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Innovative Administrative, Technical, and Public Involvement Approaches to Environmental Restoration at an Inactive Lead-Zinc Mining and Milling Complex near Pecos, New Mexico

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ABSTRACT

This paper will summarize innovative regulatory, technical, and public involvement activities associated with the investigation and remediation of lead and zinc ore mining and milling waste sites near Pecos, New Mexico. Resulting from unreclaimed mining operations conducted in the 1920s and 1930s, the site has been prominent during the past decade due to related fish kills in the Pecos River fish kills, state's role as a responsible party, potential for Superfund - CERCLA listing of the site, and state participation in funding of the multi-million dollars restoration effort.

The administrative framework and reclamation technology at the mill and tailings portion of the site, El Molino unit is reviewed with an emphasis on potentially transferable innovative methods currently being used for environmental restoration. The administrative framework responds to a local interest in a "Superfund level of cleanup without the perceived cost and delay problems of Superfund" and includes an administrative order on consent and statement of work which substitute for parallels within the Superfund process. This innovative approach may provide a model of state enforcement of Superfund level remediation, if the completed restoration efforts are fully effective and timely. The administrative process includes strong stakeholder involvement initiatives such as technical assistance and community relations contractors to enhance and focus affected community participation. Technology innovations include site characterization techniques such as heavy metal analysis using x-ray fluorescence methods, and remedial design techniques such as subsurface flow cut-off trenches integrated into surface flow diversion channels, construction of replacement wetlands, and lined, multi-layer tailings cover systems.

INTRODUCTION

Successful environmental restoration of industrial waste disposal sites provides employment and post-restoration land use opportunities, as well as long-term human and ecological risk reduction. Attaining a goal of successful and sustainable environmental restoration requires effective and lasting solutions to the unique complex of administrative and technical problems presented by the individual sites. Environmental professionals seeking to effectively restore waste disposal sites can benefit from an understanding of successful approaches used for other wastes and at other sites in order to broaden the range of proven effective approaches available for consideration at sites of concern. Experience of this type, at restoration projects outside the radioactive waste management arena where innovative technologies and administrative solutions have been demonstrated, is particularly important for radioactive waste managers. Such sites provide excellent examples of effective solutions which are applicable to radioactive waste problem sites. They also offer a much wider set of cases and methods to learn from than the very limited number of completed radioactive waste sites restorations. Since the range of radioactive waste forms, sites and administrative

settings is so wide due to the uniqueness of each site, the opportunity to apply experience from one radioactive waste problem to another may be very limited. Conversely, effective approaches from problem sites without a radioactive waste component but facing similar administrative and environmental restoration standards may be directly relevant. A prime source of such transferable restoration technology is the mining sector where large volume, heavy metal-laden wastes present complex, multi-pollutant problems where governmental and owner-operator roles are poorly defined and affected communities are actively involved in the restoration policy and design proceedings. Many mine and mill sites involve resolution of complex regulatory, technology and public involvement concerns in rural areas, often in the western US, but certainly found in other parts of the country and in every region around the globe, which are similar to the maze of decision-making and environmental technology design problems facing radioactive and chemical waste managers.

The environmental restoration process for lead-zinc mine and mill wastes near Pecos, New Mexico offers a wide array of specific examples of effective and innovative technologies and administrative and public involvement approaches potentially transferable to a variety of radioactive, and other large-volume, long-lived, chronic-hazard sites. Particularly relevant waste forms include those with dispersed heavy metal contamination, such as uranium extraction, processing and fabrication sites; low-level, buried and mixed radioactive waste sites; as well as other hard rock mining and milling and mixed metal-organic chemical sites.

BACKGROUND

The spectacularly beautiful Upper Pecos River Valley of northern New Mexico lies 20 miles west of Santa Fe. The valley is the setting for the Village of Pecos, an abandoned Pueblo Indian community now protected at Pecos National Monument, heavily used recreational attractions associated with enjoyment of the world-renowned Pecos Wilderness and other areas in the Sangre de Cristo Mountains within Santa Fe National Forest and the high-quality fishing and camping opportunities along the river. It is also the site of a long inactive mine and mill complex which produced some 2,200,000 tons of lead-zinc ore between 1926 and 1939. The mine site at Terrero (a Spanish term for mine dump) is well known by many of the 3,500 local residents and area visitors. It borders the highway which provides access to the high country of the Pecos Wilderness and is found at the mouth of Willow Creek, a local tributary to the Pecos River. Sixteen miles downstream of the mine site is the 50 acre mill and tailings complex - known locally as "El Molino" - which covers approximately one-half mile along, and with, the streambed of the Alamitos Creek. The southern end of the El Molino site is less than one-half mile from residences in the Village of Pecos and the Village's elementary and high school complex. Since state acquisition of the surface rights to the mine and mill sites in 1950, portions of the highway, mine and mill wastes have been hauled off-site for use in construction at several nearby state and federally managed campgrounds and a state fish hatchery. This complex of mine and mill sites are titled the "Upper Pecos Site" and are being managed as five units: the Pecos Mine, El Molino, State Recreation Use Areas, State Highway 63, and the Lisboa Springs Fish Hatchery.¹ This paper will focus on the El Molino unit, as the unit with the largest volume of waste, the unit closest to a residential community and the unit with the most advance environmental restoration program as of January 1995.

Though active mining ceased before World War II, substantial data is available on the nature of the materials handled at the mine and mill including the mill tailings. The ore body is reported to have been discovered in 1881, but not brought into production until 1927 by American Metals Company of New Mexico, The multi-mineral ore averaged 10.6% zinc, 3.3% lead, 0.5% copper, 2.8 oz./ton silver and 0.1 oz./ton gold, and was processed at a 600 ton per day selective flotation mill until "water problems, labor disputes and bad ground at depth contributed to the mine's shutdown in 1939". Ore was transported to the mill and tailings site, the area of the El Molino unit, via a 12 mile

aerial tramway.² Following removal of values, mill tailings were discharged into two impoundments behind embankments across Alamitos Canyon. The Canyon is drained by Alamitos Creek, an intermittent stream which flows through the Village of Pecos before reaching the Pecos River and capable of generating substantial seasonal flows from snowmelt and peak precipitation runoff events. A third impoundment was constructed downstream of the other two dams, presumably to contain eroding tailings from the upstream dams, approximately one mile from the confluence of Alamitos Creek and the Pecos River in the Village of Pecos.

In the tailings disposed of into the creek downstream of the mill site, concentrations reported for key metals and other contaminants include: 2800 to 10,000 ppm - lead; 150 to 5500 ppm - copper; 130 to 13,000 - ppm zinc; 15 to 20 ppm- silver; and 2.7 ppm - cyanide (1).

Process chemicals used in the mill include: 1) in the mica circuit - Cresylic Acid - 0.175 lb/ton of ore; 2) in the lead circuit - Lime - 0.574 lb/ton, Potassium pentasol xanthate - 0.161 lb/ton, Zinc Sulfate - 1.395 lb/ton, Cyanide - 0.060 lb/ton; and 3) in the zinc circuit - Lime - 1.848 lb/ton, Copper Sulfate - 0.783 lb/ton, Sodium ethyl xanthate - 0.500 lb/ton, Pine oil- 0.151 lb/ton (1).

In addition to the characterization of hazardous constituents in the tailings, extensive heavy metal contamination at the sites has been well documented by New Mexico state agency and operator investigations, though a range of specific data gathering activities are on-going. By the end of 1991, the following data had been developed.

Surface water samples from Alamitos Creek showed concentrations of: lead (ranging from <0.01 to 4.1 ppm), cadmium (<0.001 to 0.022 ppm), iron (<0.1 to 67 ppm) and manganese (<0.05 to 1.4 ppm) in excess of New Mexico Water Quality Control Commission (NMWQCC) standards (Pb - 0.05 ppm, Cd - 0.01 ppm, Fe - 1.0 ppm, Mn - 0.2 ppm) and United States Environmental Protection Agency (EPA) Maximum Contaminant Levels (MCLs) - (40 CFR 141: Pb - 0.05 ppm, Cd - 0.01 ppm; 40 CFR 143: Fe - 0.3 ppm, Mn - 0.05 ppm).

Filtered ground water samples showed concentrations of sulfate and manganese as well as total dissolved solids (TDS) in excess of NMWQCC standards (SO₄ - 600 ppm, Mn - 0.2 ppm and TDS - 1000 ppm) and EPA MCLs (40 CFR 143: SO₄ - 250 ppm, Mn - 0.05 ppm, and TDS - 500 ppm).

Soil data showed significant contamination for lead (background 5 -30 ppm, tailings 2800 - 10000 ppm, downstream of tailings - 1400 ppm), zinc (background 30 - 60 ppm, tailings 190 - 13000 ppm, downstream - 350 ppm) copper (background 9 - 20 ppm, tailings 150 - 5500 ppm, downstream - 290 ppm) and iron (background 13000 - 17000, tailings 44000 - 51000 ppm, downstream - 31000 ppm) (1).

Though the mine and mill complex were privately operated, the State of New Mexico acquired the sites, except for mineral rights, in 1950. At that time, the New Mexico Game Commission purchased the mine and mill site from Pecos Estates, Inc., the corporation to which the mine operator American Metals of New Mexico had transferred the real property and minerals from the Pecos Mine and El Molino sites in 1939 after shutdown. American Metal Company Limited of New York was the majority shareholder in American Metal Company of New Mexico. The recently formed Cyprus-Amax Minerals Company is the successor corporation to American Metals Company.¹ In addition to contamination at the state-owned mine and mill sites, other State Game and Fish Commission lands, and land administered the New Mexico State Highway Department and United States Forest Service lands were impacted by the use of mine waste in construction, off site uses which occurred after state surface rights acquisition. At various times since state acquisition, mine waste has been removed from the mine and mill areas for use as construction or maintenance materials within the Pecos River floodplain between the Village and the mine

including state highways, building pads, government -owned campsites and the state's Lisboa Springs Fish Hatchery (3).

The Village of Pecos is governed by a mayor -council system typical of small incorporated rural communities in the West, with the Mayor serving as chair of the Village of Pecos Board of Trustees. Local community organizations have been active and visible in the consideration of environmental and natural resources issues in the Valley. La Gente del Rio Pecos, an organization addressing community development and natural resource protection concerns (and a successor to the earlier Upper Pecos Association), includes members active in raising the initial concern about contamination, assuring legislative support for state funding of clean-up, educating residents and reviewing site plans. Southwest Research and Information Center has served as a technical assistance provider for La Gente. A local People for the West chapter, including the store manager at Terrero, remedial contractor employees and other residents has also participated in many site decision-making activities. Individual local residents have verbally indicated that mine and mill waste has been transported to home sites for construction and yardfill use and selected residents report that children play, and they as children played, in the colorful tailings residue along Alamos Creek. Active local resident use of the tailings area also include extensive shooting practice and off-road vehicle play, leading to potential lead exposure and on-site vandalism. A County Road which crosses the upper end of the tailings impoundment is the only road access to several private homesites upstream of the tailings.

While some hard rock exploration activity had occurred in the upper Pecos watershed in recent years,⁴ American Metal and its successor AMAX had long since left the area except for mineral ownership and historical linkage to the Pecos Estates, Inc. When clean up concerns were raised in the 1980s, New Mexico had no "State Superfund" or an inactive hard rock mine reclamation program to define a regulatory framework for site management. Initial studies were funded by federal funds provided to the state through the Environmental Protection Agency to support site characterization and ranking activities pursuant to the federal Superfund legislation and associated program implementation.

Environmental investigations by the New Mexico Environmental Improvement Division, now the New Mexico Environment Department (NMED), at the site began with preliminary site assessments in 1985-6,¹ with NMED and Cyprus-AMAX staff and consultants conducting site characterization and design studies since that time. While Pecos Valley resident concerns about mining and water quality have periodically been raised during the 1980s, significant public involvement in the Pecos site contamination and remediation date from the Spring of 1991. In March of that year, spring snowmelt carried contaminants into the Pecos River, killing 90,000 fish. Two campsites where mine waste was used in construction were closed due to contamination and the drop in the number of Pecos area visitors dropped off significantly, hurting the local economy. Though state studies to develop contaminant distribution and hazardous ranking data were available to the public and AMAX unveiled a "remediation plan" in May 1991, no administrative framework had been adopted to allocate financial responsibility and define clean up standards at that time (5).

INNOVATIONS IN THE REGULATORY AND ADMINISTRATIVE FRAMEWORK FOR SITE RESTORATION

Since that time, major hurdles in site administration, restoration standards setting and remedial design and construction have been crossed, and at a relatively fast pace. Less than five years have passed between significant public recognition of to the installation of an effective, at least in the short to medium range, pollution control and source containment system at El Molino. While different positions continue to be expressed as to the long-term adequacy of the remedy selected, and currently being implemented; many of the public policy steps, in terms of specific

administrative and public participation measures, provide a use set of program elements for consideration at other environmental restoration site. Including sites like the Pecos complex, which at one time, appeared to have no clear administrative, funding or design solution.

Following the fish kill in March 1991, a public meeting was convened in Pecos on May 22. In an innovative effort to work cooperatively with community interests, the meeting was convened not just by government officials but actively in conjunction with the most visible local non-governmental community-based organization, the Upper Pecos Association. Concerns raised at that time were well documented and continue to be reflected in site restoration activities. Citizen concerns included potential impacts on ground and surface water quality, active interest in prompt clean up, the need to reclaim sites for aesthetic and recreational uses, lead clean up standards and processes, downstream impacts, natural resource damage fishery impacts and use of local contractors. Parallel to the citizen concern for prompt clean up, both state officials and AMAX representatives expressed a perception that the area could be cleaned up more quickly, economically and correctly if EPA could be prevented from including the site on its Superfund (National Priority) List.⁵ This "threat of Superfund" served as a common point of concern for the parties involved in the development of an "Administrative Order on Consent (AOC)" which defined the administrative and financial responsibility of the site owners and their successors, which include both the State of New Mexico and Cyprus-Amax (through its Amax Resource Conservation Company unit). The AOC was signed on December 2, 1992 by three representatives of the State of New Mexico - NMED, NM Game and Fish Department, and NM State Highway Department - each signed, as well as AMAX (6).

The Pecos Administrative Order on Consent 7 has proven to be an effective and innovative approach to inactive waste site remediation decision-making in several critical ways. Firstly, it created an administrative framework for remediation and inter-agency communication where none had existed in state law; a framework within which governmental and private organizations agreed to share responsibility (without any party acknowledging their role in creation of the problem as stated in many "settlement" type agreements). Secondly, it contributed to the impressively strong and diverse support for appropriation of the \$5,000,000 by the New Mexico Legislature, for the states on-fifth share of the estimated clean-up cost. Thirdly, the AOC has also been recognized outside New Mexico, where it has served as a working model in Idaho at the Triumph Mine site - also an inactive mine waste site with both state government and private participants and a common interest in avoiding Superfund Listing - where it has been a valuable example used in restoration decision-making by the responsible parties and local residents (8).

The AOC, with its two attachments - a "Cost Allocation Agreement" and "Statement of Work" - establishes a site specific remediation program which is designed to provide a functional parallel to Superfund with respect to clean up criteria, remediation funding, timely performance and public involvement. The AOC and attachments restate directly and by reference the full range of Superfund criteria and criteria from other applicable state and federal requirements to be attained by the parties. Thus the AOC serves as a jointly-agreed upon demonstration to state and federal regulators that the remediation process will be at least as effective as a Superfund program, since all important Superfund milestones are incorporated in the AOC. This restatement of Superfund criteria allowed the responsible parties to provide EPA an enforceable foundation for successful site remediation without final Superfund listing, as long as substantial progress towards Superfund-level goals is maintained. An important benchmark for the responsible parties in their effort to accomplish reclamation outside the Superfund process was a Memorandum of Understanding between EPA and NMED which describes the cooperative roles of the agencies in the oversight and enforcement of response activities at the Terrero Mine Site. This cooperative role provides for implementation of the restoration program under the AOC, with EPA oversight to assure that site

restoration is as effective as it would have been were Superfund, and other relevant federal laws, applied (9).

Innovative elements in the Administrative Order on Consent include:

- * A Cost Allocation Agreement which establishes a commitment to fund the remediation with a cost sharing ratio of 80% Amax and 20% State funds, if the State of New Mexico appropriates its share of the funds through its legislative allocations. This condition was an effective incentive for New Mexico legislators to make a \$5,000,000 special appropriation in 1993.
- * A Statement of Work¹⁰ which provides for implementation of a schedule of itemized milestones including of health and environmental risk assessments, community relation plans, remedial investigations, feasibility studies, natural resource damage assessments, long-term operation and maintenance plans and other performance objectives "in accordance with CERCLA and the National Contingency Plan (NCP) and shall meet the requirements and goals of a CERCLA RI/FS and RD/RA, Community Relations Plan consistent with the NCP", and technical assistance grants including reference to EPA guidance documents.
- * A set of numerical Applicable or Relevant and Appropriate Requirements (ARARs) to guide investigations and remedial design and demonstrate Superfund level remediation as well as compliance with other state and federal requirements;
- * Establishment of a document repository for all project materials in Santa Fe and Pecos;
- * Requirements for Site Health and Safety and Quality Assurance Plans, to meet federal standards for all site workers and data gathering activities;
- * A basis for selection of long-term remedial actions which demonstrate (among other criteria): long-term effectiveness and permanence; compliance with applicable public health and environmental standards; cost-effectiveness and an ability to be implemented; reduction of toxicity, mobility, and volume, and community acceptance.
- * A schedule, in the SOW, which outlines a timetable for development and implementation of Decision Documents for each of the five operable units including preparatory studies leading up to the selection of remedial action in the Decision Documents (DD).
- * A Dispute Resolution process for the AOC parties to provide a mechanism for addressing disagreements without abandoning the overall framework.

Limitations in the AOC are also apparent, limitations which have partially undercut the achievement of timely and effective remediation. These include: 1) a lack of an explicit role in decision-making for affected community residents and organizations, interests who have continued to be active in the restoration process since the initial recognition of the problem and identification of issues to address during reclamation; 2) a lack of clarity in the roles and funding for the state agencies, which include both regulatory roles in the Environment Department, and "site owner" roles for both the in the Game and Fish and the Highway Departments; and 3) a lack of a clearly defined role for the state Office of the Natural Resource Trustee, an organization which had no operating experience prior to the AOC and which was lead by an individual with multiple roles in the AOC (the State Natural Resource Trustee was also the Chair of the state Game and Fish Commission).

INNOVATIVE PROCEDURAL AND DESIGN ELEMENTS IN THE FINAL DECISION DOCUMENT AND REMEDIAL DESIGN FOR THE EL MOLINO SITE

The transition from the need to reclaim a site to actual reclamation on the ground can be so problematic that simple attainment of successful progress toward overall reclamation goals is often the best measure of whether innovative actions taken are effective. Using this criteria, the progress to date at the El Molino site demonstrates broadly successful application of innovative environmental technology, though initially anticipated schedule dates have often proven to be unrealistic. The sequence of activities from the AOC stage through to the development and implementation of the site specific El Molino Decision Document provides extremely useful experience for interests attempting to identify successful cases of applied reclamation. These activities at El Molino are all the more notable in light of the limitations in the AOC that could have made El Molino reclamation particularly difficult. First off, El Molino became the testing ground for the AOC as the milestones set out in the SOW for the El Molino Site resulted in that site being the first site to be addressed by a remedial action Decision Document (DD). Second, El Molino initially was not recognized to be as major contamination and remedial design problem as its location and size merited, due to the press and responsible party focus on recreational and fishery impacts in the Pecos River near the Pecos Mine site.

These concerns led to public concerns about the timing and implementation of the DD, surfaced with the distribution of an original DD in April 1993. This interim Decision Document¹¹ identified a selected remedial design with conditions, presented updated contamination data a detailed set of Applicable or Relevant and Appropriate Requirements (ARARs), and a set of Statutory Determinations which concluded that "actual or threatened releases of contaminants and hazardous substances from this site, if not addressed by implementing the response action selected in this [DD], may present an imminent and substantial endangerment to public health, welfare or the environment" and that "community and state acceptance is favorable to this remedy in comparison to other alternatives presented to the public."

The interim DD was responded to very strongly by La Gente del Rio Pecos, which asserted that the development of the document had been a very closed process limited to AOC parties with no effective opportunity for public comment, along the lines of the public meeting, workshops and newsletter which typify Superfund community involvement efforts when NCP guidance found in the AOC is followed. No public meetings had been scheduled prior the issuance of this "first final" DD. La Gente also raised a substantial array of procedural and design concerns with NMED including the failure of NMED to provide any basis for the conclusions that either the statutory requirements or community involvement requirements in the AOC and SOW had been met.¹² The AOC included, directly and by reference, clear requirements for public meetings and a contractor-based community relations plan, including direct reference to NCP guidance, before issuance of a final DD. These were critical concerns for the residents who face the site-based risks daily and yet are provided no role in the AOC process other than through comment period opportunities and the (still anticipated) community relations plan.

NMED Secretary Judith Espinosa and staff responded positively to these concerns. They rapidly agree to meet with La Gente representatives and responded to the comments by agreeing to hold a public meeting in Pecos and extend a comment period after the meeting to allow additional written comments prior to the publication of a Final DD. This meeting of June 15, 1993 was advertised with bilingual flyers in local mailbox and hosted by the Village of Pecos attracted almost 100 attendees.

The public meeting and extended comment period provided by NMED were important results of community-based stakeholder involvement in the reclamation process. The on-going benefits of

these processes included heightened local community and local government involvement in the process, in addition to continued La Gente involvement, and significant improvement in the final DD issued in September 1993. Village of Pecos involvement has been dramatically enhanced as a result of increased elected official involvement and the technical efforts of Village's technical assistance contractor on the Upper Pecos Site, New Mexico Engineering Research Institute. The Village was allocated \$50,000 by the 1993 New Mexico Legislature for the technical assistance contractor, to provide a rough parallel to the Superfund Technical Assistance Grant (TAG) available for up to \$50,000. In a twist from the Superfund framework though, the New Mexico Legislature provided the funds to a unit of local government, not an independent non-profit corporation, in sharp contrast to the Superfund framework which does not allow TAGs for municipalities and requires an independent non-profit as a grant recipient. Improvements in the September 5, 1993 Final DD were incorporated into the statutory determination and design condition portions and are reflected in the summary of the Final DD below.

The Final DD reviewed site contamination data and summarized six alternative remedial designs, selected a preferred alternative and identified 19 additional items or conditions related to the NMED approval of the preferred alternative. The preferred alternative - called "Flood Conveyance Through a Channel"- was selected over the other five titled "No Action", "Institutional Controls", "Flood Conveyance Through a Pipe with Flood Attenuation", "Flood Attenuation with Multiple Upstream Dams", and "Reprocessing of Tailings Either On- or Off-site". Design elements in the selected alternative, including the additional items include:

- * Consolidate all tailings and contaminated soil with lead concentrations above the health based risk level (set at 500 parts per million) into [the two largest] tailings ponds;
- * Convey surface water through tailings ponds 1 and 2 via a lined, stable channel designed for a 6-hour 100-year storm event;
- * Reinforce side drainages leading into the main channel to minimize erosion and design for a 10-year 24-hour storm and a safety factor of 1.5 for drainage bottoms and banks;
- * Cap tailings ponds to minimize erosion (to less than 1/16" per year) and ponding and revegetate with native plant species;
- * Stabilize dams to meet state embankment engineering standards;
- * Regrade and revegetate with native species all borrow areas;
- * Replacement of wetlands lost during remediation at an appropriate location within Alamitos Canyon;
- * Install piezometers in tailings ponds 1 and 2 and monitor along with existing and new ground water monitoring wells until compliance with ARARs for eight consecutive quarterly samples is approved by NMED;
- * Evaluate potential contamination of downstream water courses and agricultural fields near the site, including soil and tissue sampled, as part of Health and Ecological Risk Assessment, required before final approval of the remedial action;
- * Develop, install and maintain measures to protect newly reclaimed areas and prevent vandalism;

* Conduct computer modelling of ground water flow and contaminant transport, develop contingency plans to protect community and private wells, and replace two existing private wells;

* Develop and implement programs to assess effectiveness of the remedy including but not limited to assessment of moisture and metals movement from the tailings ponds, revegetation success, channel system and liner stability, tailings cap stability, wetlands replacement success, and surface and ground water quality;

* Develop a long-term operation and maintenance plan to be approved by NMED upon attainment of ARARs and Remedial Action Criteria in the SOW, to be subject to review every five years.

INNOVATIONS IN SITE CHARACTERIZATION, REMEDIAL DESIGN AND CONSTRUCTION AT THE EL MOLINO SITE.

Site remedial design and construction activities have been conducted by Cyprus-Amax and their primary contractors on the project, Kenneth R. Paulsen Consulting, Woodward-Clyde Consultants and Daniel B. Stephens and Associates. All project costs are subject to the 80% Cyprus-Amax-20% New Mexico cost sharing arrangement in the CAA, resulting in Cyprus-Amax's consultants being subject, in part, to acceptance of their work products by the state as a condition of payment. This role of private contractors receiving payment from public funds appears to have enhanced the responsiveness of project contractors, as their staffs have continually recognized their responsibility to both their private contractor and the public, who through the state are also paying the consultant's bills. A full range of tailings, soil, water, and air quality sampling and analysis activities have been conducted at the site and documented in NMED-maintained document repositories in Pecos and Santa Fe.

Two innovative aspects of the site characterization efforts are notable, though highly accurate and reliable data gathering and analysis methods have been used throughout the project. A first key innovation in the process has been the early acceptance by the responsible parties of a Quality Assurance Project Plan (QAPP); a plan developed pursuant to the AOC and in conformity with EPA guidance documents identified in the SOW. The QAPP was prepared by Cyprus-Amax consultants and approved by NMED shortly after completion of the AOC. The early acceptance of this Quality Assurance Plan had several important results. The acceptance of the QAPP demonstrated that the parties could reach agreement on technical matters in addition to the administrative framework and allowed the cooperative approach to site characterization and reclamation to be further reinforced. Acceptance of the QAPP insured that all parties, including AOC parties and the public, would be able to rely on a common data base with results including reduced costs as redundant "competing data costs" were largely eliminated, allowing technical reviewers to focus on what-the-data-means, rather than was-the-data-accurate questions.

A second innovation has been the use of x-ray fluorescence (XRF) techniques for soil and tailings characterization for heavy metals, particularly lead. Public concerns for lead contamination and clean have lead to a need for the accurate mapping of the distribution of lead contamination and associated considerations of lead clean-up levels and clean up costs. The XRF method has been used to characterize lead levels at the Terrero Mine and El Molino Units in much greater detail and much faster than conventional techniques, such as off-site laboratory based inductively coupled plasma (ICP) and atomic absorption spectrometry (AAS) methods, due to the relatively low cost per sample, without sacrificing accuracy. NMED research shows a good correlation (correlation coefficients for lead and zinc comparative analyses were 0.70 and 0.74, respectively) between ICP and XRF data at the Terrero mine (13). On-site chemical analysis using portable instrumentation, with essential real time data production allows up to 100 samples or more to be analyzed at the El Molino site.¹⁴ Additional advantages to XRF include improved worker safety resulting from

elimination of acid digestion steps in conventional analysis and the non-destructive nature of the method, which leaves samples and standards available for future investigation.¹⁵ XRF data has been used to develop 200 ppm, 500 ppm, and 1200 ppm contours for lead concentrations in soil at the El Molino site relying on several hundred individual data points.

The remedial design characterized in the Final DD has evolved in several important and innovative ways as a result of restoration designers effectively incorporating both new information gathered during investigation as well as construction and technology improvements identified through public comment and agency review. Key motivations for these design enhancements are technical comments provided by the Village of Pecos, La Gente del Rio Pecos and their technical assistance providers. Both parties have raised concerns about the long-term, the hundreds to thousands of year time, durability of the existing diversion channel, and ground water flow under and through the tailings as placed (16). While this site is designed to pass surface water generated by a nominal 100-year event, substantial concern among residents has resulted in the Village of Pecos having passed a resolution recommending removal of the tailings to a "out of creek" site for permanent disposal, and consideration of the existing diversion mechanism as an interim, multi-year but not-multi-decade solution (17). La Gente concerns have also included the need to insure that long-overdue health and ecological studies and community relations and long-term operation and maintenance plans are completed before, rather than after, the final remedial design is approved. These concerns for the reliability of the diversion channel concept was heightened when a leak of acid water from the tailings into the diversion channel shortly following liner installation was observed by Village and legislative committee representatives in the fall of 1994 (18).

These potentially volatile differences have been address substantively in an innovative approach to inter-group communication. The AOC and the public participants have maintained regularly, approximately monthly, working meeting with an informal yet technical detailed discussion focus using a consensus agenda and supporting technical working documents tone. These meetings have been held in response to La Gente and the Village Mayor's concerns expressed at Village of Pecos Board of Trustees meetings; initially at the invitation of Cyprus-Amax at the site, and most recently in Santa Fe hosted by NMED. Specific design elements of note include upgrade of the diversion channel liner and cutoff trench system, replacement wetlands plans and the long-term performance of the tailings cap.

A major environmental protection milestone achieved at El Molino is the control stabilization and control of off-site movement of tailings by embankment repair and construction of a 40-mil PVC and rip-rap lined diversion channel to carry surface water above the tailings. Engineered concrete cutoff trenches, footed into excavated bedrock according to the installers, complement the system by providing a barrier to subsurface flow in the Alamitos Creek alluvium and serve as a anchor for segment of the welded PVC liner. However the liner leaked within months of installation.¹⁸ Cyprus-Amax and the state's response has been three- fold: 1)raise the channel base above the water table within the tailings (considered to the source of the leak); 2) maintain design flow volume by widening the channel; and 3) installing a horizontal piezometer and additional vertical piezometers at the cut-off trench site where the leak occurred. Benefits of this design modification are considered to be: reduced risk of leakage by locating the channel and liner above the local water level; availability of a drainage mechanism to prevent leakage even if the water table in the tailings again rises; and a more comprehensive groundwater monitoring network for the overall design.

Wetlands replacement is an integral part of the El Molino DD and is considered an important part of the plan by all parties. While debate continued on the acreage of wetlands replacement needed, initial construction of a wetlands has begun at the south end of the site, were previously deposited tailings have already been removed. Initial Cyprus-Amax plans includes a cattail dominated wetlands system utilizing seepage from the lower tailings dam site as a water source. Recent

informal working group discussions has focused on the need for wetlands restoration to replace pre-existing subsurface flow-, rather than surface flow-, dominated wetlands as originally found at the site and the recognition of the uncertain volume and quality of the tailings dam seepage flow. The working group has also used pre-reclamation plant species list to establish revegetate planning and survival criteria. Design criteria and performance specifications for the replacement wetlands are currently being developed (19).

The tailings cap has also been the subject of substantial working group discussion. The original proposal of a 15 inch cap of borrow soil, with agricultural limestone and a bactericide below and revegetation by shallow-rooting plants was determined to be "inadequate, ... at the least, an additional layer must be added that will act as a barrier for water, plant roots systems and burrowing animals".²⁰ In response Cyprus-Amax proposed, in January 1995, a typical cap section which added a 30-mil PVC liner overlaid by a geoweb drainage mat with a fabric cover below the 15 inch soil cap. Public and regulatory agency review of this proposal were in process as this paper was prepared. While the design modification responds to agency and public concern for more effective barriers layers, documentation of the relative permanence and long-term operation and maintenance aspects of the design have yet to be distributed.

As a final element in the set of effective innovations at El Molino, construction activity at the site has relied heavily on local, meaning Pecos-area, construction contractors and heavy equipment operators. This reliance on a local workforce, can be considered innovative, as it responds to a strong community-based concern and has not been mandated by project decision documents.

CONCLUSION

This overview identifies a wide array of innovative approaches to environmental restoration currently being applied at a complex heavy-metal contaminated waste site. This "effectiveness-based-on-experience" measure of success provides a potentially more valuable assessment of specific innovations than, determinations of technical merit isolated from real world application. This transfer from proven model to full-scale application is so extremely difficult because site specific conditions, rather predetermined and controllable design conditions, usually dominate environmental restoration decision-making. As a result, the identification of effective innovations which are transferable among environmental restoration projects requires a clear understanding of the administrative, public policy and technical aspects for both the innovative demonstration setting and the potential transfer site.

Few if any sites are amenable to single step, "magic bullet" type of restoration decision-making and environmental restoration. Recognizing that full long-term restoration is accomplished in a step-by-step way allows site managers and technicians to focus on innovation designed to achieve the sequence of incremental milestones necessary to achieve site-wide goals. This summary of innovative aspects of the Upper Pecos Site, El Molino Unit demonstrates how well-prepared site specific solutions can lead to substantial environmental restoration progress on a broad front by carefully tailoring the application of design innovation to the full range of site concerns. The creative solutions at the Pecos site, offer a full range of innovative concepts and designs for resolution of site-specific waste management dilemmas, including radioactive waste sites, in many places.

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