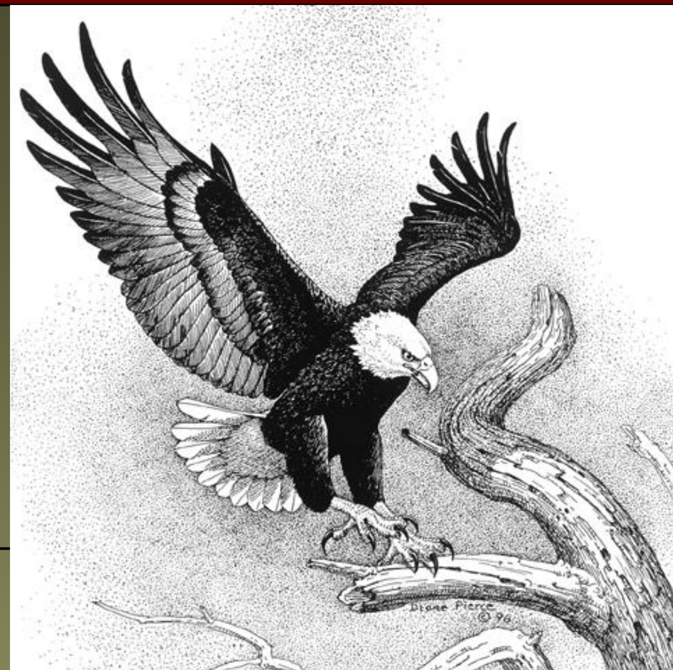

Keweenaw Bay Indian Community

AMD Environmental Issues – Underground and Surface Mining of Sulfide Minerals

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Presentation Overview

- Basic sulfide mineral reactions - qualitative
- How & why acid metal drainage occurs
- Sources: wall rock, waste rock, tailings
- Open pit vs underground
- Review of sulfide mines and the legacy
- Predictive skills and the western Lake Superior watershed

What are sulfide minerals?

- **Metallic sulfide minerals - minerals formed by the chemical combination of metals and sulfur within an intrusive magma**

- **Metallic sulfide minerals, when exposed to oxygen/air and moisture, form sulfuric acid and dissolved metals – basically when metal sulfides are subjected to oxidizing conditions**

Acid metal drainage

- A combination of oxidation and microbial catalyzed reactions produce large amounts of dissolved metals, sulfate and acidity
- Low Ph dissolves metal cations such as iron, manganese, aluminum, copper, zinc and nickel
- AMD is generally characterized by low pH (<4.5), high sulfate, and a high concentration of total metals.

ARD vs AMD

- Acid Rock Drainage (ARD) is a natural process that occurs when sulfides are exposed to oxygen and water through weathering.

- Acid Mine Drainage (AMD) is the same process; however, it occurs on a much larger scale - tremendous increase in the rate of sulfide exposure to air and water.

What’s the big deal?

- Metal sulfide minerals have been around for over a billion years – why worry?
- Answer: the AMD reaction is drastically enhanced by creation of surface area
- The more surface area, the more sulfide exposure to chemical oxidation

Mining sources of AMD

Three sources of acid metal drainage:

1) **Wall rock**

2) **Waste rock**

3) **Tailings**

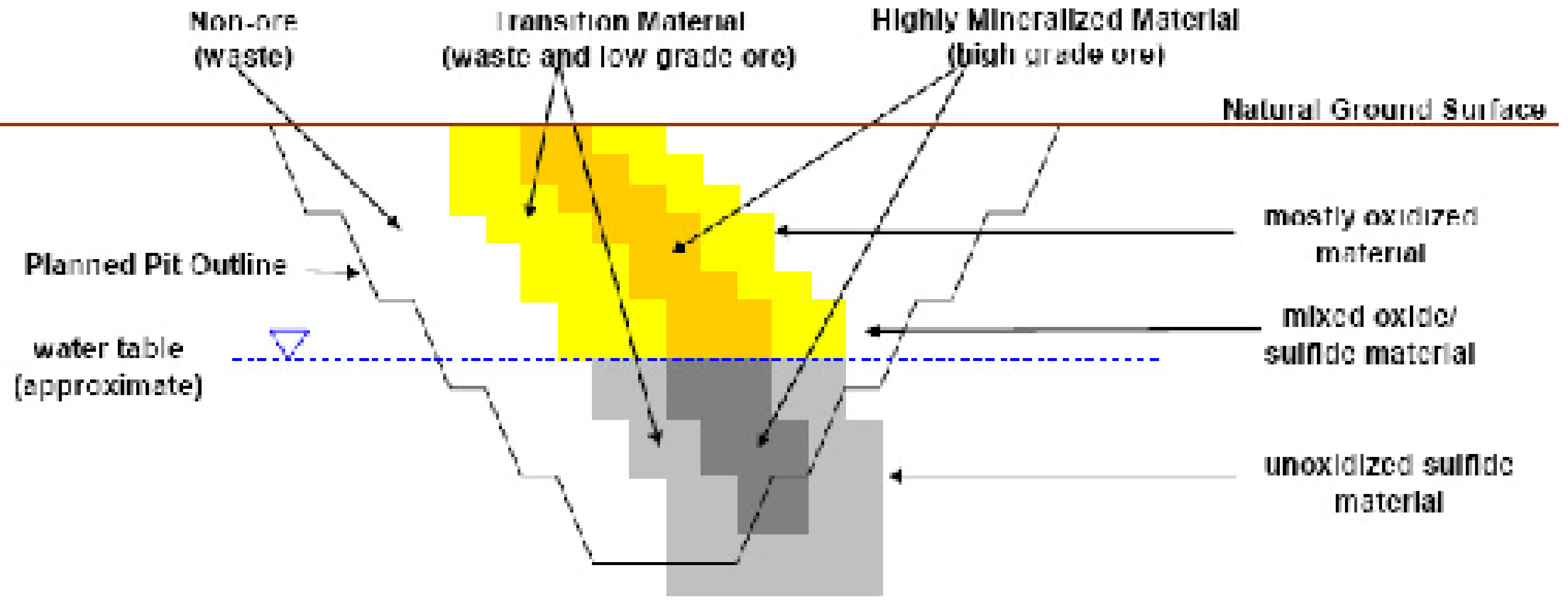
Wall rock

- Mining does not remove all the metal sulfide minerals
- Much is left at the "economic limit"
- Sulfide minerals remain in the walls or benches after the mining is completed
- Fractured by blasting, solid rock left behind is exposed to air & moisture and creates AMD

Waste rock

- Waste rock is the valueless rock which must be removed to get at the valuable rock
- Waste rock is generally just piled up off to the side of the mining operation - rain and snowmelt flow rapidly through porous piles of waste rock and leach out metals

Typical open pit - rock allocation



(Kuipers & Maest 2006)

Tailings

- Tailings - the very fine grit left over after milling the ore to liberate the metals - discharged near the mill into tailings ponds, basins or underground
- The small particle size of tailings results in maximum surface area so tailings readily generate AMD
- Proposed local mill - ground to “silt sized” with recoveries of Cu 75 to 97% and Ni 60 to 90%

Tailings underwater

- Placement of sulfide tailings underwater to eliminate exposure to air does NOT eliminate formation of AMD due to the presence of dissolved oxygen (DO)
- DO in a tailings lake can come from groundwater inflow, surface water, surface runoff, precipitation and lake turnover
- DO in the water keeps metal sulfide oxidation reaction going to generate AMD

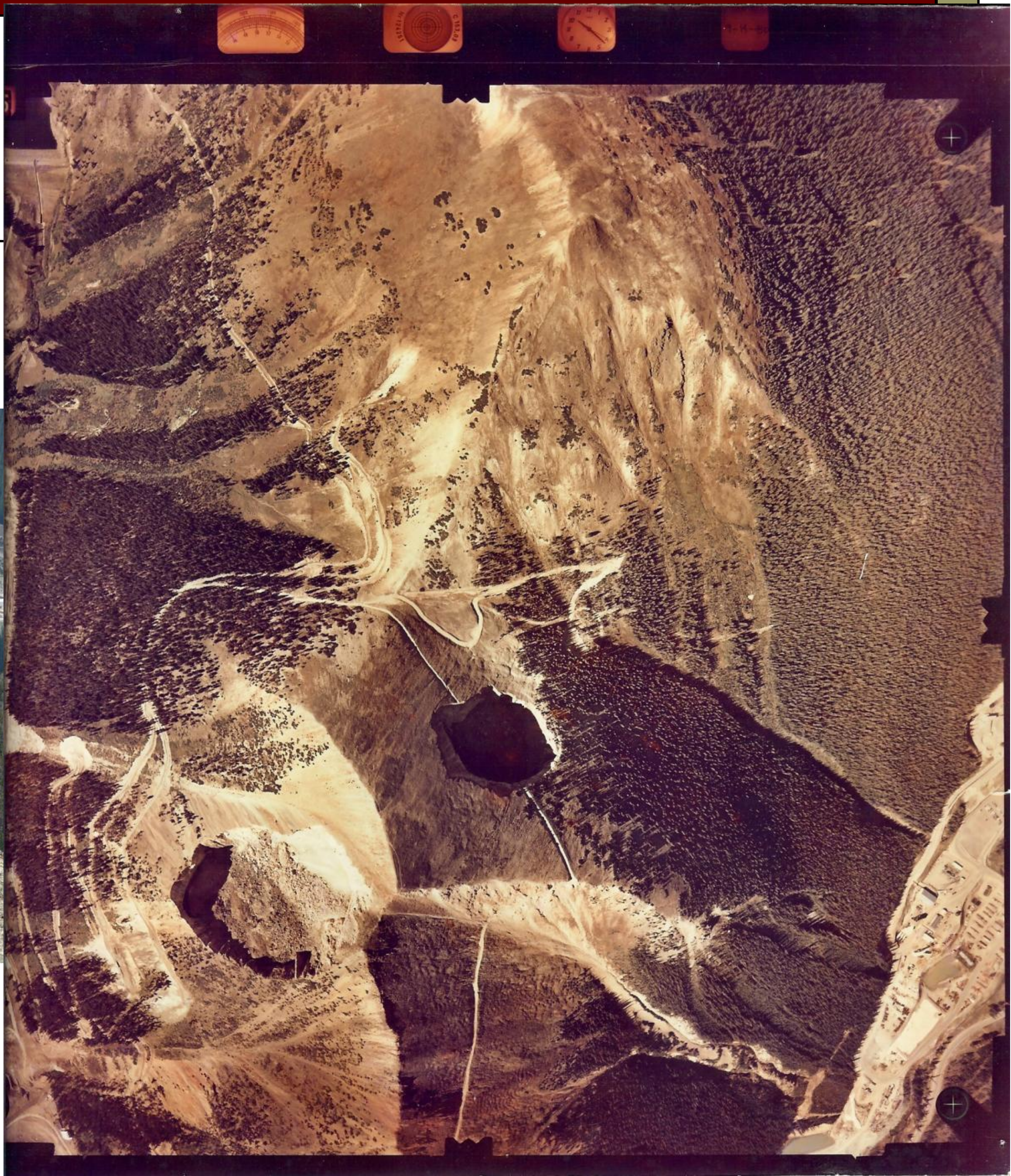
Surface vs Underground Mining

- Orebody 3-D configuration and grade determine whether open-pit or underground – not environmental factors
- Underground more expensive than open pit so used for smaller, vertical, higher grade deposits; open pits for large, lower grade deposits
- May be differences in permitting or public acceptance due to project footprint

Underground mining

- Underground mining has less waste rock
- Control wall rock exposure to climatic water
- Can control fugitive dust
- Fewer impacts to land, wildlife, surface water
- Susceptible to subsidence or surface collapse

Henderson Mine



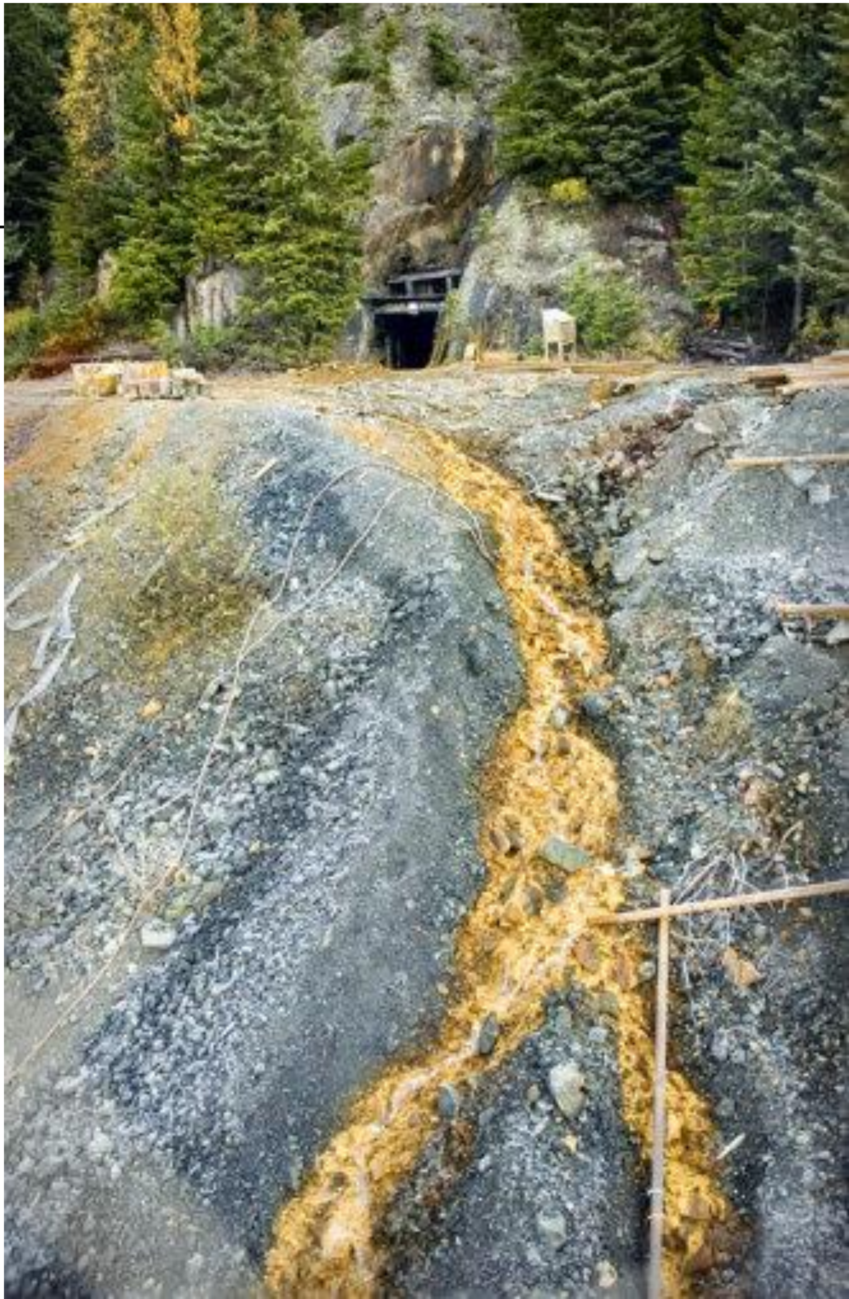
Henderson Mine

Surface or open pit mining

- Large volumes of waste rock susceptible to AMD
- Destroys large tracts of land that are scars on the landscape for decades
- Pits remain open and can generate AMD

The AMD Legacy

- **20,000 to 50,000 mines generating acid on US Forest Service lands affecting 5,000 to 10,000 miles of streams**
- **Nationally, AMD has polluted 12,000 miles of streams**



The AMD Legacy

Several large modern era mines have declared bankruptcy and left tax payers with the cleanup responsibility

This includes:

Zortman Landusky Mine MT

Summitville Mine CO

Brohm Mine SD

The AMD Legacy

largest and most expensive Superfund sites are AMD mining sites in the West

Includes:

Iron Mountain Mine CA

Bunker Hill ID

Butte-Clark Fork River complex MT

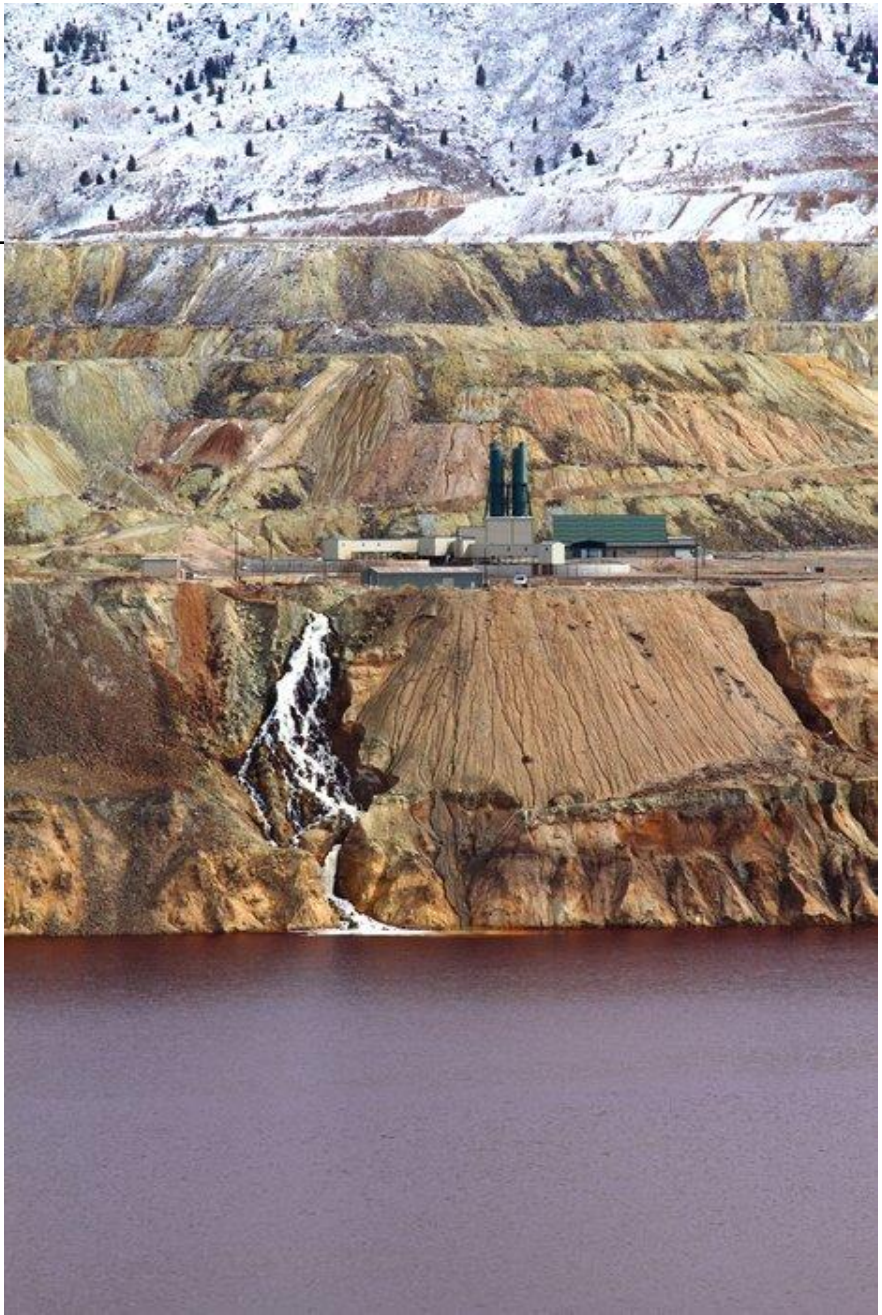
The AMD Legacy

- **500,000 inactive and abandoned hard rock mines in 32 states**
- **at least 50 billion tons of untreated, unreclaimed mining waste**
- **cleaning up of environmental problems exceed $70 billion**

Berkeley Pit

- 1 mile X 1/2 mile X 1/3 mile deep
- 900 feet of water and rising: < 150 feet to the natural water table
- pH of 2.5 & laden with heavy metals

Berkeley Pit



- Groundwater flow direction reversal when pit water reaches natural water table
- Perpetual pump and treatment to prevent widespread aquifer contamination
- Same for ANY AMD runoff or leachate collection – perpetual care

Greens Creek Mine

- high potential for AMD in surface waste
- 2.7 million tons of waste per year
- released 59 million pounds of toxic chemicals in 2000
- 20 to 50 years for most of its waste to start generating acid mine drainage
- mine surface water may need to be treated for hundreds of years to remove acid & metals.

Bingham Canyon

- 72 sq mi plume of sulfate contamination
- Under 70,000 Salt Lake-area homes
- Large, long term and expensive groundwater cleanup project

Spruce Road, Ely

- Leaching copper, arsenic & other metals
- AMD from only 10,000 tons 40 years ago
- Twin Metals would extract and dump 40,000 tons <u>per day</u> in same area

LTV Dunka – bench test for AMD

- Dunka mine near Babbitt MN had taconite overlain by sulfide containing waste rock.
- stockpiled more than 20 million tons of waste rock in large rock dumps
- Waste rock has been leaching copper, nickel and other metals into wetlands and streams that flow into Birch Lake not far from the Boundary Waters
- An average of 300,000 to 500,000 gallons run off the waste rock dumps each month, according to MPCA documents

Acid Mine Drainage – a threat?

- Is AMD some theoretical hypothesis yet to be proven in the lab or field?
- An emotional rant by over zealous tree huggers with nothing better to do
- We have thousands of example mines occurring over thousands of years

ACID METAL DRAINAGE IS REAL

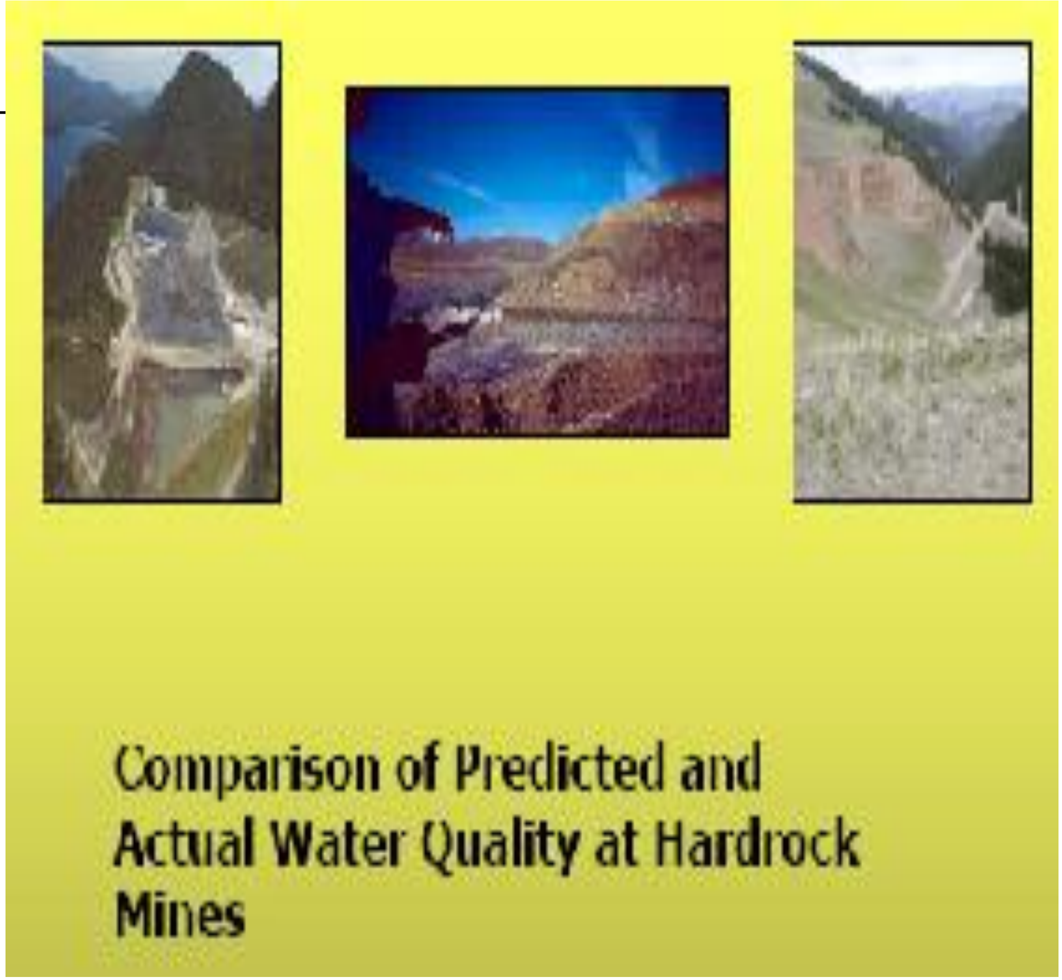
So how well do we understand (and use) the science?

- Industry --that was then –this is now--mines from way back when don’t even belong in the mine evaluation process

- Technology and our understanding of the science of AMD plus comprehensive regulations - modern mines simply will not pollute …………so let’s take a look at the sulfide mineral mining record

Kuipers and Maest study of hardrock mines

- Modern mine – permitted under NEPA & required an Environmental Impact Statement
- "major mines" in the US based on disturbed acreage, financial assurance or metal production
    - 183 hardrock mines in 14 states



“Comparison of Predicted and Actual Water Quality at Hardrock Mines” (Kuipers & Maest 2006)

- study found that 100 percent of hardrock mines predicted compliance with water quality
- In practice, 76 percent of mines had mining related water quality exceedences in surface or ground water

From: “*Comparison of Predicted and Actual Water Quality at Hardrock Mines*”	**% with impacts to surface water**	**% with exceedences of surface water standards**	**% with exceedences that predicted no exceedences**
Mines with close proximity to surface water & elevated acid drainage potential	**92%**	**85%**	**91%**

From: *"Comparison of Predicted and Actual Water Quality at Hardrock Mines"*	**% with impacts to ground water or seeps**	**% with exceedences of standards in ground water or seeps**	**% with exceedences that predicted no exceedences**
Mines with close proximity to ground water & elevated acid drainage Potential	**93%**	**93%**	**86%**

State of the Art or Industry Standard

- Do these numbers reflect our BEST technological effort?
- Do they reflect industry standard?
- What can we conclude, what should we learn from the performance of “modern mines”?

We have to recognize

- Mining results in major disruption of geologic & biologic systems – potential for major impacts
- The scientific community attempts to predict major impacts
- Are our predictive skills - up to the challenge? Apparently not

Regulatory Approach

- Be technically rigorous in reviewing mining permit applications and particularly EISs
- Recognize uncertainties and the risk they pose to the environment
- Require large safety factors and detailed and proven contingency plans to reflect the uncertainties – make conservative decisions
- Regulators must be ready, and encouraged if appropriate, to just say no to risky mining projects

In Closing

The ultimate disaster and flagrant disregard of our responsibilities as stewards of the land would be that we - all of us here today – are witness to decisions that lead to the environmental degradation of the largest and cleanest body of fresh water on the planet

Good or Bad Genie

The genie is still in the bottle, trapped in billion year old rock. Blasting, crushing and moving hundreds of millions of tons of reactive rock will let the acid metal genie out of the bottle

Are we releasing a friendly genie or a toxic legacy for decades and centuries to come?

Questions & Comments?