

Terrero Mine and El Molino Mill Cleanup

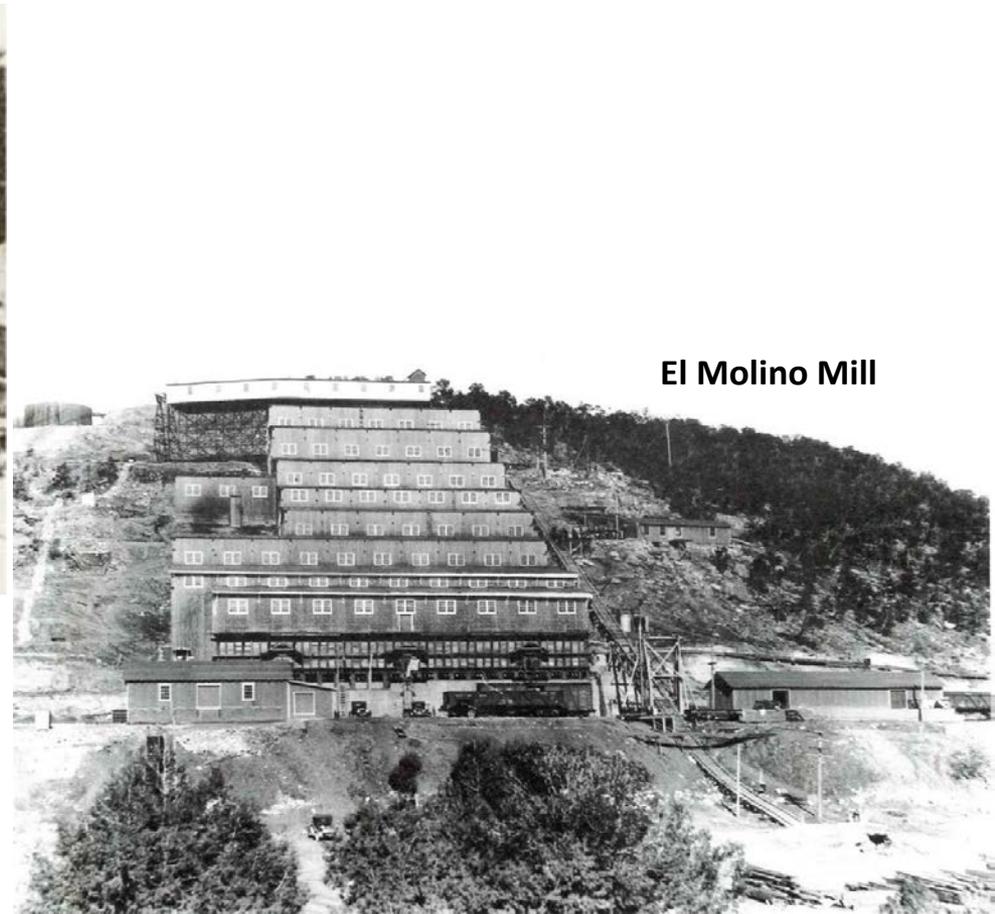
Briefing Report

For the Radioactive and Hazardous Materials Committee

November 12, 2015



Terrero Mine



El Molino Mill



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Significance of Terrero and El Molino

- **Legacy mining/milling sites that discharged acid rock drainage and suspended solids into surface water.**
- **Heavy metal contamination of surface water.**
- **Fish kills downstream of Terrero mine site.**
- **Concentration of metals into the food web.**
- **Similar mine waste issues and concerns along the Animas River.**

State Ownership

- **The State of New Mexico acquired ownership of the mine and mill sites after operations ceased.**
- **The state also owned some of areas where mine waste had been used as fill.**
- **Terrero and El Molino have undergone significant reclamation funded in, part by, appropriations from the Legislature.**

Acid Rock Drainage (ARD)

- Sulfide ore bodies and associated gangue rock, like at Terrero, contain pyrite (fool's gold, FeS_2) and other minerals that can oxidize and release sulfuric acid and metals into water.
- Undisturbed ore bodies exposed at the surface can generate ARD.
- Mine workings, mine waste piles, and mill tailings piles can increase the magnitude of ARD.
- ARD can pollute ground and surface water and kill fish.

Terrero Mining History

- **Terrero is a volcanogenic massive-sulfide ore body, the largest of its kind in N.M. Major ore minerals included sphalerite (ZnS), galena (PbS) and chalcopyrite (CuFeS₂). The mine site also contained many other minerals including native gold and metalliferous sulfides, carbonates and sulfates.**
- **The ore body was discovered near the confluence of Willow Creek with the Pecos River in 1881. Large-scale mining occurred from 1927-39. Terrero was one of the largest producers of lead and zinc in the U.S.**
- **Ore was crushed at the mine site and then transported by a 12 mile long aerial tramway to the El Molino Mill in Alamitos Canyon.**

Mine Site Contamination

- **Waste rock from was deposited into Willow Creek and in to the Pecos River floodplain. Runoff from the mine site contained acidic metal-laden ARD, and suspended solids with elevated metals.**
- **Runoff from the mine site flowed into beaver-created wetlands, before emptying into the Pecos River.**
- **Under normal flow conditions, solids settling and microbial metal reduction in the beaver wetlands, greatly reduced the impact of mine runoff on the Pecos River.**
- **During high runoff, however, the ability of the beaver wetlands to attenuate contaminants was diminished, and higher levels of metals entered the Pecos River.**

Mine Contamination, Contd.

- **Sediments panned from Willow Creek contained grains of sphalerite, galena, chalcopyrite, pyrite and other minerals associated with the mine site.**
- **Pecos River sediments downstream of the mine site contained elevated concentrations of metals.**
- **Elevated metals also were detected in benthic macroinvertebrates, fish tissue and in small mammals.**
- **The Pecos River and Lisboa Springs Fish Hatchery, 11 miles downstream of the mine, had a history of major fish kills that coincided with runoff events in the watershed.**
- **High levels of zinc and aluminum are believed to have been at least partly responsible for some of the fish kills.**

Terrero ARD Seep



The white and brown precipitates and froths consist of iron, copper and zinc sulfates, and iron and aluminum oxides and hydroxides. From McLemore and Brandvold (2001).

El Molino Milling History

- The El Molino Mill processed 1,293,000 tons of ore from the Terrero Mine.
- The mill produced:
 - 440,000,000 pounds of zinc
 - 138,000,000 pounds of lead
 - 19,000,000 pounds of copper
 - 5,000,000 ounces of silver
 - 178,000 ounces of gold
- In their day, the mine and mill were the largest employer in the State of New Mexico.

Mill Site Contamination

- **Mill tailings were deposited into two impoundments in Alamitos Creek.**
- **Lead concentrations in the tailings ranged from 2,800 to 13,000 ppm.**
- **The tailings dams failed in 1973 resulting in tailings dispersal downstream in Alamitos Creek and most likely into the Pecos River.**
- **After dam failure, erosion of the tailings by Alamitos Creek provided an ongoing source of contamination into the watershed.**
- **Surface water contained cadmium, lead, iron and manganese in excess of state and federal standards.**
- **Stream sediments contained elevated iron, copper, lead and zinc.**
- **Groundwater in monitoring wells near the tailings piles contained sulfate, manganese and total dissolved solids in excess of state standards.**

El Molino Mill Tailings and ARD



Mine Waste Used as Fill

- **Up until the 1970s, waste had been removed from the mine and mill sites and used as fill material for roads, campgrounds, camping pads, a trailhead, and at the Lisboa Springs Fish Hatchery.**

1991 Fish Kill

- **Spring runoff in 1991 caused a massive fish kill. More than 90,000 trout died at the hatchery, alone.**
- **The fish kill brought attention to contamination from the mine and mill.**

Also in 1991

- **In response to concerns about human health exposure to mine waste that had been used as fill, the U.S. Forest Service closed several forest roads, two campgrounds and one trailhead.**
- **The Fish and Wildlife Service released a report, based on samples collected in 1990, that found elevated metals in fish and mammals near Terrero.**
 - **Lead in edible fish tissue was at or near the human consumption criterion.**
 - **Lead in small mammal tissue exceeded the criterion for raptor protection.**

“Perfect Storm” for Pecos

- **The 1991 events caused a decrease in recreational visitors to the Pecos area, which negatively impacted the local economy.**

A Path Forward

- **Discussions among industry, government agencies and community stakeholders reached a consensus that corrective actions were necessary, but that Superfund listing should be avoided.**
- **As described by Robinson (1995), the community was interested in a "Superfund level of cleanup without the perceived cost and delay problems of Superfund".**
- **In addition to the successor business of the original mining company, several state and federal government agencies had potential liability by ownership of land that contained mine and mill waste.**
- **The potentially responsible parties negotiated an Administrative Order on Consent (AOC) and Statement of Work which contained many provisions parallel to the Superfund process.**

1992 AOC

The Administrative Order on Consent (AOC) was signed on December 2, 1992 by:

- **NMED**
- **N.M. Natural Resource Damage Trustee**
- **N.M. Department of Game and Fish**
- **N.M. Highway and Transportation Department, and by**
- **AMAX Resource Conservation Company.**

The AOC included a Cost Sharing Agreement where AMAX was responsible for 80% of the total cost of investigation, remediation and natural resource damages for the mine and mill, and the State of N.M. was responsible for 20%.

The U.S. Forest Service was not a party to the AOC, but allocated \$1.2 million to remove or cap mine waste that had been used as fill at roads and campgrounds.

1992 AOC Statement of Work

The AOC addressed contamination at the Terrero Mine, El Molino Mill, campgrounds and recreational use areas, roads, and at the Lisboa Fish Hatchery.

The AOC included the following elements:

- Remedial investigation
- Health and Environmental Risk Assessment
- Community Relations Plan
- Natural Resource Damage Assessment
- Interim Remedial Actions
- Feasibility Study
- Decision Document
- Remedial Design
- Remedial Action

Corrective Actions

- **Excavation, consolidation and stabilization of mine waste and mill tailings with multi-layered covers. Chip seal of some fill materials.**
- **Mine waste was removed from Willow Creek and the stream bed was reconstructed. Mill tailings in Alamitos Creek were stabilized and the stream was reconstructed over an impermeable liner on top of the tailings.**
- **Interception and diversion of both surface and subsurface flow from mine and mill waste in order to prevent ARD.**
- **Geomorphic restoration of floodplains, wetlands and riparian habitats.**
- **Revegetation of disturbed areas.**
- **Closure of dangerous mine shafts.**
- **Corrective actions, monitoring and maintenance are ongoing in 2015.**

Terrero Mine Waste Piles Before and After Cleanup



A lead cleanup target of 500 mg/Kg (parts per million) was used.

El Molino Mill Tailings Before and After Cleanup



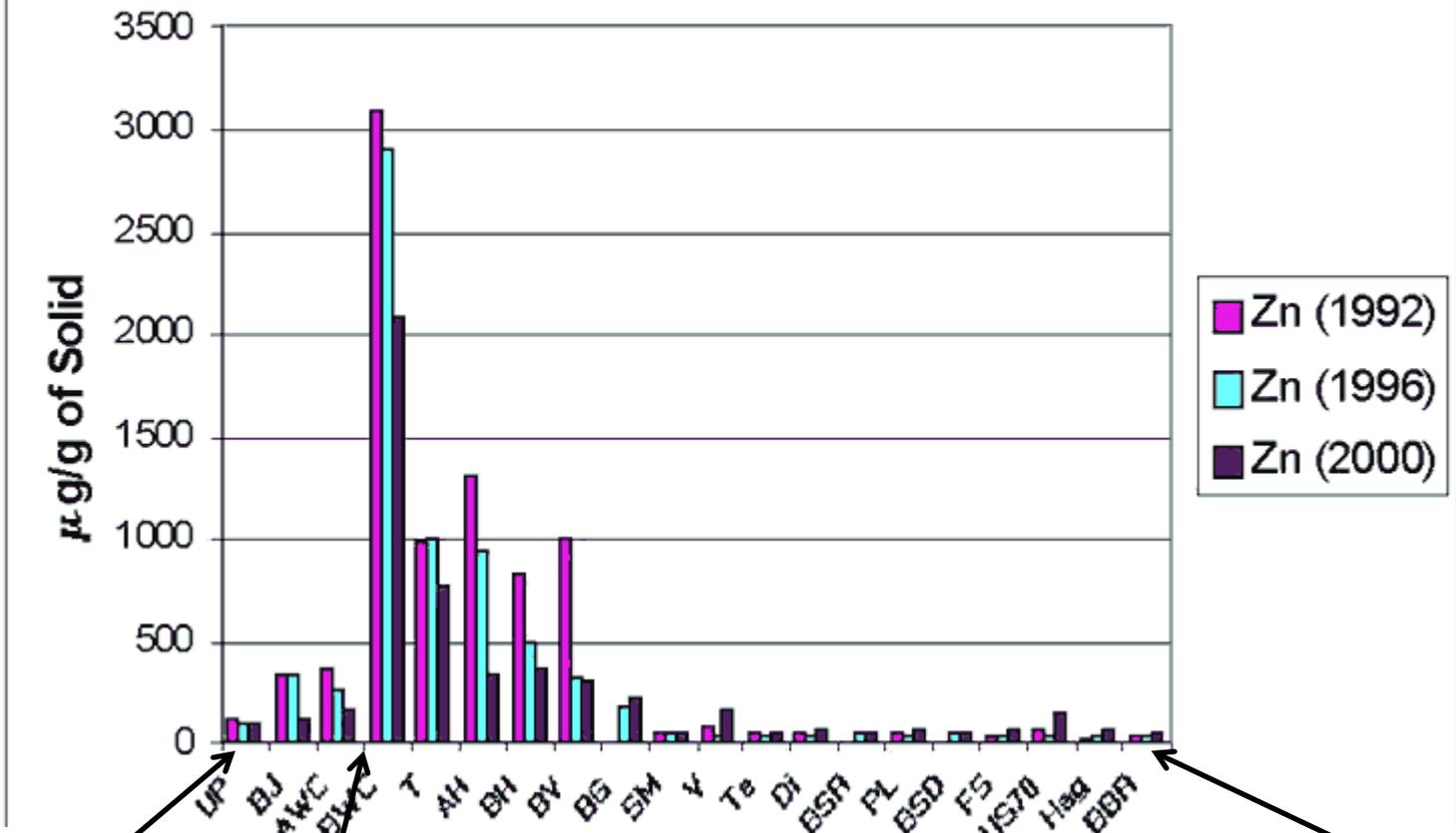
Improvement of Sediment and Water Quality

- **Restoration activities began in 1991, before the AOC was signed in 1992.**
- **No fish kills attributable to the Terrero Mine have occurred since the mid 1990s.**
- **By 2000, metal concentrations in Pecos River sediment downstream from the mine had decreased.**
- **Exceedances of Water Quality Criteria for cadmium, zinc and turbidity in Willow Creek also decreased after restoration.**
- **The NMED Surface Water Quality Bureau removed turbidity from the list of impairment parameters for Willow Creek in 2004, and removed cadmium and zinc from the impairment list in 2012.**

Zinc Attenuation in Pecos River Stream Sediment after Remediation

Zn Concentrations in Stream Sediments

From McLemore and Brandvold (2001)

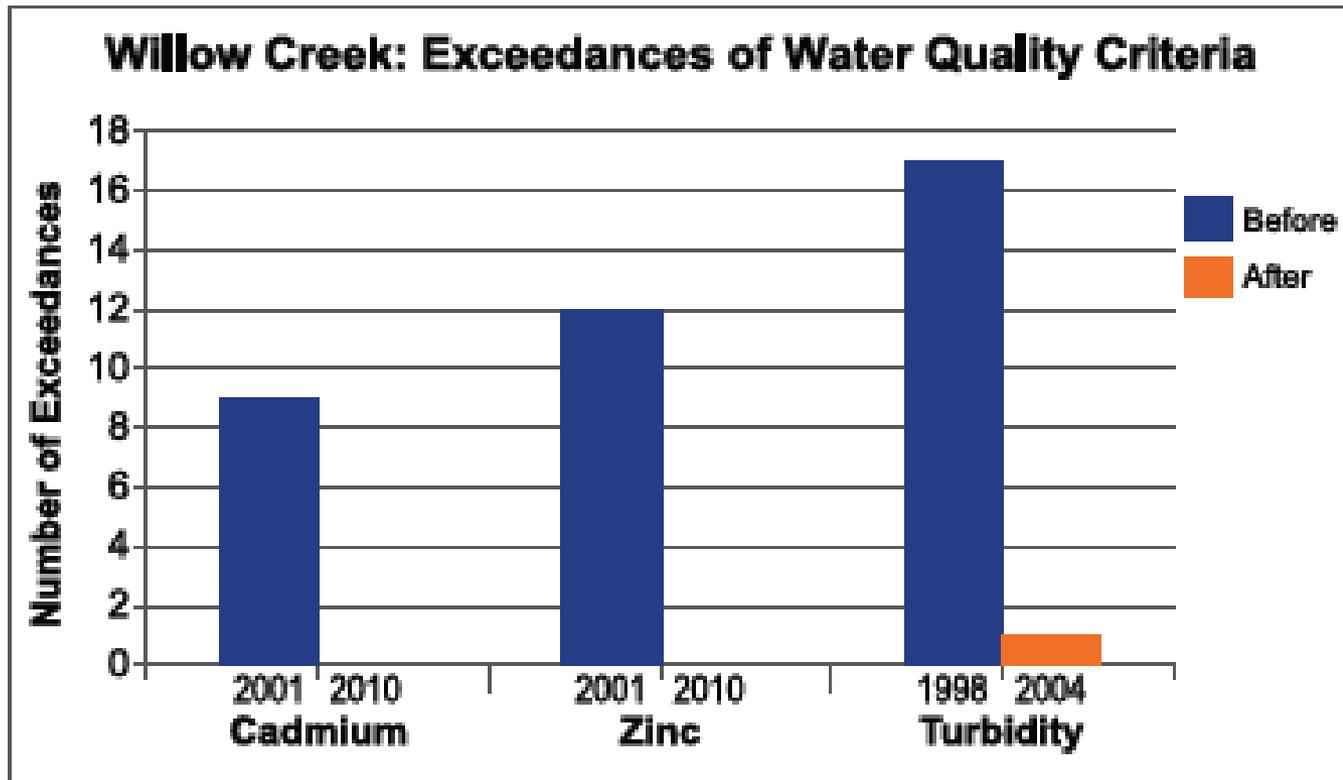


Pecos Wilderness

Willow Creek

Carlsbad

Decrease of Water Quality Criteria Exceedances after Remediation



From Guevara and Mayerson (2014)

**Willow Creek
Acid Rock
Drainage
Before
Cleanup**



Willow Creek After Cleanup



Questions?

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