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SUMMARY OF ENVIRONMENTAL ISSUES AT EL MOLINO MILL, NORTH-CENTRAL NEW MEXICO

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Abstract—The El Molino mill, located northwest of the Village of Pecos, New Mexico, has been investigated as a potential hazardous waste site under the Comprehensive Environmental Response, Compensation and Liability Act, or CERCLA, since 1985. Under the CERCLA process, the New Mexico Environment Department has identified the mill site as an operable unit requiring a remedial investigation, a feasibility study, remedial design/remedial action, and long-term operation and maintenance of a remediation plan. Three tailing impoundments constructed adjacent to El Molino mill in Alamitos Canyon are in close proximity to schools and residential areas in Pecos and pose potential risks to human health from contaminated soil and ground water. The tailing materials, characterized by low pH values and elevated concentrations of metals, may potentially affect nearby soils, surface water, air quality, and ground-water quality in domestic and municipal water supplies.

INTRODUCTION

The Pecos mine, located approximately 16 mi north of the Village of Pecos, was in operation from 1926 to 1939 producing lead, zinc and small amounts of copper, gold and silver, from a massive sulfide deposit. The ore was transported via a 12-mi aerial tramway to El Molino mill in Alamitos Canyon approximately 2 mi northwest of Pecos. Remnants of mine and mill structures are still visible along NM-63 and County Road B52, respectively (Fig. 1). Current environmental concerns surrounding El Molino mill are primarily associated with tailing impoundments constructed in Alamitos Canyon. This paper summarizes the environmental issues and investigations relevant to El Molino mill.

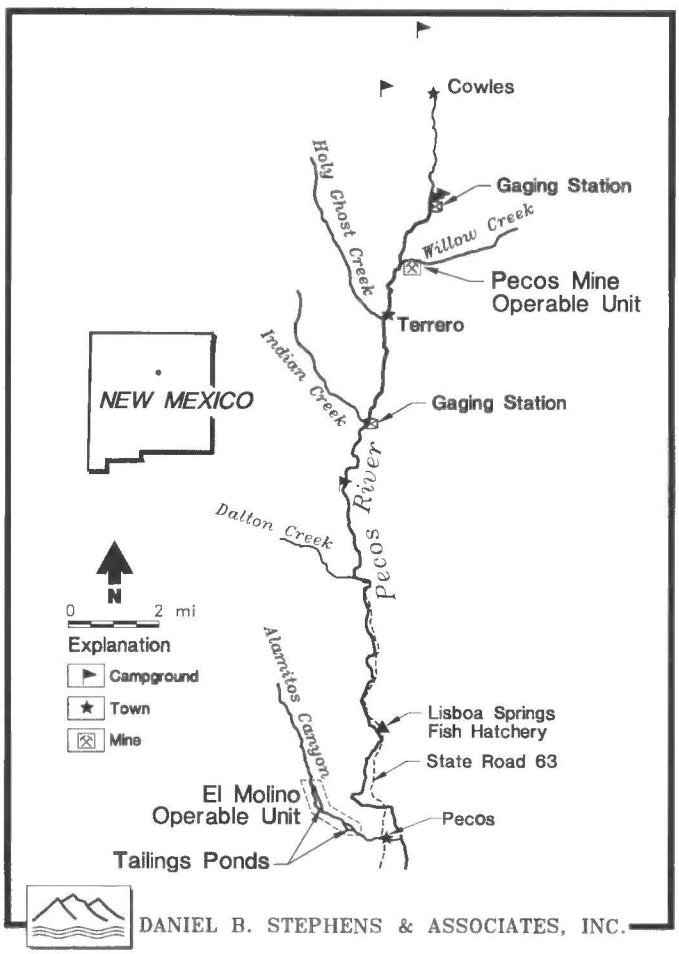

FIGURE 1. Location of Pecos mine and El Molino mill operable units.

REGULATORY FRAMEWORK GOVERNING ENVIRONMENTAL INVESTIGATIONS

The El Molino mill was first investigated by the U.S. Environmental Protection Agency (EPA) and the New Mexico Environment Department (NMED) as a potential hazardous waste site under the Comprehensive Environmental Response, Compensation, and Liability Act, or CERCLA, in 1986. Under a consent order signed in December, 1992, the State of New Mexico as the current site owner, and the previous mine operator, volunteered to investigate and characterize the site, to perform human health and environmental risk assessments, and to design and implement a reclamation plan under the direction of the New Mexico Environment Department. The most significant health and environmental issues are concerned with surface water impacts and potential soil and ground-water contamination from lead, zinc, copper and silver originating from the mill tailing.

For the purposes of investigation and cleanup, NMED has identified El Molino mill and associated tailing dumps located in Alamitos Canyon as one of five operable units of the Pecos mine site. Following the CERCLA process, the El Molino operable unit will proceed through the following four activities prior to closure:

1. Remedial Investigation—A series of comprehensive field investigations and data analyses to define the nature and extent of contamination and to identify any actual or potential impacts to surface water, ground water, soil and sediment, flora and fauna, and air quality.
2. Feasibility Study—An evaluation of remedial alternatives which may be implemented to minimize or eliminate present or potential future impacts from mine or mill wastes.
3. Remedial Design and Remedial Action—The design and construction of remediation and monitoring systems.
4. Long-term Operation and Maintenance—Operation and maintenance of the remedial and monitoring systems.

As of this writing, the remedial investigation and feasibility study for the El Molino operable unit have largely been completed, a reclamation plan has been developed, and implementation of the plan is forthcoming.

Public document repositories containing the administrative record for the site have been established for public viewing in Pecos and Santa Fe. Information presented for the El Molino mill operable unit has been compiled from company reports available in the administrative record.

EL MOLINO MILL OPERABLE UNIT

The El Molino mill operable unit (Fig. 1), located in Alamitos Canyon within the Bert Clancy Fish and Wildlife Area, totals approximately 47 acres. Associated with the mill are three tailing impoundments constructed along an intermittent stream in Alamitos Canyon (Fig. 2). The upper two tailing impoundments (TP-1 and TP-2) were deactivated in 1939 and have been slowly eroding since that time. The largest and uppermost tailing impoundment, TP-1, is 33 acres in area. The middle tailing im-

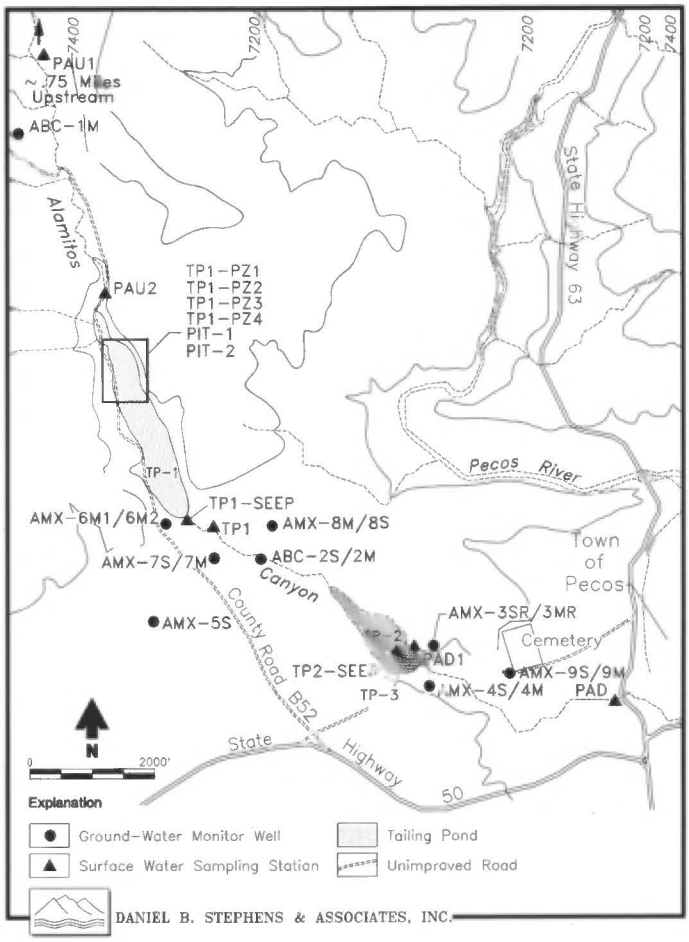

FIGURE 2. Water quality monitoring stations for El Molino mill.

poundment, TP-2, encompasses 11 acres. The third and smallest tailing pond (TP-3) is approximately 3 acres in size, and was constructed about 200 yds downstream of TP-2 for flood and erosion control after a July, 1970 flood in Alamitos Canyon.

As a result of erosion from, and infiltration through, the tailings, the NMED has determined that the site requires remedial action to minimize potential impacts to surface and ground water in the area downgradient of the tailings. Because several domestic supply wells and two schools are located less than 1 mi from the tailing ponds, a major concern at El Molino is for potential risks to human health from exposure to contaminated soil and ground water. Numerous studies have been conducted at the site since 1986 in order to support decisions regarding human health and environmental impact (e.g., Amax Resource Conservation Company, unpubl. report, 1993; Daniel B. Stephens & Associates, Inc., unpubl. report, 1994). These studies were undertaken to characterize the tailing materials, soils, vegetation, wildlife, geology, hydrologic and hydrogeologic conditions, and water quality.

The tailing and interstitial pore waters are characterized by low pH levels and elevated concentrations of metals. Residual metals in the tailings, including lead, zinc, copper and silver, reflect the metals recovered during processing of the poly-metallic ore. The tailing materials impounded at TP-1 and TP-2 are saturated with water at depths greater than approximately 7 to 12 ft below ground surface. Subsurface water in the tailing originates from precipitation on the surface of the tailing material, infiltration of surface flow from Alamitos Creek, and subsurface flow from alluvial aquifers associated with Alamitos Creek and adjacent drainages. Not unexpectedly, analytical results (Table 1) generally show the tailing water to have acidic pH values of 4.2 to 4.9 and concentrations of sulfate, and some heavy metals including iron, cadmium, manganese, lead, and zinc elevated above New Mexico Water Quality Control Commission (NMWQCC) water quality standards. Water quality samples from seeps at the base of TP-1 and TP-3 generally have pH values that are more acidic than surface water samples collected upstream of the tailings, and levels of iron and copper that exceed EPA water quality criteria for freshwater aquatic life (Table 2).

The tailings generally do not support vegetation, due principally to the acidic conditions and also possibly to elevated metals concentrations. Shallow weathered bedrock soils adjacent to the tailing have washed onto the surface of the lower half of TP-1, creating a patchy veneer of growth media that has supported the natural revegetation of over 100 different plant species. This vegetation, combined with the intermittent water course, has resulted in the formation of a natural wetland on the southern half of TP-1. Although the substrate for this wetland is mill tailing, typical wetland vegetation communities have colonized this area. As the reclamation plan for the tailing is implemented, this wetland area will be lost to capping in order to meet the primary objective of protecting human health. To the extent possible, some additional wetlands will be constructed to replace the lost wetland or augment other existing wetlands in the area.

The quality of surface water in Alamitos Creek has also been affected as it traverses the tailing impoundments. The surface water regulatory standards used to evaluate surface water quality are defined by a hardness-based calculation that establishes chronic toxicity for freshwater aquatic life (U.S. EPA, 1986). The calculated standard provides a value for dissolved metal concentration at a measured hardness that will not unacceptably affect freshwater aquatic organisms if a 4-day average concentration does not exceed the standard more than once every 3 years on the average. Cadmium and zinc have been detected in surface water downstream of TP-1 in concentrations elevated above background and also exceeding EPA criteria for fresh-water aquatic life (Table 2). Sediment samples from Alamitos Creek also show elevated levels of iron, copper, lead and zinc when compared to upstream samples. In order to mitigate surface water impacts and to prevent further stream water infiltration, seepage and erosion at TP-1, Alamitos Creek has been rerouted through a channel engineered with a synthetic liner.

Geologic mapping at the site (Johnson, 1973; Adrian Smith Consultants, Inc. unpubl. report, 1988) shows that TP-1 is located on limestone of the upper Madera Formation, and the drainage below TP-1, including all of TP-2 and TP-3, rests on sediments of the Sangre de Cristo Formation. Geologic logs of ground-water monitoring wells installed south of TP-1 and TP-2 indicate that the Sangre de Cristo and upper Madera Formations in this area consist predominately of shales and silty shales.

The significance of the shales in the stratigraphic sequence is threefold. First, shales have characteristically low hydraulic conductivities, which limit the mass flux of fluids vertically through the sediments and significantly impede contaminant migration. Second, because of their high clay content, the thick sequences of shales provide high attenuation capacity for metals at pH values characteristic of waters at the site. Finally, the low hydraulic conductivities associated with the shales allow these units to act as confining layers for aquifers located lower in the Madera Formation. Such confined conditions often result in upward vertical hydraulic gradients, which further protect ground water in the Madera Formation against the potential for contamination by downward advection.

A network of wells has been installed in Alamitos Canyon to monitor ground-water quality in, adjacent to, and downgradient of the tailing impoundments and to characterize hydrologic conditions in the area. There are currently 16 ground-water monitoring wells completed in the Madera Formation, 7 monitoring wells in the Sangre de Cristo, 7 monitoring wells in alluvial material adjacent to the tailing impoundments, and numerous piezometers in the tailing materials at each impoundment.

Water level and well boring lithologic data from these and other domestic supply wells indicate that ground water suitable for domestic and agricultural use typically occurs at depths greater than 100 ft below ground surface. Results of water quality sampling indicate that metals concentrations in downgradient wells in the Madera limestone are comparable to the upgradient control well (Table 1). The constituents of concern to

TABLE 1. Summary of ground-water chemistry results.

	Cadmium	Copper	Iron	Manganese	Lead	Silver	Zinc	Sulfate[1]	pH[2]
NMWQCC Standard[3]	0.01	1	1	0.2	0.05	0.05	10	600	6-9
Location									
ABC-1M[4]	0.00012	0.0052	0.053	0.057	<0.001	<0.0001	0.027	36	7.58
ABC-2M[4]	<0.0001	<0.001	<0.02	<0.01	<0.001	<0.0001	<0.01	37	9.62
ABC-2S[4]	<0.0001	<0.001	0.031	0.049	<0.001	<0.0001	<0.01	68	8.06
AMX-3MR[4]	<0.0001	0.0023	0.072	<0.01	<0.001	<0.0001	<0.01	66	8.17
AMX-3SR[4]	<0.0001	0.0011	<0.02	<0.01	<0.001	0.00011	<0.01	320	8.85
AMX-4M[4]	<0.0001	0.0022	0.28	<0.01	<0.001	<0.0001	<0.01	46	9.39
AMX-4S[4]	<0.0001	0.0017	0.041	<0.01	<0.001	0.00016	<0.01	550	8.38
AMX-5S[4]	<0.0001	0.001	<0.02	<0.01	<0.001	<0.0001	<0.01	220	7.7
AMX-6M1[4]	<0.0001	0.0023	0.024	0.068	<0.005	0.00013	0.024	550	7.25
AMX-6M2[4]	0.00025	0.006	0.021	0.24	<0.005	0.0001	0.040	600	7.12
AMX-7M[4]	<0.0001	0.0023	0.024	<0.01	<0.001	<0.0001	<0.01	98	9.31
AMX-7S[4]	<0.0001	0.0023	0.044	<0.01	<0.005	0.00016	0.015	1800	6.91
AMX-8M[4]	<0.0001	0.0012	0.042	<0.01	<0.001	<0.0001	<0.01	33	9.59
AMX-8S[4]	<0.0001	<0.001	<0.02	0.051	<0.001	<0.0001	<0.01	61	7.65
AMX-9M[4]	<0.0001	0.0019	0.40	<0.01	<0.001	<0.0001	<0.01	52	9.06
AMX-9S[4]	<0.0001	<0.001	0.039	<0.01	<0.001	<0.0001	<0.01	86	9.11
PIT1[5]	0.00044	0.0058	2800	14	0.11	0.0011	96	15000	4.2
PIT2[5]	0.0014	0.00034	1300	17	0.63	0.0004	140	8200	4.8
TP1-PZ1[5]	0.15	0.0022	3100	46	0.85	0.004	450	17500	4.9
TP1-PZ2[5]	3.4	0.13	13000	150	0.029	0.015	3500	90200	4.42
TP1-PZ3[5]	0.33	0.11	1300	17	1.2	0.0026	150	1100	4.29
TP1-PZ4[5]	0.037	<0.001	400	6.9	1.4	0.00065	150	4200	4.28

Note: All concentrations are expressed in mg/L.
[1] Sulfate samples are unfiltered. All other values represent dissolved metals; samples field-filtered with 0.45-micron filter.
[2] pH values measured in the field.
[3] New Mexico Water Quality Control Commission Regulations for Ground-Water, Section 81-1, October 1992.
[4] Ground-water samples collected in the third quarter of 1994.
[5] Tailing water samples collected in the first quarter of 1994.

NMED (lead, zinc, copper, silver) are either not detected or are detected at trace levels significantly below water quality standards. The pH values in the wells range from 7.1 to 9.6, and are sufficiently high that significant transport of dissolved metals would be unlikely in the ground-water system.

In order to address potential erosion of tailing materials, infiltration of surface water through the tailing, and potential impact to surface and ground waters, a remedy has been selected to reclaim the tailing materials and associated contaminated soil located in Alamitos Canyon. The major components of the selected remedy include:

1. Consolidation of all tailing and contaminated soil with lead concentrations above a health-based risk level, as determined in a health risk assessment, into tailing impoundments 1 and 2;
2. Conveyance of surface water through tailing impoundments 1 and 2 via a lined, stable channel system designed for a 6-hour 100-year storm event;
3. Reinforcement of side drainages leading from the canyon tributaries into the main channel in tailing impoundments 1 and 2 to minimize erosion. These tributary drainages shall meet the design criteria for a 10-year, 24-hour storm event and a safety factor of 1.5 for drainage bottom and bank stability;
4. Capping of tailing impoundments 1 and 2 with a slope to minimize erosion and ponding, and revegetation with native plant species;
5. Stabilization of tailing dams 1 and 2 to meet the State Engineer Office regulations for dams;
6. Replacement of wetlands lost during remediation activities;

TABLE 2. Summary of surface-water chemistry results.

Location	Cadmium (µg/L)	Copper (µg/L)	Iron (µg/L)	Lead (µg/L)	Silver (µg/L)	Zinc (µg/L)	Hardness (mg/L)	pH[1]
PAD[2]	0.55 (10)	4.8 (126)	0.089 (1)	<5.0	0.19 (478)	0.021 (1)	1600	8.1
PAD1[2]	4.8 (8)	3.4 (99)	0.028 (1)	<5.0	0.12 (291)	0.16 (0.87)	1200	8.0
PAU1[2]	<0.10	<1.0	0.042 (1)	<1.0	<0.1	0.016 (0.25)	270	8.35
PAU2[2]	1.8 (4)	6.7 (42)	0.11 (1)	18 (109)	<0.1	0.2 (0.37)	440	8.06
TP1[2]	7 (5)	1.8 (62)	0.037 (1)	<5.0	<0.1	0.6 (0.55)	700	8.36
TP1-SEEP[3]	<0.1	<1.0	36 (1)	<1.0	0.47 (2940)	0.21 (3)	4600	6.6
TP2-SEEP[3]	8.4 (12.8)	205 (166)	7.3 (1)	<1.0	3.0 (827)	1.8 (2)	2200	4.95

Note: All values represent dissolved metals; samples field-filtered with 0.45-micron filter.
Values in parentheses are hardness based EPA water quality criteria for freshwater aquatic life (EPA, 1986).
[1] pH values for stream water measured in the field first quarter 1994; pH values for seep water measured in the field third quarter 1993.
[2] Stream water samples from Alamitos Creek.
[3] Seep water samples from base of tailing ponds.

7. Continued quarterly ground-water sampling of all monitoring wells until sampling stations meet water quality standards for eight consecutive quarters;
8. Installation of piezometers in tailing impoundments 1 and 2 with quarterly monitoring.

The design and construction phase of tailing reclamation is currently underway. Consolidation of material into tailing impoundments 1 and 2, construction of a lined surface water channel, and stabilization of the tailing dams was completd in 1994. Capping of the tailing material is expected to be completed during 1995.

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