/Pebble_Project_Preliminary%20Assessment%20Technical%20Report_Februa (32 MB) is an informal name for an important 2011 economic analysis of the proposed Pebble Mine (/Issues/MetalsMining/pebble-mine-gold-copper-prospect-alaska.html). Along with the mine developer's 2006 Water Right Application (http://dnr.alaska.gov/mlw/mining/largemine/pebble/water-right-apps/), it is the most detailed information the public has of the mine developer's intentions. The analysis was performed by Wardrop Engineering Inc. and commissioned by Northern Dynasty Minerals, half-owner of Pebble Limited Partnership (the developer). This detailed analysis contains estimates of volume

to be mined, costs, profitability, technical challenges, transportation needs, power requirements, hazardous wastes, and other information.