Engineering Evaluation Cost Analysis

May 1996

Prepared for
Federal Tailings Pile Site

by
Environmental Protection Agency -- Region VII

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Introduction

The purpose of this engineering evaluation/cost analysis (EE/CA) is to screen and evaluate removal action alter:atives for controlling releases of contaminants and improvement of the stability of the banks and slopes at the Federal Tailings Pile (Federal) site near Park Hills, Missouri. The State of Missouri has completed detailed engineering and cost evaluation of various alternatives to stabilized the Federal Dams. This EE/CA is largely based on the findings contained in those studies. While the State of Missouri's objectives were to decrease the threat of seismic failure of the structures, EPA's goal is to reduce the threat of release of hazardous substances from the site. The Federal site resulted from decades of mining and milling lead.

State of Missouri and EPA investigations have revealed significant lead levels in tailings on the site and in the sediments downstream of the site. In addition, lead has been found in sediments, water, and aquatic life in tributaries leaving the site and in the Big River downstream of the mining areas in St. Francois County. The State of Missouri in cooperation with the EPA prepared a Site Inspection Report on the Federal Site on March 11, 1994, as a part of a Superfund evaluation. On March 20, 1996, the Missouri Department of Health, as part of its Exposure Assessment, released preliminary analysis of blood lead data for areas in St. Francois County showing significantly more blood-lead elevations in the study area than in a control area. This Exposure Assessment will ultimately attempt to determine if mine tailings are contributing to elevated blood-lead concentrations; those results are not available at the time of writing this EE/CA. Based on the criteria set forth in Section 300.415(b)(2) of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), EPA has determined that the site poses a threat to public health and the environment and that a removal action is necessary to reduce the threat.

An EE/CA is required for all non-time-critical removal actions, pursuant to Section 300.415(b)(4) of the National Contingency Plan, 40 C.F.R. § 300.415(b)(4). This EE/CA evaluates removal action alternatives for the Federal site, describes the removal action alternative that EPA recommends, and explains the rationale for that recommendation. Background information on the site is presented in this EE/CA and in the references. Also, EPA has established an Administrative Record file for the removal action at this site. It contains all of the information that EPA has considered or relied on thus far in evaluating removal alternatives. The Administrative Record file is available for public review at the following locations:

EPA Region VII Docket Room
726 Minnesota Avenue
Kansas City, KS 66101
Telephone: (913) 551-4038

Mineral Area College
5270 Flat River Road
Park Hills, MO

EPA has not made a final decision on the removal action to be taken at this site. Publication of this EE/CA opens a 30-day public comment period on the proposed removal action. EPA encourages the public to comment on the alternatives analyzed in this EE/CA. Written comments should be submitted to:

U.S. Environmental Protection Agency
Region VII
Office of External Programs
726 Minnesota Avenue
Kansas City, KS 66101
ATTN: Hattie Thomas

After the close of the public comment period, EPA will issue an Action Memorandum, which will present EPA's selected removal action and describe the basis for that selection. In that Action Memorandum, EPA may modify the proposed alternative presented in this EE/CA or select other removal options, based on public comments or new information. Any comments on this EE/CA that are received during the comment period will be addressed by EPA in a responsiveness summary, which will be attached to the Action Memorandum

Site Characterization

Site Location

The Federal site lies on the eastern edge of the Ozark Highlands in St. Francois County (see Figure 1: Site Location Map). The site is situated in the Shaw Branch of the Flat River , a tributary to the Big River. Residential areas and the town of Park Hills are adjacent to the site to the north. The site is located in the St. Joe St. Park.

St. Joe State Park is managed by the Missouri Department of Natural Resources' Division of State Parks. Central to the 8,561-acre park is an approximately 800-acre tailings pond created behind a 130-foot high dam resulting from the lead mine and mill operations of the St. Joe Minerals Corporation (formerly St. Joe Lead Company.) St. Joe Lead operated a series of mines and mills in the district from around 1900 to 1972. Tailings from a "jig" mill were deposited by a conveyor system to form what is now known as the "chat pile" on the northwestern edge of the park. Tailings from the most recent mill, which employed the flotation separation process, were hydraulically placed behind either of two conjoined dams located in a tributary of the Flat River. The older dam, known as the Original Dam, is a "sidehill" type, while the newer dam, known as the Main Dam, is a cross-valley type. The dams are joined to form an "L" shaped structure. The crest height of the Main Dam is approximately 135 feet from the original stream bed. The dams are constructed of tailings material with a veneer of shot rock. Decant structures were incorporated to act as a drain for excess surface water runoff and to return processed water to the mill. Due to characteristics of the tailings and slimes behind the dams, the materials do not easily drain or dewater and are therefore saturated at various levels. The impounded tailings extend roughly southward from the dam up the tributary approximately two miles. The tailings act as dams for tributary branches, thus forming several lakes in the upper watershed.

The St. Joe Minerals Corporation ceased mining and milling operations at the site in 1972. The land was transferred to the state of Missouri in 1976 for the express purpose of establishing a state park. The mill was included with the transfer and now comprises the Missouri Mines State Historic Site. The park and site have been developed to provide recreational and educational opportunities to approximately 545,000 visitors per year.

Federal Tailings Pile Site
Location Map

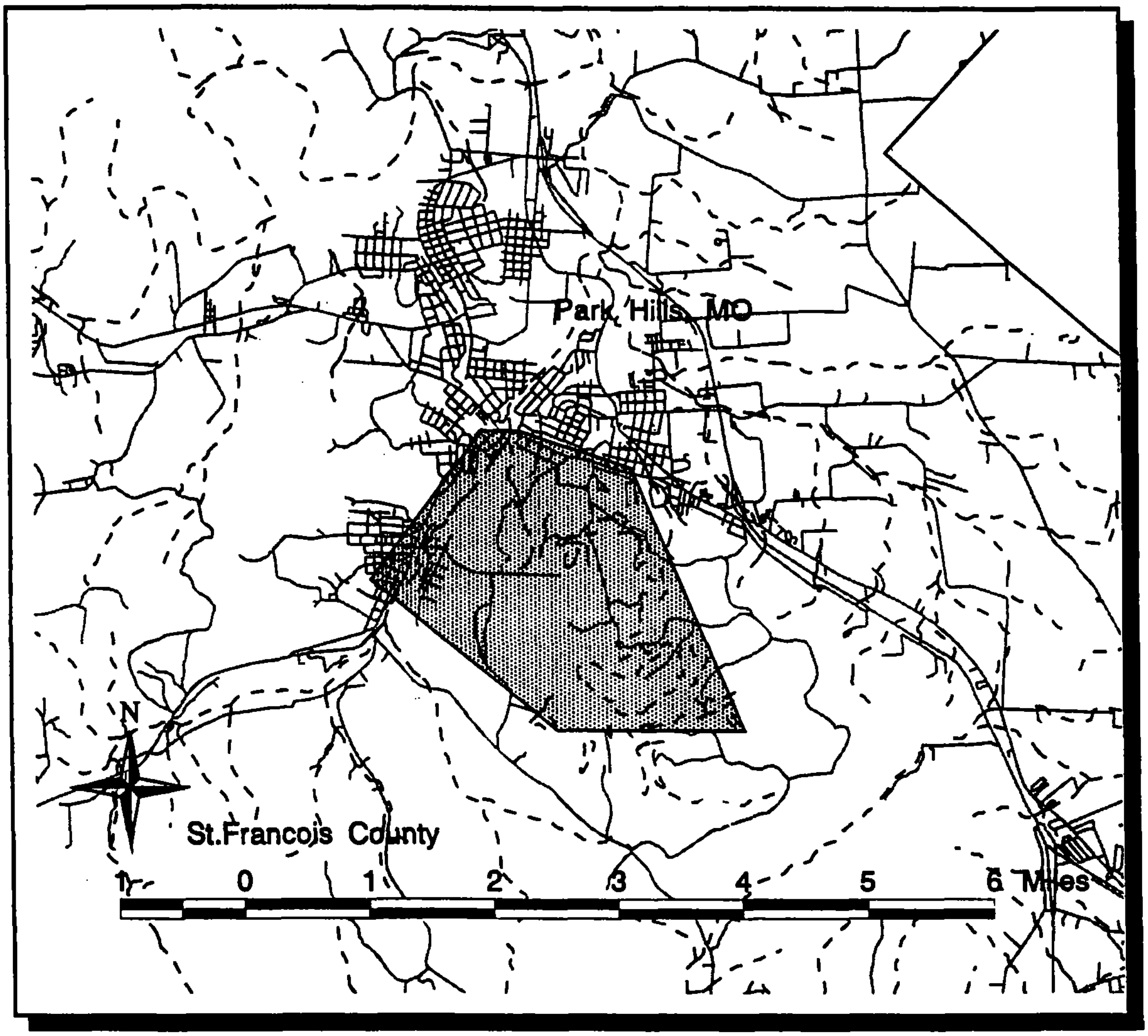

Figure 1

Site Background

The Federal site is located in an area known as the Old Lead Belt. The Old Lead Belt is located in St. Francois County in southeastern Missouri and covers an area of approximately 110 square miles. Lead was discovered in the area prior to 1700. Until the 1860's, mining in the area was restricted to shallow workings from pits and trenches. In 1864, the St. Joseph Lead Company purchased 964 acres and began mining activities in Bonne Terre, Missouri. Diamond-bit core drilling of the area began in 1869 and led to the discovery of lead-rich ore deposits under the Missouri towns of Bonne Terre, Park Hills, Flat River, Leadwood and Elvins. As many as 15 lead companies operated in the area from the late 1800's to 1900's. However, by 1933, all of the properties in the area had been acquired by the St. Joseph Lead Company. The St. Joseph Lead Company is presently known as The Doe Run Company. The St. Joseph Lead Company acquired the holdings of the Federal Lead Company, including the Federal site, in 1923. Mining activity in the area decreased in the 1950's and 1960's as the ore deposits were depleted and with the discovery of the Viburnum Trend (New Lead Belt), which had higher grade ore. The Federal Division of the St. Joseph Lead Company was the last mine to close in the Old Lead Belt in 1972.

In 1980, the Missouri Department of Conservation (MDC) determined that some fish in the Big River downstream lead mining activities in St. Francois County contained elevated lead levels. As a result of the findings, Missouri Department of Health (MDOH) issued a press release, cautioning local residents not to eat bottom-feeding fish taken from a 50-mile stretch of the Big River from the City of Leadwood downstream to Washington State Park (Ref. 10).

Surface Features/Topography

The Federal site lies on the eastern edge of the Ozark Uplift in St. Francois County, Missouri. The major physical features in the area are the St. Francois Mountains to the south, the Farmington Plain to the east, and the dissected topography of the Salem Plateau located to the north (Ref. 15).

Much of the site consists of dry and unvegetated tailings. Because the tailings material is dolomitic sand and silt that is easily suspended in the air, wind erosion and airborne dust are a major problem at the site.

Geology/Soil Information

Much of the site's soil is characterized by Psamments soils, which were formed from processed dolomitic material created during lead mining. The permeability of the soils is relatively high, and surface runoff is slow to medium. The available water capacity is low. The natural fertility is very unbalanced, and fertilization is required to make the soil suitable for any plant growth. The percent of organic matter in the soil is also very low. The generalized stratigraphic sequence for this area includes the Potosi, Derby-Doerun, Davis, Bonneterre, and Lamotte formations as well as

Precambrian igneous rocks. The Bonneterre and Lamotte sandstones form the principal aquifer of the area. The Bonne Terre formation is the major ore-bearing formation in the Old Lead Belt.

The vast underground mine workings and ancillary activities have modified the natural groundwater flow regime making interpretation of site-specific hydrology very complex. Many miles of abandoned underground mine workings are now filled with ground water. It is estimated that 100,000 exploratory borings were drilled in the Old Lead Belt. Most of these borings were not properly plugged or sealed. Consequently, the mining activity in the region has potentially altered the ground water flow.

The depth to the water table on site is very shallow upstream of the dams often coming out at the surface. The shallow ground water flow in the area is assumed to be toward the Shaw Branch Several seeps at the toe of the dam flow into the Shaw Branch.

Surrounding Land Use and Populations

The superintendent and his family are the only residents in the park. The superintendent's residence is about one-quarter of a mile from the nearest portion of the tailings pile. There are 12 full time workers in the park and 3 full-time workers at the historic site. The nearest private residence is located 150 feet from the tailings pile on the northwest portion of the site. The nearest school is 0.65 mile from the tailings impoundment and there are 5 schools within 1/4 to 2 miles from the site. There are about 600 residents within 1/4 mile of the site boundary, 1,670 residents within 1/4 to ½ mile, and 4,050 residents between ½ and one mile of from the site. The total population within a 4-mile radius of the site is approximately 17,000. This information was presented in a 1994 Site Inspection Report.

Three public water supplies are within four miles of the site, Park Hills, Gumbo, and Leadwood. These supplies use five wells and service about 14,000 people. The total number of private wells in the proximity of the site is unknown.

Sensitive Ecosystems

The Missouri Conservation Department has designated 11 miles of the Big River from Mammouth Road bridge to Brown's Ford Road bridge in Jefferson County, approximately 20 miles downstream from the site, as a Special Black Bass Stream management Area.

Meteorology

St. Francois County is hot in summer, especially at low elevations, and moderately cool in winter, especially on mountains and high hills. Rainfall is fairly heavy and well distributed throughout the year. Snow falls nearly every winter, but snow cover lasts only a few days at a time.

In winter, the average temperature is 35°F, and the average daily minimum temperature is 24°F. In summer, the average temperature is 75°F, and the daily average maximum is 88°F (Ref.

11).

Sixty percent of the total annual precipitation, or 23 inches, usually falls in April through September. The heaviest recorded 1-day rainfall event is 4.95 inches at Farmington, Missouri, 5 miles southeast of Park Hills, on June 30, 1957. Thunderstorms occur on about 50 days each year, primarily in summer. Average annual snowfall is 12 inches (11).

The average relative humidity is about 60 percent. Humidity is higher at night and the average at dawn is 80 percent. The prevailing wind is from the south. The month of March has the highest winds, averaging 12-miles per hour.

Previous Stabilization Efforts

None

Source, Nature, and Extent of Contamination

Waste Quantity

The lead at the Federal site is a result of 70 years of stockpiling of mine wastes. Mine tailings cover approximately 800 acres and may be as much as 120 feet deep. Determining the actual waste volume would require extensive site characterization information that has not been collected to date. But, millions of tons of partially saturated mine waste are impounded behind the Federal dams.

Tailings and Soil

As a part of the sample collection during the Site Inspection (SI), one sample at the base of the Elvins Hill Climb show lead concentration of over 20% lead (210,000 milligrams per kilogram (mg/kg)); other samples that were collected during the SI were less than 4,000 mg/kg of lead. Cadmium and zinc have also been detected in tailings samples from the site, at maximum concentrations of 170 mg/kg and 4,100 mg/kg, respectively (Ref. 1). The primary contaminant of concern at this site is lead.

Sediment and Surface Water

Sediment samples were collected from the Big River in July 1990. Sample results showed the lead concentrations were highest at locations adjacent to the Big River Pile near Desloge. Lead was not detected in sediment and water samples that were collected near Irondale, Missouri, approximately 16.5 miles upstream from the Big River Pile. Lead was detected at 720 mg/kg in a sediment sample obtained from the Big River approximately 1 mile upstream of the Big River Pile. A water sample collected at this location showed 15 µg/l of total lead. A sediment sample and water sample collected from the Big River about 400 feet downstream of the Big River Pile contained lead at concentrations of 5,500 mg/kg and 30 µg/l, respectively. The Flat River enters the Big River about 2.75 miles downstream the Big River Pile. Results from sediment and water sampling in the Flat River were 3,500 mg/kg in sediment and 32 µg/l in water. The elevated lead levels indicate that migration of contaminants from the mining site piles into the river has occurred and continues to occur.

Groundwater

During the Site Inspection (ref 2), groundwater samples were taken from six wells; two samples were taken from the River mines Municipal well, one sample was taken from the well serving the city of Desloge, two samples were taken from the well serving the state park, and one sample was taken from the well serving a private residence south and east of the tailings. Analytical results of samples taken from these wells show the following lead, zinc, and cadmium concentrations in µg/l (all the samples were not analyzed for the same chemicals):

Well Location	Lead	Zinc	Cadmium
River mines before treatment		132	
River mines after treatment	12	206	
Desloge	6		
Park	5	59	
Park		13	9
Private residence	16	26	

As mentioned previously, because extensive mine shafts and tailings exist in the area, it is difficult to determine whether the lead detected in the wells is the result of the contamination from the Federal site, other sources, and/or from natural occurrence.

Air

MDNR collected air quality data during the years 1981-1983 near Flat River, approximately 2 miles southeast of the site (Ref. 5). Analytical results were all within the National Ambient Air Quality Standard (NAAQS) for lead of 1.5 micrograms per cubic meter (ug/m^3), calendar-quarter average (Ref. 6). Contaminant concentrations in the air during gusty wind conditions or during periods of high-intensity winds might exceed previous sampling results and could exceed the NAAQS.

Aquatic Life

As part of an investigation conducted in 1982 by the National Fisheries Laboratory, tissue samples were collected at various locations on the Big River. The highest lead concentrations (140 micrograms per gram - ug/g) in crayfish samples were found downstream of Desloge, while lead concentrations of 1.4 ug/g were found in crayfish samples upstream of Desloge. Analysis of Redhorse sucker samples also indicated elevated lead levels in fish collected near the site (0.57 ug/g) as compared to those upstream (0.02 ug/g). The dietary limit recommended by the World Health Organization (WHO) for Redhorse sucker is 0.3 ug/g. MDOH has issued a previously referenced press release, cautioning persons not to consume bottom-feeding fish taken from a 50-mile stretch of the Big River from the City of Leadwood (near the Federal site) downstream to Washington State Park (Ref. 10).

Release of Contaminants

Some industrially produced lead compounds are readily soluble in water. However, metallic lead and the common lead minerals are relatively insoluble in water. Natural compounds of lead are not usually mobile in normal surface or ground water, because the lead leached from ores is adsorbed by ferric hydroxide or combines with carbonate or sulfate ions to form insoluble compounds.

Movement of lead and its inorganic and organo-lead compounds as particulates in the atmosphere is a major environmental transport process. The transport of lead in the aquatic environment is influenced by the speciation of the ion: the lead ion may be affected by other elements, compounds or conditions present, with its mobility within the environment depends on site-specific conditions. Lead exists mainly as the divalent cation in most unpolluted waters and becomes adsorbed into particulate phases. However, in waters with more chemical elements or organic compounds, the organic complexing is most important.

Sorption processes appear to exert a dominant effect on the distribution of lead in the environment. Adsorption to inorganic solids, organic materials, and hydrous iron and manganese oxides usually controls the mobility of lead, resulting in a strong partitioning of lead to the bed sediments in aquatic systems. The sorption mechanism most important in a particular system varies with geological setting, pH, availability of ligands, dissolved and particulate ion concentrations, salinity, and chemical composition. The equilibrium solubility of lead with carbonate, sulfate, and sulfide is low. Over most of the normal pH range, lead carbonate, and lead sulfate control solubility of lead in aerobic conditions, and lead sulfide in anaerobic conditions. Lead is strongly bound to organic materials present in aquatic systems and soil.

Transport of lead-bearing tailings material from the site could occur because of wind erosion, sediment transport, catastrophic failures, and leaching.

Dispersal of tailings particulates through the air can be a significant transport mechanism. The tailings material is lead-laden dolomitic sand and silt, which is easily suspended in the air and carried off-site. A release to air has been documented. Although the release did not exceed National Ambient Air Quality Standards, movement of material and subsequent deposition on the soil may be of concern. Blowing sand and dust is evident. Accumulation of dust on indoor and outdoor surfaces may provide additional opportunities for human health exposures to lead. The areas at the site that are most likely to be a source of airborne particulates are the dry and unvegetated tailings areas. The analysis and potential correction of this pathway of contaminant release is not being addressed by the actions being evaluated by this EE/CA, but will be analyzed in the future.

The St. Francois aquifer system is dolomitic, and thus the ground water is alkaline. Lead normally has limited solubility in alkaline water, reducing the potential for lead contamination of ground water. This EE/CA does not evaluate or address potential groundwater contamination problems. The significance of off-site transport of lead from the tailings via groundwater flow will be evaluated in later studies.

Past sampling by EPA has revealed elevated lead levels in both sediments and in aqueous samples taken from the Shaw Branch and the Flat River downstream of the site. The Shaw Branch receives runoff discharges from the tailings pile, seepage from the dam, and/or dissolved metal leached from the tailings or leached from the sediments transported from the tailings. The elevated metals levels indicate that migration of contaminants from the site into the river has occurred. This EE/CA is addressing the surface water pathway.

The Missouri Dam Safety Council and the Missouri Department of Natural Resources' Division of Geology and Land Survey's Dam and Reservoir Safety Program (DNR-DGLS) have found the St. Joe State Park tailings dams to be unsafe and not in compliance with the Missouri Dam and Reservoir Safety Law, Sections 236.400 through 236.500, RSMo. A Position Paper, included herein as Appendix C, from Dr. James H. Williams, Acting Director and State Geologist, DNR-DGLS, addresses the dams' seismic and static instability and the potential for environmental and human health impacts. The conclusion are "that the failure of the dam is an imminent and significant threat to human health and the environment. Without repair and stabilization, this deterioration will worsen at an accelerated rate especially during periods of high and prolonged rainfall. This weakening of the dams makes them even more susceptible to failure by water-related or seismic events. The more likely time and cause of failure is during a prolonged rainfall or passible snowmelt with a large and rapid runoff."

Site Impact on Public Health and Welfare or the Environment

Exposure of humans and other organisms to lead and its compounds may occur by inhalation or ingestion. This results in lead accumulation in living tissues, including blood. Human exposure may result in toxic effects to the brain and central nervous system, resulting in lead encephalopathy, permanent brain damage, peripheral neuropathy, and, in children, permanent learning disabilities. Kidney damage may occur, which may be reversible following short-term exposure, but is permanent if exposure is prolonged. Exposure may inhibit hemoglobin synthesis, resulting in anemia and shortened life span of red blood cells. Lead exerts a toxic effect following conception and may injure fetuses (Ref. 20).

The levels of lead in the on-site tailings piles pose a potential threat to animal life coming into contact with the soil and to freshwater aquatic life encountering runoff from the site. Lead has the potential to bioaccumulate in the food chain. Lead is toxic to mammals, fishes, and birds, especially waterfowl, and it can reduce or eliminate various bacteria or fungi that assist in decomposing organic matter.

A press release has been issued by MDOH, cautioning local residents against eating fish caught from the Big River downstream of Desloge due to high lead residues. The Big River receives drainage from many mine waste areas including the Federal Tailings Pile. However, the river is still used for other recreational purposes, such as swimming and boating. These activities promote ingestion of, and dermal contact with, contaminated water.

Because lead has been detected in some of the private drinking wells in the area, additional groundwater studies are planned.

Basis for Removal Action

To justify conducting a removal action, EPA must determine that the site poses a threat to public health or welfare or the environment, based on consideration of the eight factors listed at Section 300.415 (b)(2) of the NCP, 40 CFR § 300.415 (b)(2). If, based on those factors, EPA determines that a threat exists, a removal action is justified in order to abate, prevent, minimize, stabilize, mitigate, or eliminate the release or threat of release of hazardous substances. As set forth below, EPA has evaluated these factors and determined that a removal action is justified.

The principal threat is from the potential for catastrophic failure of the dams. The dams hold back millions of cubic yards of saturated mine wastes. If the dams were to fail, the residences and the ecological communities would be threatened by not only lead exposure but potentially physical inundation.

The lead in the tailings at the site presents a threat of "actual or potential exposure to nearby human populations." There are numerous residences in close proximity to the site, with about 600 residents within 1/4 mile of the site. "High levels of hazardous substances at or near the surface that may migrate." Sampling and analysis of tailings from the site have indicated concentrations of lead as high as 210,000 mg/kg. Much of the tailings pile is dry and unvegetated and thus is susceptible to erosion via wind and storm-water runoff. In 1993, the State of Missouri collected sediment samples of the Flat River having lead concentration of 24,700 mg/kg and in Shaw Branch at 3,400 mg/kg, suggesting that mining wastes are affecting the stream sediment downstream of the site.

There are "weather conditions that may cause hazardous substances to migrate or be released" at the site. Winds sufficient to cause airborne transport of contaminants are not uncommon at the site. Also, because of the structural instability of the dams, intense rainfall or a seismic event could trigger a catastrophic release of the tailings into Shaw Creek and downstream.

Identification of Removal Actions

Removal Action Scope and Objectives

The objective of this non-time-critical removal action at the Federal site is to mitigate the threat to public health or welfare or the environment resulting from surface release of lead-contaminated material from the tailings pile. The removal action will address the release of material associated with the dam seepage, and potential catastrophic failure. These current and potential releases present a threat to the downstream population and the ecological communities. A remedial investigation and feasibility study (RI/FS) will be conducted in the near future to assess the nature and extent of groundwater, air, and other on-site and off-site exposures. The need for remedial action addressing such contamination would be assessed.

Statutory Limits on Removal Actions

Section 300.415(b)(5) of the NCP, 40 CFR § 300.415(b)(5), stipulates that the cost and duration of a removal action conducted by EPA is limited to $2 million and 12 months, unless an exemption to these limits is obtained. Section 104(b) of CERCLA provides for two types of exemptions to these statutory removal limits: 1) the "emergency" waiver; and 2) the "consistency" waiver. The "emergency" waiver provides additional funding or extends the removal action time, when continued response actions are immediately required to prevent, limit, or mitigate an immediate risk to public health or welfare or the environment. The "consistency" waiver provides additional funding or extends the removal action time to implement a removal action that is otherwise appropriate and consistent with the final response action to be taken. In this EE/CA, one of the factors considered in the evaluation of each removal alternative is whether the removal can be completed within the statutory limits, or whether the removal could qualify for an exemption from the limits

Applicable or Relevant and Appropriate Requirements

Section 300.415 (I) of the NCP provides that fund-financed removal actions under CERCLA Section 104 shall, to the extent practicable considering the exigencies of the situation, attain applicable or relevant and appropriate requirements (ARARs) under federal or state environmental or facility-siting laws. Other advisories, criteria, or guidance may be considered for a particular site.

Under CERCLA, as amended by SARA, a requirement may be either "applicable" or "relevant and appropriate" to a specific removal action, but not both. Applicable requirements are those public and environmental health and welfare requirements, criteria, and/or standards promulgated under federal or state law that address specific circumstances or scenarios at a CERCLA site. Relevant and appropriate requirements are those public and environmental health and welfare requirements, criteria, and/or standards promulgated under Federal or State law that, while not applicable to a specific site's circumstances or scenarios, address problems or situations sufficiently similar to the circumstances of the release or the response action and are well-suited to the site.

In addition to applicable or relevant and appropriate requirements, EPA and the state may identify other advisories, criteria, or guidance to be considered for a particular release. The "to be considered" (TBC) category consists of advisories, guidance, or criteria developed by EPA, other federal agencies, or the state that may be useful in developing CERCLA remedies.

ARARs are categorized into three main groups: chemical, location, and action specific. Each group is defined below:

Chemical Specific

Requirements that set technology or risk-based concentrations/limits in various media. This group can also be used to determine discharge limits, treatment standards, and disposal requirements for removal activities. Chemical-specific ARARs are also used in evaluating the effectiveness of removal alternatives.

Location Specific

Requirements that provide a basis for assessing the restrictions during the formulation and evaluation of potential location-specific remedies. Removal action alternatives may be restricted by federal and state laws concerning proximity of sensitive human populations and environments.

Action Specific

These requirements are activated during the consideration of removal alternatives. Action-specific requirements govern such categories as air emissions, treatment residues, and off-site disposal policies.

The ARARs for the proposed removal action for the Federal site are discussed in detail later in this EE/CA.

Identification and Initial Screening of Removal Action Alternatives

This EE/CA identifies and evaluates removal action alternatives to mitigate problems associated with erosion and bank stability at the Federal site. As stated previously, this removal action will not address groundwater which may be contaminated as a result of releases from the site, contaminated sediment previously deposited in the rivers, nor air contamination from the site. These releases will be addressed, if necessary, in a future remedial action. Screening alternatives were evaluated in the Seismic Dam Stability Study, Phase 1 and are summarized below.

Screening Alternatives

Excavation and Replacement

The alternative would replace the liquefaction-susceptible portion of the tailings with non-liquefiable compacted fill. This alternative was not carried forward because of the problems with local instability during excavation.

Dewatering

Surface Drainage

Breaching the dams would cause significant downstream problems, therefore this alternative was not carried forward independently but partial implementation was considered in conjunction with other features.

Internal Drainage

Measure to improve internal drainage include slurry walls, cutoff wall , vertical drains, horizontal drains and pumped wells. Of these methods, the most common employed for tailings dams is horizontal drainage, which may be useful in mitigating static stability problems produced by seepage. Because of the nature of the tailings, the time frame to cause a significant change in the phreatic surface necessary to improve stability would be many years. The long-time frame would not meet the short-term need to stabilized a hazardous situation; this alternative was not carried forward.

Soil Improvement Measures

Surcharge Loading

The soft cohesive soils could potentially be improved by placing additional loading at the surface of the piles or by inducing a vacuum in the soil profile. However because of the expected nature of the tailings in this instance, these options do not appear to be cost-effective alternatives and were not considered further.

Electro-Osmosis

Electrical currents can consolidate soft soils but this method requires large amounts of power. Initial evaluation of this technology suggested that further detailed evaluation was warranted and this alternative was carried forward in the study.

Vibrocompaction

This method involved inducement of liquefaction by a vibrating probe, thereby consolidating the soil. The soil gradation present in the tailings pile was not conducive to this alternative and therefore it was not carried forward for further evaluation.

Blasting

Charges placed at depth can induce consolidation of material. However, blasting at this site would pose a sizable risk to inducing slope instability and therefore was not considered further

Air Jetting

Introduction of compressed air can induce settlement of the tailings and increase the density of the material. The technique was considered to be viable for the site and was carried forward for more detailed analysis.

Dynamic Compaction

This technique increases density by repeatedly dropping a heavy weight on the ground surface. The method was carried forward for further analysis in conjunction with installation of wick drains.

Grouting

This is the process of introducing cement of or other chemicals into the soil pores. One specialized method, called jet grouting, which uses a special drill bit to churn and force material horizontally aware from the hole was consider for further evaluation.

Deep mixing

The last technique considered was the use of a large diameter auger with mixing paddles to inject and mix cement grout . This technique was carried forward for analysis.

Descriptions of Removal Action Alternatives

Following are descriptions of the removal actions alternatives considered for the Main Dam and the Original Dam, along with a cost estimate for each alternative. Appendix A contains detailed information concerning cost estimates for each removal action alternative.

No Action Alternative

The Main Dam may contain slimes layers beneath the face of the embankment that would cause failure if they were to liquefy. These layers are assumed to be contiguous with either the upper slimes zone or the lower slimes layer, as described in the Phase I report. For conceptual design purposes, the lower sands are assumed not to liquefy for existing conditions and the options considered. A dam breach would severely impact the downstream ecological system and human health through the catastrophic release of hazardous substances. In addition to the immediate physical damage caused by the release, residual long-term effects would be expected and would have to be repaired to prevent continuing loss of tailings from the impoundment by streamflow erosion, and a new sediment catchment basin of considerable volume would be required downstream from the resulting flowslide. Additionally, the tailings flowslide surface would have to be regraded, reclaimed and revegetated, and it is likely that substantial volumes of tailings would have to be removed from downstream reaches of Shaw Branch (Davis Creek) or the Flat River channel. The cleanup of just the Shaw Branch is estimated to cost about $3.4 million for a Main Dam Failure and $3.4 million for an Original Dam failure.

Electro-Osmosis

Electro-osmosis is a technically feasible option for improving both the upper and lower slimes of the dams. Treatment would be expected to be most effective for the softest upper slimes. Also, for purposes of conceptual design, the lower sands are assumed not to liquefy and would remain untreated. The required width of the treated zone would extend approximately 350 to 400 feet back from the embankment crest. Electro-osmotic treatment would be effective for seismic ground motions up to those that would induce liquefaction in the treated material. For purposes of cost estimating it is assumed that a 5-foot thick working fill pad would be required on the surface. Electrodes on 20-ft centers are also assumed, with estimated power consumption of 60 kwh/yd'. Power costs were based on rates of $0.028/kwh for a large primary service category. Estimated construction cost is $4.1 million for the Main Dam and $3.1 million for the Original Dam.

Jet Grouting/Dynamic Compaction/Wick Drains

This option includes treatment of the lower slimes layer in the Main Dam by jet grouting. Because jet grouting would be too expensive for the larger zone of upper slimes, dynamic compaction would be used on the upper material. Dynamic compaction alone, with an effective depth of up to about 40 ft., was not considered as a viable option due to the depth to the lower slimes layer. Wick drains would be provided in the upper slimes to enhance the effectiveness of dynamic compaction, which would otherwise be marginal in the soft, saturated fine-grained material. Tthe Jackson Lake Dam (Farrar, et. al, 1990) has material similar to the Federal Dams and is a well-documented application of wick drains. Considering that the St. Joe upper slimes are softer than the Jackson Lake soils; dynamic compactio. vould be somewhat less effective here. Both dynamic compaction and jet grouting would be required for a distance of about 150 feet behind the Main Dam crest. Jet Grouting on the Original Dam would be performed only for the upper slimes layer, the lower slimes layer would remain untreated. A 5-foot surface fill pad for dynamic compaction is provided for in the estimate, and wick drains on 5-foot centers are also assumed. The estimated costs are $7.1 million for the Main Dam and $7.9 million for the Original Dam.

Deep-Mixing Cells

The concept of deep-mixing cells is to construct a rigid honeycomb block comprised of overlapping columns of mixed-in-place grout and tailings. The tailings internal to the honeycomb cells are assumed to be rigidly confined by the cells, and therefore immune to the development of cyclic shear strains and liquefaction. The honeycomb block of cells extends across the entire length of the dam and thus acts, in effect, as a retaining wall to confine the liquefied slimes behind it. The cells are assumed to be constructed to a maximum depth of 80 feet below the tailings surface, with either non-liquefiable sand tailings or natural soils at their base. The cost estimate for this alternative is $ 12.6 million for the Main dam and $15.2 million for the Original Dam.

Berms

The final remedial option evaluated for the Main Dam is a stabilizing berm, which would be constructed of compacted tailings fill taken from borrow areas within the impoundment. Conceptual design for the berm has been performed assuming liquefaction of the upper and lower slimes layers according to the interpretations provided in the Phase I report. Neither the lower saturated sand tailings in the Main Dam nor the foundation soils are susceptible to liquefaction. By providing confinement for all liquefied materials in the dam, the berm would result in a low but unquantified probability of failure. Estimated costs for the Main Dam berm are $1.4 million and $1.0 million for the Original Dam.

Common Features

Additional Features common to all alternatives - Features that would also be incorporated into any of the proposed alternatives would include surface water drainage improvement, and flood routing, infiltration controls, and decommissioning of decant structures.

Analysis of Proposed Removal Action Alternatives

This section evaluates and compares six proposed removal action alternatives for stabilization of the tailings pile. Each proposed alternative is evaluated for its effectiveness, implementability, and the costs associated with its implementation.

Effectiveness

Long-term Effectiveness

Except for the Berm and the No-Action Options, the alternatives have similar long-term effectiveness. The Berm option is somewhat more effective in reducing the risk of liquification failure. The Berm option also would not require extensive verification procedures to demonstrate that the structure is stable. The No Action alternative would not meet the long-term need for reducing the threat of release of hazardous material from the site.

Short-term Effectiveness

Implementation of any of the structural alternatives may result in short-term risks to local residents from exposure to airborne lead-laden particulates. This may occur during grading of the tailings' surface to develop general drainage pathways, which is part of all the alternatives. In addition to posing short-term health risks, fugitive dust from removal activities could also have adverse effects on the environment. Engineering controls, such as application of water or dust suppressants during field activities, would be implemented as needed to prevent a threat to the community and uncontaminated areas (e.g., nearby vegetated areas). Air monitoring for metals and particulates would be conducted to ensure the effectiveness of efforts to prevent airborne contaminant migration. The No Action Alternative would not change the short-term effectiveness.

Exposure to dust containing lead could also pose a short-term threat to on-site workers during the removal action. Protective clothing and appropriate respirators would be employed if necessary to ensure proper protection of workers. In addition, personal air monitoring would be implemented to ensure the adequacy of personal protective equipment.

Implementability

Ability To Construct

The proposed alternatives have been successfully implemented at a number of sites that exhibited similar conditions as the Federal site. No construction of operational problems have been reported or noted. Some of the alternatives, however would require extensive field testing to assure that they can be constructed. These including electro-osmosis, dynamic compaction, jet grouting, and deep-mixing. Therefore, delays in removal schedules would be needed to complete that testing.

Demonstrated Performance

The proposed alternatives have been successfully implemented at a number of sites that exhibited similar conditions as the Federal site. The techniques have been used to successfully improve the structural stability in similar situations. Some of the alternatives, however would require extensive field testing to assure performance. These including electro-osmosis, dynamic compaction, jet grouting, and deep-mixing.

Environmental Conditions

All of the alternatives face difficulties posed by climate conditions. During winter, achieving soil compaction would be difficult due to freezing ambient temperatures. Successful planting or seeding would also likely be limited to periods of relatively moderate temperature in spring and fall. Sudden downpours of precipitation may also affect the implementation of the alternatives. Precise planting schedules, of course, will depend on the seeds or plants selected.

Contribution To Remedial Performance

The objective of each of the alternatives is to prevent any additional contaminant migration from the tailings pile to off-site areas, including the Shaw Branch, the Flat River, and the Big River. The proposed alternatives would accomplish this objective by improving drainage at the site and improving sediment loss to the stream system and reducing the threat of catastrophic releases.

Existing contamination in the stream and river system is not being addressed by the removal action. Any response action addressing lead contamination in these waters will take place in a subsequent remedial action. By preventing further releases from the tailings pile to the surface waters, each of the alternatives evaluated for this removal action would contribute to the efficient performance of any future long-term remedial action.

Availability of Equipment, Materials, and Personnel

Much of the construction materials could come from existing mine waste piles if the material can be placed such that leaching of lead or other metals does will not exceed TCLP standards and release of sediment meets ARARs. Discharges shall also be required to meet storm water ARARs. The equipment and labor necessary to implement any of the alternatives is readily available.

Availability of Post-Removal Site Control

Post-removal site control would be negotiated with the State of Missouri in order to maintain the long-term effectiveness of each of the alternatives.

Cooperation with Other Agencies and Permits Required

MDNR has participated in the preparation and review of the preliminary draft of this EE/CA and is in agreement with the concepts proposed. Community acceptance of the proposed alternative will be evaluated at the close of the public comment period on this EE/CA. A responsiveness summary will be attached to the Action Memorandum containing EPA's selected removal action. Because all of the alternatives involve only on-site activity, permits would not be required.

Costs

The estimated costs of construction of the principal technology associated with each alternative was discussed previously. Reviewers should be aware that estimated unit costs for work to be performed under a specific alternative would be higher when the ancillary activities are added (e.g. sediment control measures) and they may also be higher than standard industry cost because of the premium labor and equipment rates associated with hazardous waste site work that may require specialized equipment and worker health and safety training.

Compliance with ARARs

Pursuant to Section 300.415(I) of the NCP, on-site removal actions conducted under CERCLA are required to comply with those requirements of other federal and state environmental and siting laws that are applicable or relevant and appropriate ("ARARs") to the circumstances found at the Federal Site, to the extent practicable considering the exigencies of the situation. Applicable requirements are those public and environmental health and welfare requirements, criteria, and/or standards that address specific circumstances or scenarios at a CERCLA site. Relevant and appropriate requirements are those public and environmental health and welfare requirements, criteria, and/or standards promulgated under federal or state law that, while not applicable to a specific site's circumstances or scenarios, address problems or situations sufficiently similar to the circumstances of the release or response action and are well-suited to the site.

Determination of ARARs

Following are the ARARs for this removal action. The response alternatives previously described and evaluated would comply with all of these ARARs.

National Ambient Air Quality Standards (NAAQS)

The KNACKS under the Clean Air Act, 42 U.S.C. §7401 et. seq., 40 CFR Part 250, and 10 CSR 10-6.010, establish ambient air quality standards for emissions of lead and particulate matter. The removal action will involve significant amounts of regrading and movement of tailings, which could cause the airborne release of both lead and particulate matter. Because the site is not considered a "major source" under the Clean Air Act, the KNACKS are not applicable. However, they are relevant and appropriate during on-site construction activities. Air monitoring will be conducted and controls such as dust suppression will be applied as necessary during removal activities to ensure that airborne emissions of particulates and lead during removal actions are below the following KNACKS: (a) for particulate matter, 150 $\mu g/m^3$, 24 hour concentration, or 50 $\mu g/m^3$ annual arithmetic mean; (b) for lead, 1.5 $\mu g/m^3$ quarterly average.

Fugitive Particulate Matter Regulations

The Fugitive Particulate Matter Regulations, 10 CSR 10-6.170, provide restrictions on releases of particulate matter to ambient air. These regulations will be applicable to any fugitive emissions of particulate matter which occur as a result of on-site construction activities.

Dam Safety Regulations

MDNR has promulgated Dam Safety Regulations (10 CSR 22-1.010) governing construction and management of dams. Under the regulations, "dam" is defined as "any artificial or man-made barrier which does or may impound water" and which is more than 35 feet in height. "Tailings dam" is defined as "an existing dam or reservoir used for the impoundment or retention of tailings or a proposed, existing, or newly constructed dam and reservoir for which the anticipated or contemplated use is the impoundment or retention of tailings." The tailings dams at the Federal site are subject to these regulations due to their crest height and construction. This removal action responds to the requirements of the Dam Safety Regulations and is intended to bring the dams into compliance with those regulations. The dams' stability will be improved by reshaping their profiles to reduce the slopes and by taking measures to eliminate their susceptibility to failure from earthquake loading and overtopping by storm water flows.

Surface Mining Control and Reclamation Act (SMCRA)

SMCRA governs activities associated with coal exploration and mining. Because the standards and regulations promulgated under SMCRA are intended for active coal mines, they are not applicable to actions at the site. However, certain of the surface mining standards found in 30 CFR Part 816 are relevant and appropriate because they address circumstances that are similar to those found at the site. The requirements will be complied with by each of the alternatives.

Sediment Control Measures (§ 816.45)

SMCRA requires that sediment control measures be designed, constructed, and maintained to minimize erosion and prevent additional sediment from entering the streamflow of adjacent watercourses. The removal action will involve runoff diversion and channelization as well as slope stabilization designed to control sedimentation. One of the principal objectives of the removal action is to reduce the amount of lead-laden sediment going to the Shaw Creek. Accordingly, this portion of the SMCRA regulations will be complied with.

Siltation Structures (§ 816.46)

SMCRA requires that when siltation structures such as sedimentation ponds are used, they must contain spillways and be designed to (1) provide adequate sediment storage volume; (2) contain or treat 10-year, 24-hour precipitation events; and (3) provide a non-clogging dewatering device adequate to maintain detention time. Any erosion control basins constructed as part of drainage improvement efforts will be constructed in compliance with these requirements.

Grading Requirements (§ 816.102)

SMCRA requires that disturbed mining areas be graded to minimize water pollution and erosion, eliminate highwalls and depressions, prevent slides, and achieve original contour. The proposed removal actions involve significant amounts of regrading, which will be done in compliance with these performance standards to the extent practicable.

Revegetation (§ 816.111)

SMCRA requires that on regraded areas and all mining-disturbed areas, a vegetative cover must be established which is comprised of native species, capable of stabilizing surface soil from erosion, permanent, and capable of self-regeneration. A vegetative cover will be established at the site which satisfies these requirements.

Clean Water Act (CWA) Direct Discharge Requirements

On-site discharges from a CERCLA site to surface waters must meet the substantive requirements of the National Pollutant Discharge Elimination System (NPDES) program. At the Federal Site, site runoff from the tailings pile will be channeled directly to the Shaw Branch through discernable conveyances such as pipes or ditches. These discharges must comply with the substantive NPDES requirements. These include use of best available technology economically achievable pursuant to Section 301(b) of the CWA and compliance with state effluent limitations and water quality standards pursuant to 10 CSR 20-7.0150 and 10 CSR 20-7.031. Because the discharges to the Shaw Creek will be on-site discharges, only the substantive provisions of the NPDES program must be complied with; the administrative requirements of the NPDES program do not have to be followed and an NPDES permit is not required. MDNR has, however, issued an NPDES storm water discharge permit for the site, under the auspices of the Missouri Clean Water Commission. The permit includes performance standards to ensure satisfaction of the requirements of the above regulations, including whole effluent toxicity analysis. All provisions of the permit will be complied with during construction.

Section 404 of the CWA regulates the placement of fill in waterways, dredging of materials from waterways and wetlands impact mitigation. A Section 404 permit, issued by the US Army Corps of Engineers, is in effect for the project.

Cleanup of the surface water is beyond the scope of this removal action, and thus Clean Water Act requirements are not cleanup ARARs for the surface water.

Storm Water Requirements (10 CSR 20-6.200)

The State of Missouri has promulgated regulations that are applicable to storm water discharges associated with areas where industrial activity, including mining, has taken place in the past and significant materials remain and are exposed to storm water. The substantive requirements of the storm water program must be complied with at the site so long as runoff from the site comes into contact with the tailings. Once a vegetative cover has been established which prevents runoff from coming into contact with the tailings, these requirements will have been met.

Protection of Flood plains

As required by Executive Order 11990 and 40 CFR 6, Appendix A, if a proposed federal government action is located in or affects a 100-year floodplain, the action must be designed and carried out so as to avoid adversely impacting the floodplain wherever possible. In addition, the actions' planning must reflect consideration of flood hazards. The site is in the 100-year floodplain of Shaw Creek, and thus the removal action will be designed to protect against flood hazards. Erosion control basins and other features of the stabilized slopes will be designed and constructed in such a manner as to be protected during flood events.

RCRA Subtitle D Solid Waste Disposal Regulations

The RCRA Subtitle D program (40 CFR Part 257), as well as the State of Missouri Solid Waste Management Law and Regulation, regulates the management of nonhazardous solid waste. 40 CFR Part 257 establishes requirements for maintenance of a facility at which solid wastes are disposed. The tailings at the site are solid wastes and thus these regulations are applicable for the removal action. The regulations require that the facility be maintained so as to prevent a wash-out of solid waste and that the public not be allowed uncontrolled access to the facility. These requirements will be complied with by the removal action since slope stabilization, long-term maintenance, and access control are key elements of all of the proposed alternatives.

Determination of Non-ARARs

EPA has analyzed a number of other state and federal laws and determined that they are not ARARs with respect to this removal action. Following is a brief discussion of the basis for EPA's determination that certain laws are not ARARs.

RCRA Subtitle C Hazardous Waste Regulations

The tailings at the site are the result of mineral extraction and benefication activities, and are therefore excluded from regulation as hazardous wastes under Subtitle C (40 CFR Part 260, et. seq.) pursuant to RCRA §3001(b)(3)(A)(iii). The Subtitle C requirements are therefore not applicable requirements. In addition, the RCRA hazardous waste requirements, including closure requirements, are not relevant and appropriate with respect to the removal action.

Groundwater Requirements

Groundwater cleanup is beyond the scope of this removal action, and thus Maximum Contaminant Levels under the Safe Drinking Water Act are not ARARs for this removal action. Similarly, groundwater monitoring is not part of the removal action either. State requirements for well drilling and well construction are not ARARs for this action.

Other Criteria to Be Considered

Finally, in addition to applicable or relevant and appropriate requirements, EPA and the state may identify other advisories, criteria, or guidance "to be considered" for a particular release or response action. Following are the "to be considered" criteria and guidance for this removal action.

State of Missouri Metallic Minerals Act

This law only regulates closure of active metallic minerals mining operations. Thus, it is not an ARAR for closure of abandoned mine lands such as the site. However, the closure standards and criteria under the Metallic Minerals Act will be reviewed and considered during design of the removal action.

EPA/OSWER Interim Guidance on Soil Cleanup Levels

EPA/OSWER Revised Interim Guidance Concerning Soil Lead Cleanup Levels at Superfund Sites, OSWER Directive #9355.4-12, provides guidance on the procedures for determining appropriate soil cleanup levels. The State of Missouri Department of Health has also established guidance on "Any Use Soil Levels." The issue of direct soil exposure is not, however, being addressed by this actions and will be left for future analysis in an RI/FS.

Recommended Removal Action Alternatives

The use of berms to stabilize the dams is substantially more cost effective in achieving the same remediation goals than any other option. Therefore, the following items are proposed for the stabilization of the Federal Tailings Dam:

1. Storm Runoff Controls including developing and implementing a detailed Site Drainage Plan.
2. Construction of a Sedimentation Pond.
3. Construction of Spillways and surface water control facilities.
4. Draining ponded water from work areas.
5. Decommissioning all existing outlets and pipelines.
6. Drainage control of saturated soil materials at the toe of the original dam.
7. Construction of Berms.
8. Revegetation of Disturbed areas.

The details of this proposal is discussed in the St. Joe State Park Seismic Dam Study, Phase II Report, April 1992. A summary cost estimated is include in Appendix A.

The EPA intends to reach agreement with the State of Missouri, for post-removal monitoring and maintenance. The agreement will establish responsibility and procedures for performing long-term operation and maintenance of the constructed features. Efforts will be made to restrict unauthorized access to the site by posting warning signs along the perimeter of the site and around areas of newly established vegetation and cover material.

Cost Management

Costs directly associated with performing the EE/CA and preparing the report are CERCLA Section 104(b) expenditures. As 104(b) expenditures, EE/CA costs would not be charged against the project ceiling, but could be recovered from PRPs. Therefore, it is necessary to track EE/CA costs and cleanup cost separately.

EE/CA Funding

Performing and preparing this EE/CA report was funded by CERCLA fund allocated to the EPA Region VII.

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APPENDIX A

Cost Estimate

APPENDIX B

Photographic Records

APPENDIX A

Cost Estimations For Proposed Removal Action Alternative

FEDERAL TAILINGS PILE SITE
Park Hills, MO.

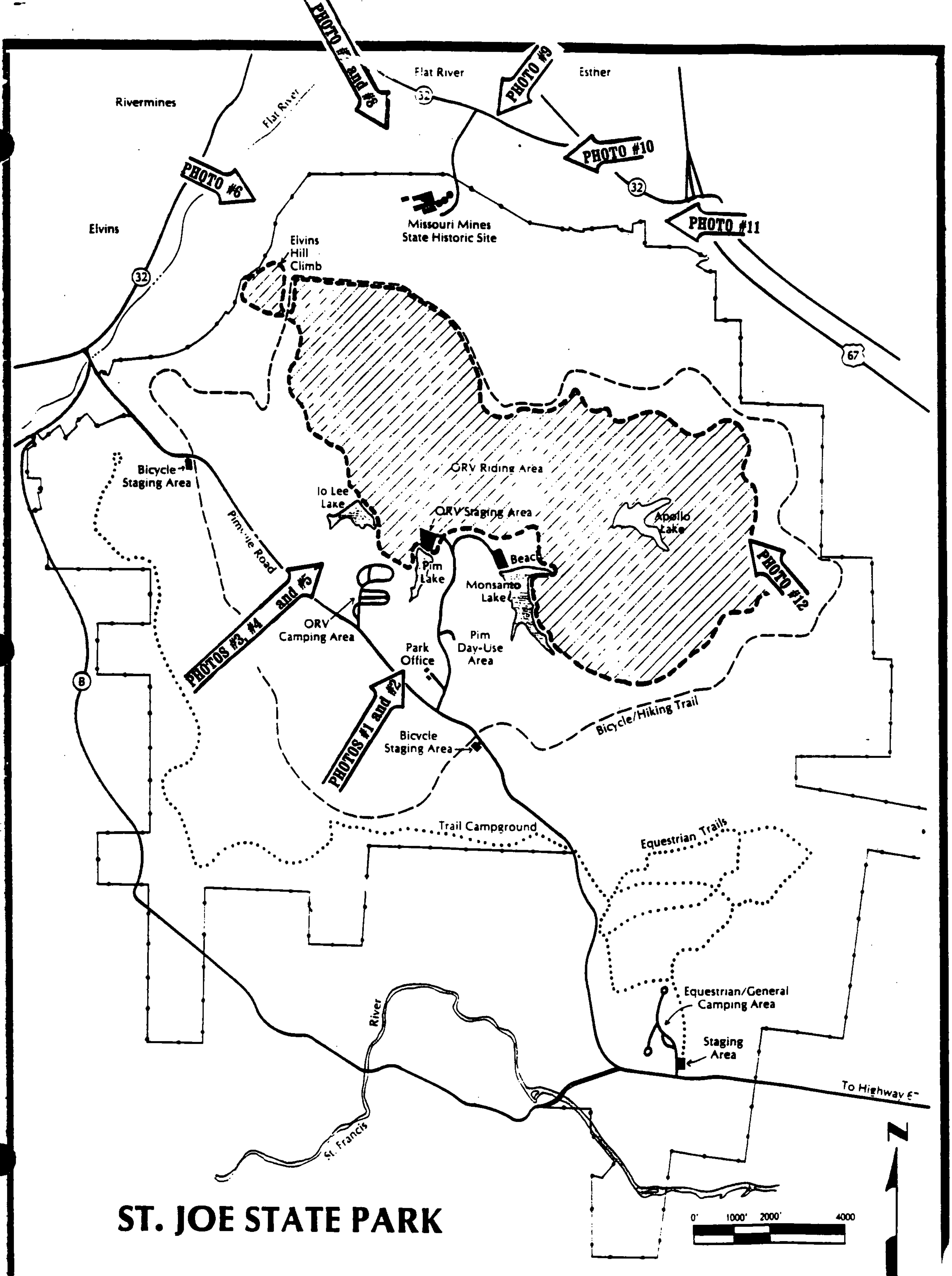
Item	Quantity	Unit Price	Total Price
	BERMS		
	Main Dam		
Fill	720,000 yd'	$1.75	$1,260,000
Gravel Drain	3,000 yd'	$5.00	$ 15,000
Erosion Control	L.S.	$25,000	$25,000
Subtotal			$1,300,000
	Original Dam		
Fill	550,000 yd'	$1.75	$962,500
Gravel Drain	2,000 yd3	$5.00	$10,000
Erosion Control	L.S.	$20,000	$20,000
Subtotal			$992,000
	FLOOD CONTROL		
	Main Dam		
Fill	250,000 yd'	$1.00	$250,000
Service Spillway (decant)	L.S.	$50,000	$50,000
Emergency Spillway (upgrade)	L.S.	$150,000	$ 150.000

Subtotal			$450,000
Original Dam			
Decants	L.S.	$50,000	$50,000
Spillway	L.S.	$50,000	$50,000
"Railroad Embankment" Spillway	L.S.	$30,000	$30,000
Subtotal			$130,000
Construction Cost Total			$2,872,000
Final Design and Construction			
Monitoring; assumed to be 10% of est. construction costs, add			$287,200
Indirect expenses; assumed at 5% of construction costs, add			$143,600
Grand Total			~,302,800

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

AERIAL PHOTOGRAPHS OF THE ST. JOE STATE PARK SITE FLAT RIVER, MISSOURI

MAY 13, 1994



ST. JOE STATE PARK

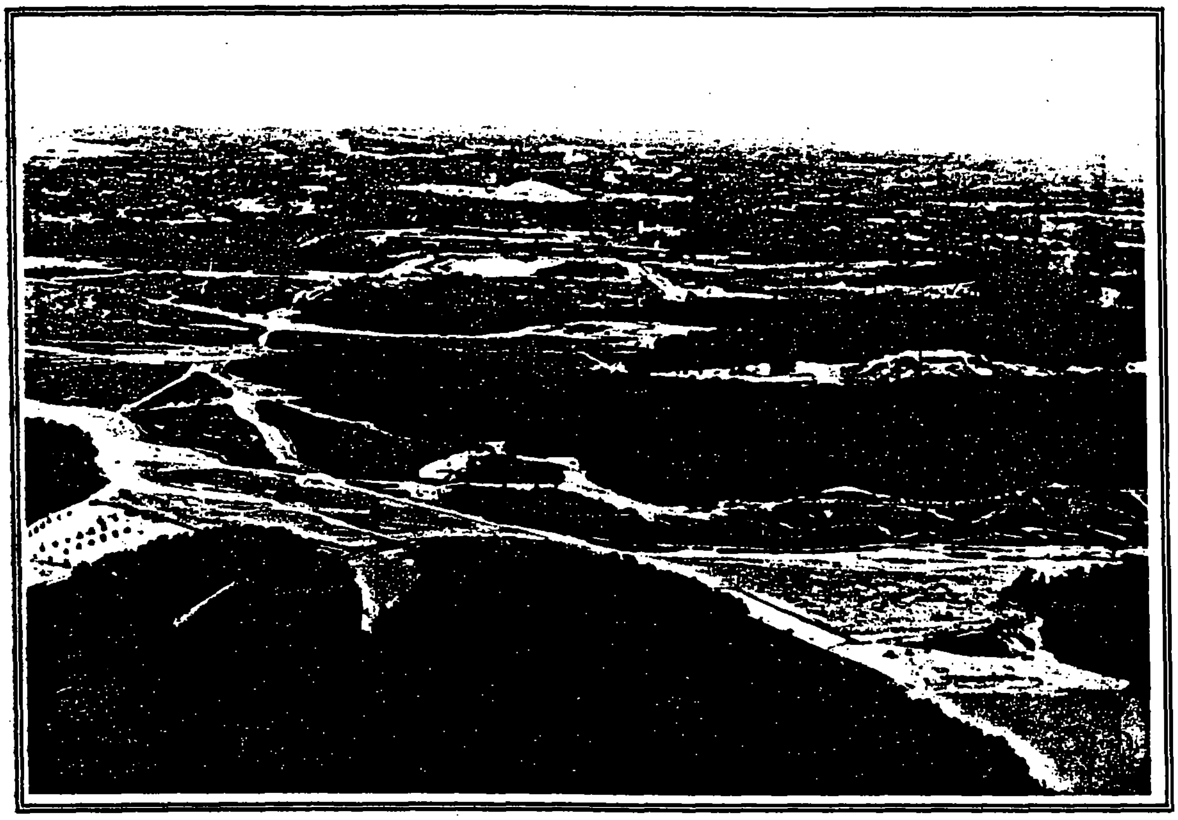


PHOTO #: 1 **SITE:** ST. JOE STATE PARK, FLAT RIVER, MO **DIRECTION OF VIEW:** NORTH
PHOTOGRAPHER: PAUL DOHERTY **WITNESS:** ANNE OLBERDING **DATE:** 5/13/94
DESCRIPTION: VIEW TO THE NORTH. MONSANTO LAKE BEACH IS IN THE RIGHT FOREGROUND. PIM LAKE, THE ORV STAGING AREA AND ORV CAMPGROUND AREA IS TO THE LEFT FOREGROUND. THE ORV RIDING AREA IS IN THE PHOTO CENTER. THE TOWNS OF ELVINS, RIVERMINES, FLAT RIVER AND ESTHER ARE IN THE BACKGROUND.

PHOTO #: 2 **SITE:** ST. JOE STATE PARK, FLAT RIVER, MO **DIRECTION OF VIEW:** NORTHEAST
PHOTOGRAPHER: PAUL DOHERTY **WITNESS:** ANNE OLBERDING **DATE:** 5/13/94
DESCRIPTION: VIEW TO THE NORTHEAST. MONSANTO LAKE BEACH IS IN THE LOWER RIGHT. PIM LAKE AND THE ORV STAGING AREA IS TO THE LOWER LEFT. THE ORV RIDING AREA IS IN THE PHOTO CENTER/BACKGROUND.

PHOTO #: 3 **SITE:** ST. JOE STATE PARK, FLAT RIVER, MO **DIRECTION OF VIEW:** NORTH
PHOTOGRAPHER: PAUL DOHERTY **WITNESS:** ANNE OLBERDING **DATE:** 5/13/94
DESCRIPTION: VIEW TO THE NORTH. APPROACHING JO LEE LAKE (OBSCURED BY TREES) IN THE FOREGROUND. THE OLD AND NEW TAILINGS DAMS ARE IN THE BACKGROUND. THE ORV RIDING AREA IS IN THE PHOTO CENTER. STANDING WATER IS VISBLE IN THE BACKGROUND.

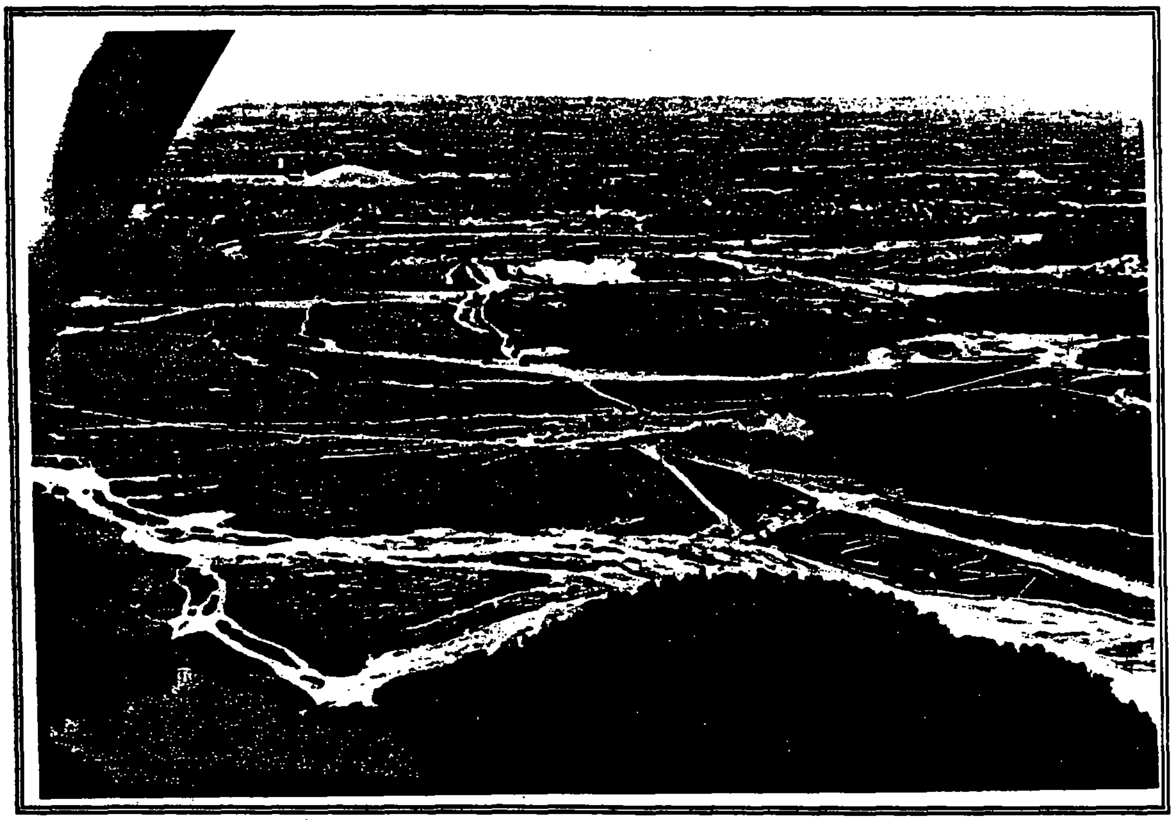


PHOTO #: 4 **SITE:** ST. JOE STATE PARK, FLAT RIVER, MO **DIRECTION OF VIEW:** NORTH
PHOTOGRAPHER: PAUL DOHERTY **WITNESS:** ANNE OLBERDING **DATE:** 5/13/94
DESCRIPTION: SAME VIEW AS PHOTO #3. JO LEE LAKE IS VISIBLE IN THE FOREGROUND. THE TOWNS OF FLAT RIVER AND ESTHER ARE IN THE BACKGROUND.

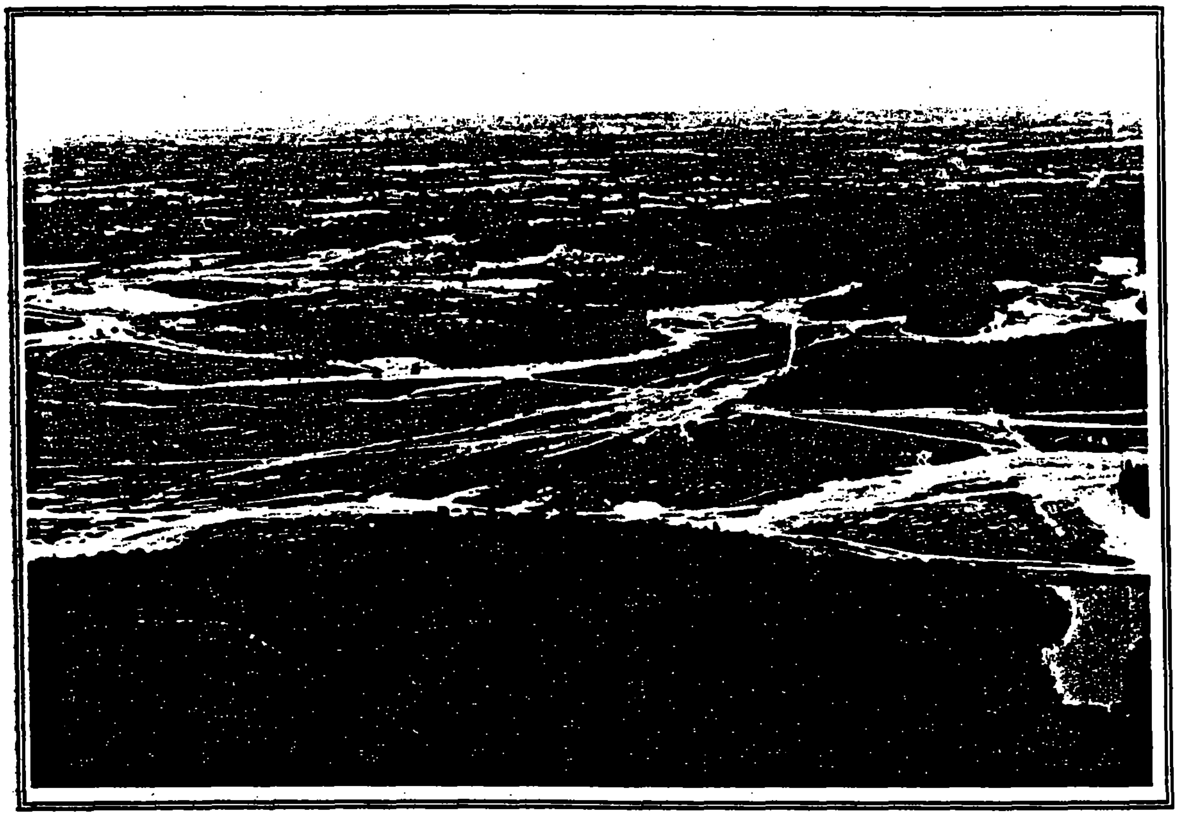


PHOTO #: 5 **SITE:** ST. JOE STATE PARK, FLAT RIVER, MO **DIRECTION OF VIEW:** NORTHEAST
PHOTOGRAPHER: PAUL DOHERTY **WITNESS:** ANNE OLBERDING **DATE:** 5/13/94
DESCRIPTION: VIEW TO THE NORTHEAST. JO LEE LAKE IS TO THE LOWER RIGHT. THE ORV RIDING AREA IS IN THE PHOTO CENTER/BACKGROUND. STANDING WATER IS VISBLE IN THE BACKGROUND.

PHOTO #: 6 **SITE:** ST. JOE STATE PARK, FLAT RIVER, MO **DIRECTION OF VIEW:** EAST
PHOTOGRAPHER: PAUL DOHERTY **WITNESS:** ANNE OLBERDING **DATE:** 5/13/94
DESCRIPTION: VIEW OF TAILINGS PILE, STANDING WATER AND MINE WORKS LOCATED DIRECTLY WEST OF THE NEW TAILINGS PILE DAM.

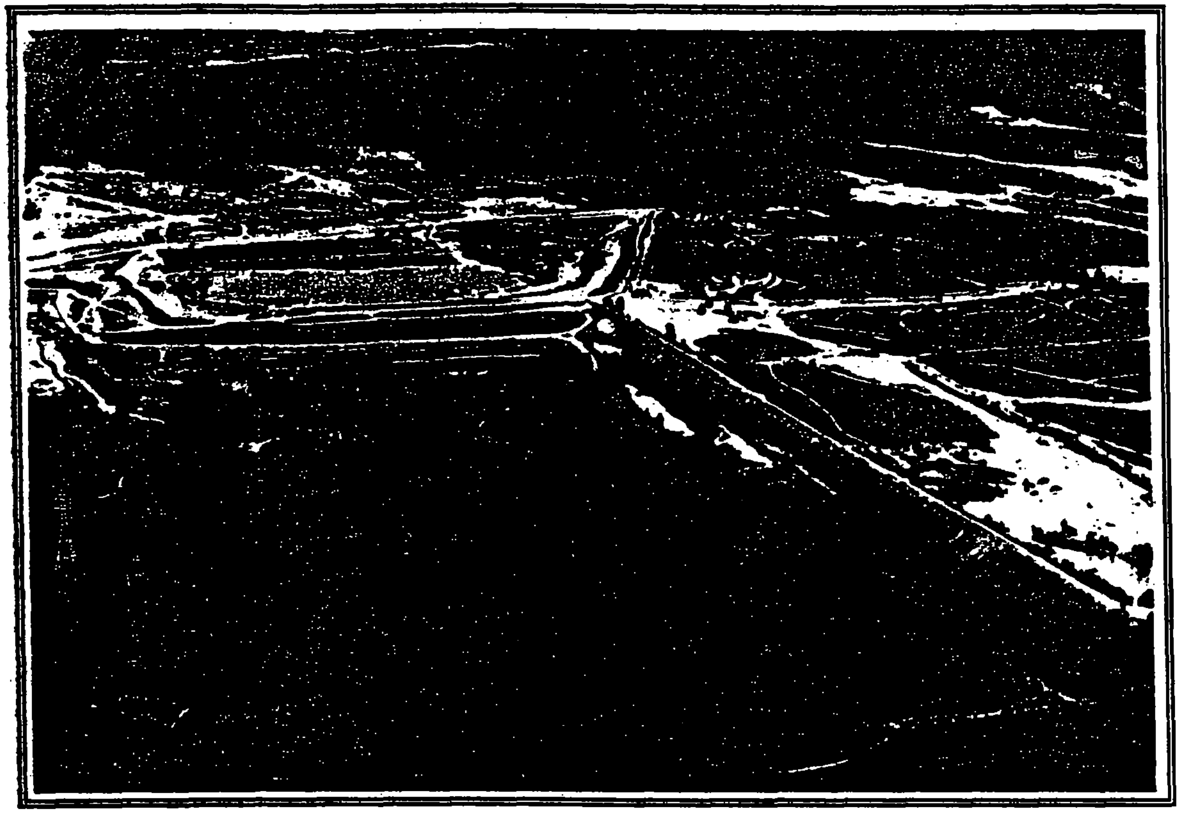


PHOTO #: 7 **SITE:** ST. JOE STATE PARK, FLAT RIVER, MO **DIRECTION OF VIEW:** EAST
PHOTOGRAPHER: PAUL DOHERTY **WITNESS:** ANNE OLBERDING **DATE:** 5/13/94
DESCRIPTION: VIEW TO THE EAST. THE OLD TAILINGS DAM IS TO THE LEFT. THE NEW TAILINGS DAM IS TO THE RIGHT. STANDING WATER AND THE PARK ARE IN THE BACKGROUND.

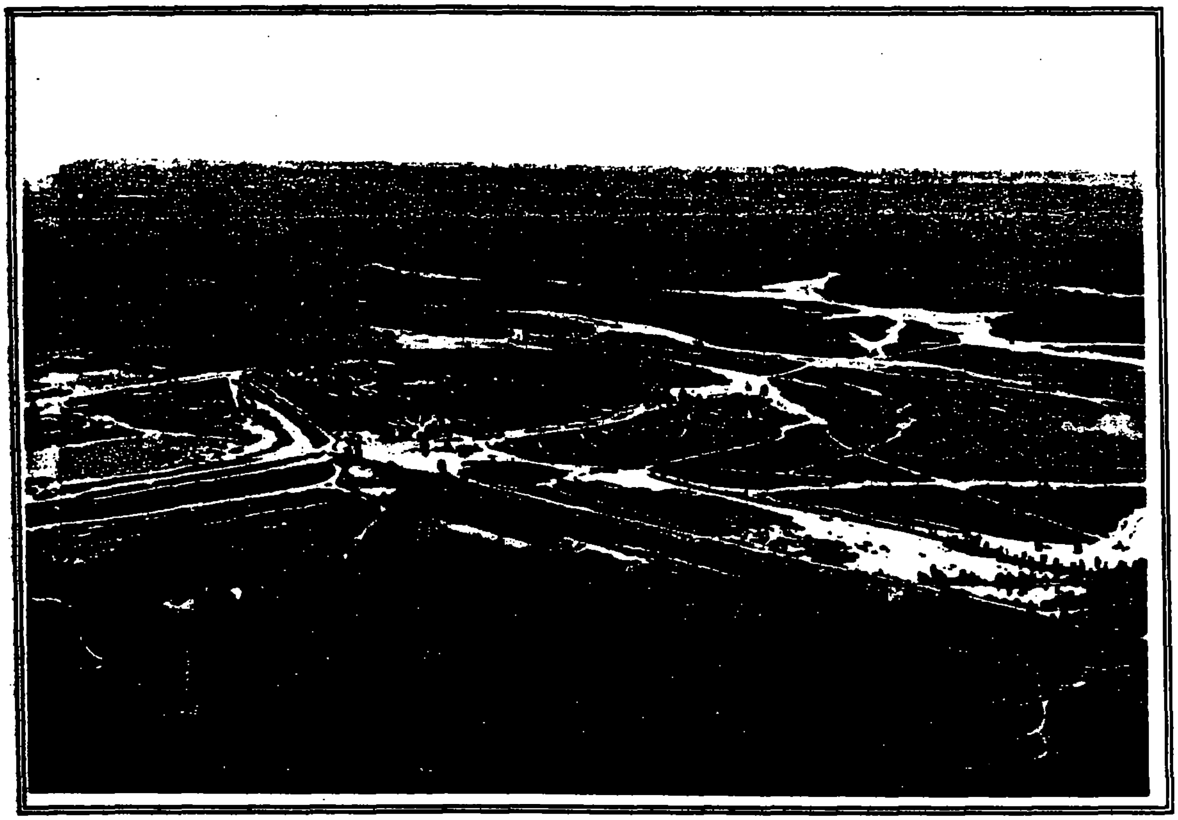


PHOTO #: 8 **SITE:** ST. JOE STATE PARK, FLAT RIVER, MO **DIRECTION OF VIEW:** SOUTHEAST
PHOTOGRAPHER: PAUL DOHERTY **WITNESS:** ANNE OLBERDING **DATE:** 5/13/94
DESCRIPTION: SAME GENERAL VIEW AS PHOTO #7. THE OLD TAILINGS DAM IS TO THE LEFT. THE NEW TAILINGS DAM IS TO THE RIGHT. STANDING WATER AND THE PARK ARE IN THE BACKGROUND. MONSANTO LAKE IS TO THE UPPER RIGHT.

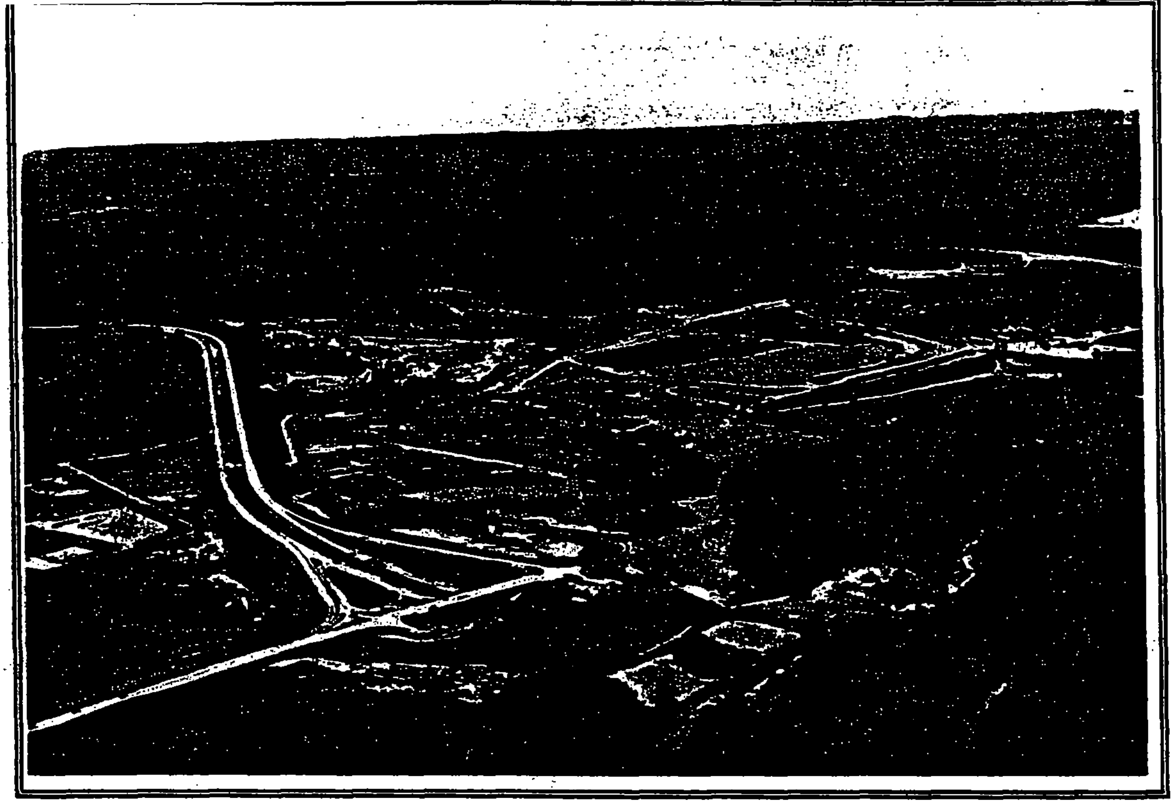


PHOTO #: 9 **SITE:** ST. JOE STATE PARK, FLAT RIVER, MO **DIRECTION OF VIEW:** SOUTHEAST
PHOTOGRAPHER: PAUL DOHERTY **WITNESS:** ANNE OLBERDING **DATE:** 5/13/94
DESCRIPTION: VIEW TO THE FORMER ST. JOE MINE MILL, NOW THE MISSOURI MINES STASTE HISTORIC SITE. STATE HIGHWAY 32 IS TO THE LEFT. THE TAILINGS DAMS ARE TO THE RIGHT.

PHOTO #: 10 **SITE:** ST. JOE STATE PARK, FLAT RIVER, MO **DIRECTION OF VIEW:** SOUTHWEST
PHOTOGRAPHER: PAUL DOHERTY **WITNESS:** ANNE OLBERDING **DATE:** 5/13/94
DESCRIPTION: CLOSER VIEW OF THE MISSOURI MINES STASTE HISTORIC SITE. STANDING WATER IS VISIBLE IN THE CENTER OF THE PHOTO. THE NEW TAILINGS DAM IS IN THE BACKGROUND.

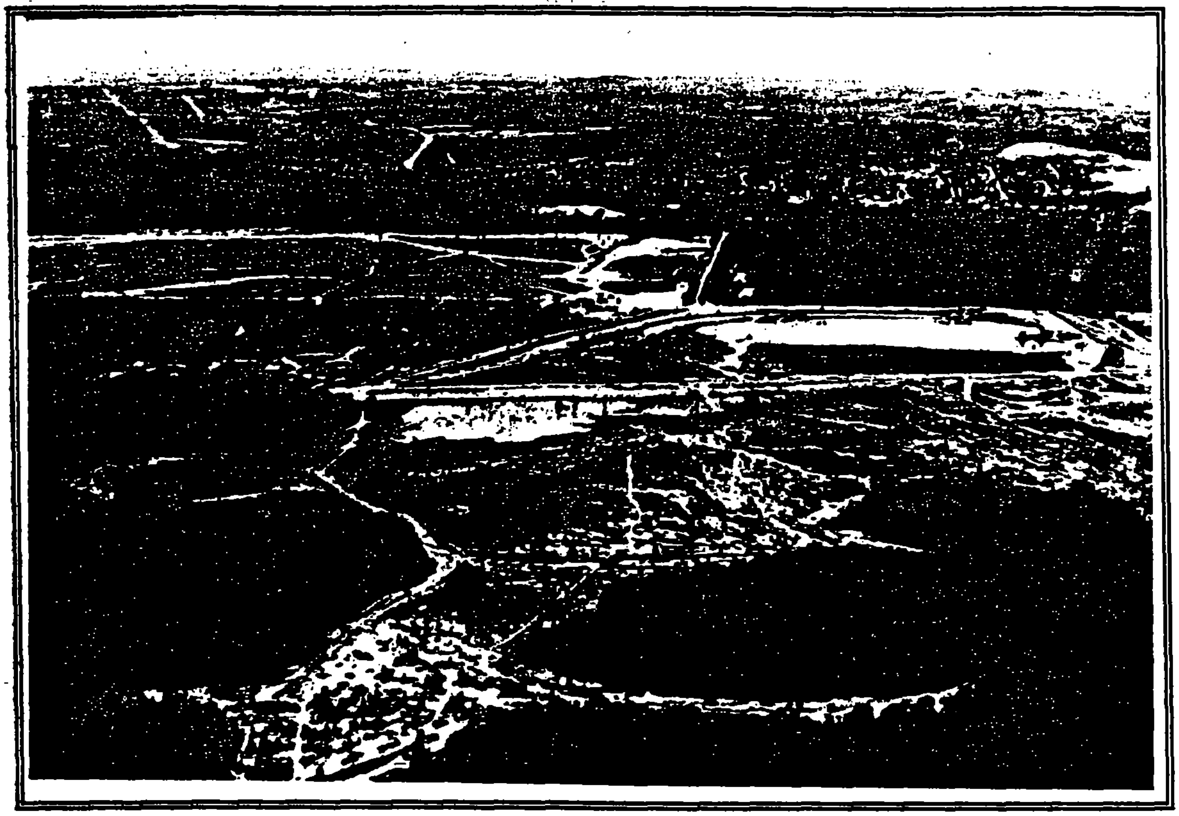


PHOTO #: 11 **SITE:** ST. JOE STATE PARK, FLAT RIVER, MO **DIRECTION OF VIEW:** WEST
PHOTOGRAPHER: PAUL DOHERTY **WITNESS:** ANNE OLBERDING **DATE:** 5/13/94
DESCRIPTION: VIEW OF STANDING WATER ABOVE THE TAILINGS DAMS. THE ORV RIDING AREA IS IN THE FOREGROUND AND TO THE LEFT.

PHOTO #: 12 **SITE:** ST. JOE STATE PARK, FLAT RIVER, MO **DIRECTION OF VIEW:** NORTHWEST
PHOTOGRAPHER: PAUL DOHERTY **WITNESS:** ANNE OLBERDING **DATE:** 5/13/94
DESCRIPTION: VIEW OF THE PARK AND ORV RIDING AREA LOOKING TOWARDS THE NORTHWEST. THE TOWNS OF ELVINS, RIVERMINES, FLAT RIVER AND ESTHER ARE IN THE BACKGROUND.

APPENDIX C

ST. JOE STATE PARK DAM

ST. JOE STATE PARK DAM
St. Francois County, Missouri
September 21, 1995

The St. Joe State Park Dam is a complex of two dams. The original dam has a north/south alignment; the adjoining main dam is aligned in an east/west direction. Both dams retain fine sediment, mostly silt and sand-size tailings formed as a waste by-product in lead mining and mill processing. Each dam is in excess of one hundred feet in height and together impound over 800 acres of tailings. Each was constructed by the upstream method, meaning that the materials forming the dams are coarser sand-size tailings that are deposited over finer-sized tailings in the impoundment. Large rock boulder-sized material is mixed with the coarser sand-sized material to form the downstream face of the dam.

Minimal engineering design was part of the dam construction. There are no apparent internal designed features in the dam to control seepage. Water levels in the tailings are only a few feet below the surface of the tailings. As these tailings are within a few feet of the crest of the dam, there has been piping of tailings through the dam during large prolonged storm events.

Failure of the dams will cause a major release of a large volume of tailings into surface water of streams accessible to the public and known for fish and other aquatic life. Both tailings and water inundation are a threat to human and animal life and the environment. The damage of such a massive uncontrolled release of tailings and the ensuing high volume of sediment runoff will cause tailings releases to reach the Big River. It is conceivable that some finer-sized portions of the tailings would eventually reach the Meramec River.

Storm events and natural degradation have greatly impacted the integrity of the dams. Recent site inspections have identified deteriorated conditions caused by over steepening of portions of the downstream slope and associated piping of finer-sized tailings through the dam.

The risk of dam failure is also high due to the probability of a moderate earthquake. Many of the conditions that contribute to a storm-related failure are the same conditions that make the dams subject to catastrophic failure caused by an earthquake. An earthquake-related event will cause the tailings to liquify and destroy the ability of the dams to hold back the tailings. Such a failure will cause a massive loss of tailings into Shaw Branch approximately 0.5 miles from the community of Park Hill, Missouri.

Through natural weathering processes associated with the age of the dam and poor construction methods, evidence of considerable deterioration and degradation of the dam structure is now evident. The following is a list of physical evidence creating concern for the integrity of this structure.

1. Significant piping of tailings has occurred through the dam structure, especially during a prolonged 1993 storm period. This piping also has greatly over steepened the upper slope of the left (western) portion of the main dam. A small sinkhole has developed on the downstream portion of the original dam. Depressions exist along the upstream face of the main dam, especially near the decant tower. These may be erosional in nature especially as an aftermath of large storm and runoff events such as in 1993.

2. Leakage of water and fines along the vertical and horizontal portions of the main decant structure is obvious. The tailings have been carried through the dam and off-site along the interior and exterior of the pipes serving as the decant structure. This phenomena is creating instability in the area where the pipes go through the dam and discharge to Shaw Branch.

3. Water under head is moving under and through the toe of the dam. Several hundred gallons per minute of seepage discharges along the toe of the dam in the form of boils and seeps and flows into Shaw Branch. This water then moves off-site.

4. The current spillway design is inadequate to handle drainage. The lack of capacity allows water to accumulate behind the dam both on top of the slimes and within the tailings. This process accelerates the process and impact of the problems noted above.

The evidence as described leads to the conclusion that the failure of the dam is an imminent and significant threat to human health and the environment. Without repair and stabilization, this deterioration will worsen at an accelerated rate especially during periods of high and prolonged rainfall. This weakening of the dams makes them even more susceptible to failure either by water-related or seismic events.

To conclude, the potential of dam failure is increasing. It could occur at any time and without warning. The more likely time and cause of failure is during prolonged rainfall or possible snowmelt with a large and rapid runoff. A seismic shaking also occurs without warning in the Midwest including the St. Francois County area. There is no stopping the failure of a large dam once it begins. Steps should be taken as required, as soon as possible, to eliminate any future problems with runoff contamination into water ways, neighboring land, and populated areas.

(Signature on File)

James H. Williams, Ph.D.
Acting Director and State Geologist
DNR Division of Geology and Land Survey
P.O. Box 250
Rolla, MO65401
314/368-2101

FM00616PA

Ref 18 C9-8

JOHN ASHCROFT
Governor

FREDERICK A. BRUNNER
Director

STATE OF MISSOURI
DEPARTMENT OF NATURAL RESOURCES

Division of Energy
Division of Environmental Quality
Division of Geology and Land Survey
Division of Management Services
Division of Parks, Recreation, and Historic Preservation

Site: Big River Mine
ID #: MOD981126899
Break: 1.3
Other: MDNR 2-2-88

MEMORANDUM

Date: February 2, 1988

To: Bob Overfelt

From: Gene Cassin, Air Pollution Control Program

Subject: Air Quality Data at Flat River

Attached are data you requested concerning air quality in Missouri's Old Lead Belt in San Francois county in the vicinity of exposed mine tailings. The hi-vol monitor was at the location shown on the attached map for the period 1981, 1982, and 1983.

Monitor filters taken during the initial period of January through August 1981, after being analyzed for TSP, were also checked for lead, with the resultant quarterly averages for lead given on an attached data sheet. No additional filters in the 3 year period were analyzed for lead.

CC: Jim Burris, R.A., PBRO

STATE: MISSOURI (26) AQDMS-II AIR QUALITY DATA REPORT DISPLAY N09997 PAGE 19

AQCR: 138 AGENCY(P1): STATE COLLECT METH: HI-VOL SLAMS/NAMS(31): OTHER/NOT CLASSIFIED
CNTY: 4220 PROJECT(04): COMPLAINT INVESTIGATION ANALYSIS METH: GRAVIMETRIC RPT AGNCY/SMSA: / 0000
AREA: 1640 PARM(11101): TOTAL SUSPENDED PARTICULATE SAMPLING INTR: DAILY UTM ZONE: 15
SITE: 001 UNITS(01): U-GMS/M3 (25DEG C,1019 M-BARS) SAROAD KEY: 26/1640/001/F/06 UTM EASTING: 719.4620
YEAR: 1981 MINIMUM DETECT: 1 UTM NORTHING: 4191.3850
LOCALE: FEDERAL MILL ROAD-CRABTREE FUNERAL HOME, FLAT RIVER, MISSOURI ST. FRANCOIS TIME ZONE(06): CENTRAL

	PRIMARY	SECONDARY
FEDERAL STANDARD	75 UG/M3 (25 C) ANNUAL GEOMETRIC MEAN	60 UG/M3 (25 C) ANNUAL GEOMETRIC MEAN
STATE STANDARD	PRIMARY STATE STANDARD FOR PARAMETER = 11101	SECONDARY STATE STANDARD FOR PARAMETER = 11101

MONTH

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	NO.	MEAN	MAX
01													0		
02								69					1	68.	69
03													0		
04					42								1	42.	42
05			33.4										1	33.4	33.4
06											24	35	2	29.5	35
07													0		
08													0		
09		33.6											1	33.6	33.6
10	39.3			89	17								3	41.77	89
11			36.4										1	36.4	36.4
12												49	1	49.	49
13										47			1	47.	47
14													0		
15		45.1				73	47						3	55.37	73
16	64.0				45								2	54.5	64.0
17			51.7										1	51.7	51.7
18											89		1	89.	89
19										12			1	12.	12
20								79					1	79.	79
21		37.2											1	37.2	37.2
22													0		
23			64.2										1	64.2	64.2
24													0		
25													0		
26													0		
27		64.9											1	64.9	64.9
28				129									1	129.	129
29			64.3										1	64.3	64.3
30											17		1	17.	17
NO	2	4	5	2	3	1	1	2	0	2	3	2	27		
MEAN	51.65	44.59	50.	99.	34.67	73.	47.	69.		29.5	43.33	42.		50.55	
MAX	64.0	64.9	64.3	129	45	73	47	79		47	89	49			129

STATE: MISSOURI (26) AQDMS-II AIR QUALITY DATA REPORT DISPLAY N9997 PAGE 17

AQCR: 138 AGENCY(PTS) STATE COLLECT METH: HI-VOL SLAMS/NAMS(13): OTHER/NOT CLASSIFIED
CNTY: 4220 PROJECT(06): COMPLAINT INVESTIGATION ANALYSIS METH: GRAVIMETRIC RPT AGNCY/SMSA: / 0000
AREA: 1640 PARM(11101): TOTAL SUSPENDED PARTICULATE SAMPLING INTR: DAILY UTM ZONE: 15
SITE: 001 UNITS(01): U-GMS/M3 (25DEG C,1013 M-BARS) SAROAD KEY: 26/1640/001/F/04 UTM EASTING: 719.4620
YEAR: 1982 MINIMUM DETECT: 1 UTM NORTHING: 4191.3850
LOCALE: FEDERAL MILL ROAD-CRABTREE FUNERAL HOME FLAT RIVER, MISSOURI ST. FRANCOIS TIME ZONE(05): CENTRAL

	PRIMARY	SECONDARY
FEDERAL STANDARD	75 UG/M3 (25 C) ANNUAL GEOMETRIC MEAN	60 UG/M3 (25 C) ANNUAL GEOMETRIC MEAN
STATE STANDARD	PRIMARY STATE STANDARD FOR PARAMETER = 11101	SECONDARY STATE STANDARD FOR PARAMETER = 11101

MONTH

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	NO.	MEAN	MAX
01											21	9	2	15.	21
02										58			1	58.	58
03								26					1	26.	26
04		46				39	55						3	46.67	55
05				16									1	16.	16
06			49										1	49.	49
07												19	1	19.	19
08										12			1	12.	12
09											49		1	49.	49
10						37	34						2	35.5	37
11				102									1	102.	102
12			61										1	61.	61
13											14	42	2	28.	42
14									5	27			2	16.	27
15													0		
16		20				32							2	26.	32
17				17									1	17.	17
18			66										1	66.	66
19											8	17	2	12.5	17
20									23	17			2	20.	23
21													0		
22		25				41	46						3	37.67	46
23	129			39									2	84.	129
24			53										1	53.	53
25											18	21	2	19.5	21
26									29	49			2	39.	49
27													0		
28		58				14	56						3	46.	58
29				29	26								2	27.5	29
30			130										1	130.	130
31												24	1	24.	24
NO	1	4	5	5	1	5	4	1	3	5	5	6	45		
MEAN	129.	43.	71.8	43.6	26.	32.6	51.	26.	19.	32.6	22.2	21.83		34.47	
MAX	129	58	130	102	26	41	56	26	29	58	49	42			130

STATE: MISSOURI (26) AQDMS-II AIR QUALITY DATA REPORT DISPLAY N09997 PAGE 10

AQCR: 138 AGENCY(F3): STATE
CNTY: 4220 PROJECT(04): COMPLAINT INVESTIGATION
AREA: 1640 PARM(11101): TOTAL SUSPENDED PARTICULATE
SITE: 001 UNITS(01): U-GMS/M3 (25DEG C.1013 M-BARS)
YEAR: 1983
LOCALE: FEDERAL MILL ROAD-CRABTREE FUNERAL HOME FLAT RIVER, MISSOURI ST. FRANCOIS

COLLECT METH: HI-VOL
ANALYSIS METH: GRAVIMETRIC
SAMPLING INTR: DAILY
SAROAD KEY: 26/1640/001/F/04
MINIMUM DETEC: 1

SLAMS/NAMS(3): OTHER/NOT CLASSIFIED
RPT AGNCY/SMSA: / 0000
UTM ZONE: 15
UTM EASTING: 719.4620
UTM NORTHING: 4191.3050
TIME ZONE(06): CENTRAL

	PRIMARY	SECONDARY
FEDERAL STANDARD	75 UG/M3 (25 C) ANNUAL GEOMETRIC MEAN	60 UG/M3 (25 C) ANNUAL GEOMETRIC MEAN
STATE STANDARD	PRIMARY STATE STANDARD FOR PARAMETER = 11101	SECONDARY STATE STANDARD FOR PARAMETER = 11101

MONTH

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	NO.	MEAN	MAX
01			201										1	201.	201
02											22		1	22.	22
03									68	93			2	80.5	93
04								41					1	41.	41
05		21				30	122						3	57.67	122
06	59			22	166								3	82.33	166
07			HALF										0		
08											18		1	18.	18
09									86	35			2	60.5	86
10								49					1	49.	49
11		72				48	99						3	73.	99
12	33			24									2	27.	33
13			41										1	41.	41
14											32	16	2	24.	32
15									36	30			2	33.	36
16								51					1	51.	51
17						45	92						2	64.	82
18	44			22									2	33.	44
19		41	52										2	46.5	52
20											5	43	2	24.	43
21									24	11			2	17.5	24
22													0		
23		54				85	34						3	58.	85
24	21			38									2	29.5	38
25			38										1	38.	38
26											17		1	17.	17
27									43	20			2	31.5	43
28								64					1	64.	64
29						40	34						2	37.	40
30	26			30	22								3	26.	30
31			18										1	18.	18
NO	5	4	5	5	2	5	5	4	5	5	5	2	52		
MEAN	36.	47.	70.	26.5	94.	53.	74.2	51.25	51.4	37.5	18.8	29.5		47.40	
MAX	59	72	201	38	166	86	122	64	86	93	32	43			201

STATE: MISSOURI (26) AQDMS-II AIR QUALITY DATA REPORT DISPLAY N09997 PAGE 16

AQCR: 139 AGENCY(S): STATE COLLECT METH: HI-VOL SLAMS/NAMS(3): OTHER/NOT CLASSIFIED
CNTY: 4220 PROJECT(04): COMPLAINT INVESTIGATION ANALYSIS METH: ATOMIC ABSORPTION RPT AGNCY/SRSA: / 0000
AREA: 1640 PARM(12128): LEAD SAMPLING INTR: DAILY UTM ZONE: 15
SITE: 001 UNITS(01): MICROGRAMS/CUBIC METER SAROAD KEY: 26/1640/001/F/06 UTM EASTING: 719.4620
YEAR: 1981 MINIMUM DETECT: .001 UTM NORTHING: 4191.3850
LOCALE: FEDERAL MILL ROAD-CRABTREE FUNERAL HOME FLAT RIVER, MISSOURI ST. FRANCOIS TIME ZONE(00): CENTRAL

MONTH

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	NO.	MEAN	MAX
01													0		
02								0.27					1	.27	0.27
03													0		
04				0.10	2.29								2	1.195	2.29
05			0.10										1	.1	0.10
06													0		
07													0		
08													0		
09		0.02											1	.02	0.02
10	0.10			0.10	0.15								3	.1433	0.15
11			0.10										1	.1	0.10
12													0		
13													0		
14													0		
15		0.10				0.11	0.06						3	.09	0.11
16	0.20				0.11								2	.155	0.20
17			0.10										1	.1	0.10
18													0		
19													0		
20								0.18					1	.18	0.18
21		0.20											1	.2	0.20
22													0		
23			0.20										1	.2	0.20
24													0		
25													0		
26													0		
27		0.10											1	.1	0.10
28				0.40									1	.4	0.40
29			0.20										1	.2	0.20
NO	2	4	5	3	3	1	1	2	0	0	0	0	21		
MEAN	.15	.135	.14	.2	.85	.11	.06	.225						.2509	
MAX	0.20	0.20	0.20	0.40	2.29	0.11	0.06	0.27							2.29

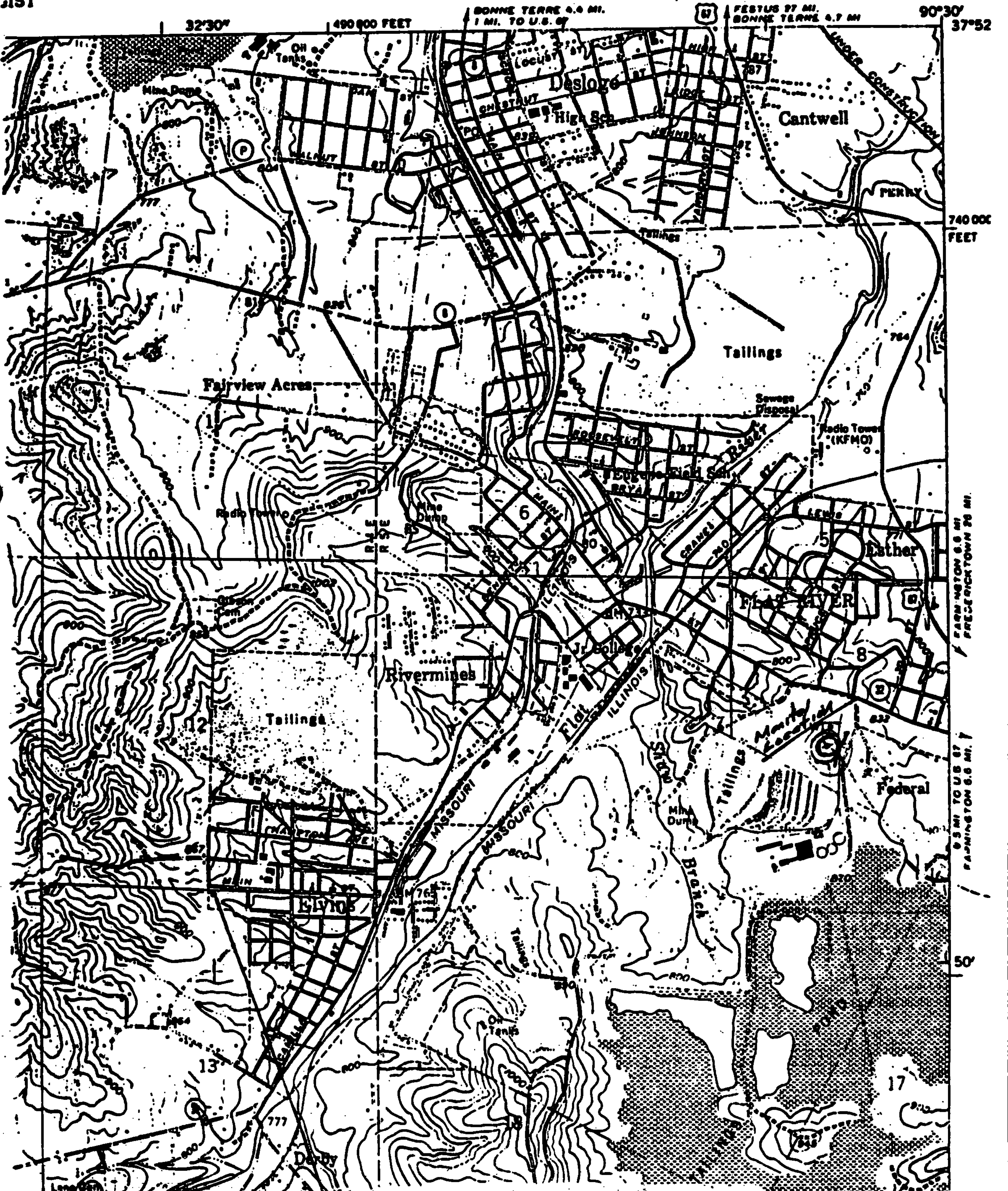
.14 µg/m³ 1.09 .17

Quarterly Average

Nat'l Standard (NAAQS) = 1.5 µg/m³

RCES
GIST

FLAT RIVER QUADRANGLE
MISSOURI–ST. FRANCOIS CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
SE/4 BONNE TERRE 15' QUADRANGLE



EPA HAZARDOUS SITE EVALUATION DIVISION

Field Investigation Team Zone II

CONTRACT NO. 68-01-7347

ecology and environment, inc.

International Specialists in the Environment

Final Report
Listing Site Inspection
Big River Mine Tailings
Volume I
Desloge, St. Francois County, Missouri
TDD #F-07-9004-011 PAN # FM00616XA
Site #Y60 Project #003
Submitted to: Region VII EPA by E & E/FIT
Superfund Contact: Greg Reesor
FIT Task Leader: Bob Overfelt, AFITOM
Date: October 30, 1991

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LIST OF APPENDICES

LIST OF FIGURES

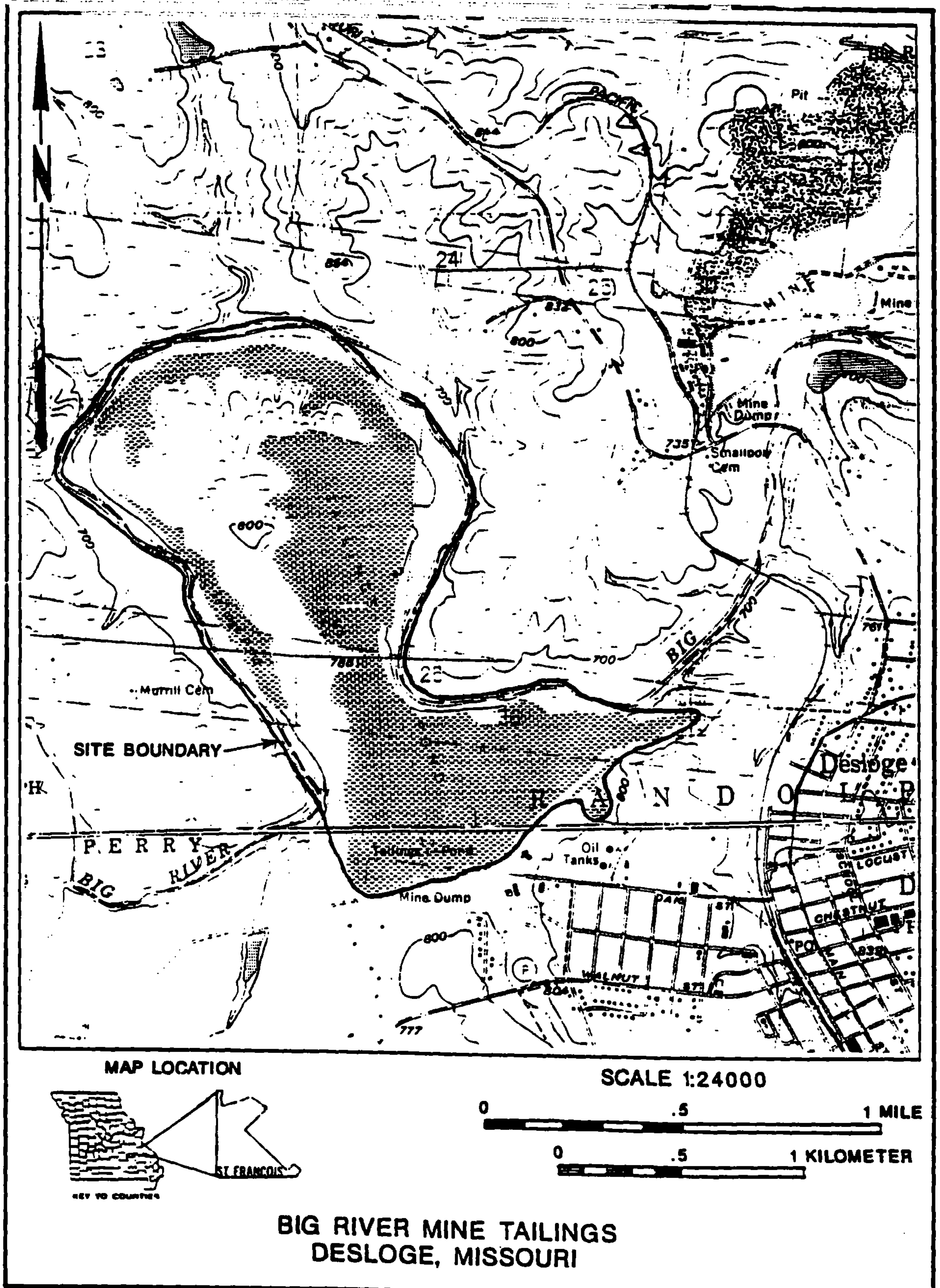
LIST OF TABLES

SECTION I: INTRODUCTION

The Ecology and Environment, Inc., Field Investigation Team (E & E/FIT) was tasked by the U.S. Environmental Protection Agency (EPA) under Technical Directive Document (TDD) #F-07-9004-011 (Appendix B) to conduct a Listing Site Inspection (LSI) of the Big River Mine Tailings site near Desloge, Missouri.

The Big River Mine Tailings site is located in St. Francois County adjacent to the north and west boundaries of the town of Desloge, Missouri (Figure 1-1). This area of southeast Missouri is a region known as the "Old Lead Belt" and was formerly a major producer of lead. The coordinates of the approximate center of the site are 37° 53′ 11.4" N latitude and 90° 33′ 00.0" W longitude (USGS 1982).

The objectives of the LSI were to determine the level of toxic metals of concern present in the tailings on site and characterize how the site is influencing the ambient air, surface water, and ground water quality on site as well as in the surrounding area. The LSI field work was conducted July 21 through 29, 1990 by E & E/FIT members: Bob Overfelt, team leader and sampler; Chris Williams, Site Safety Officer and sampler; Sharon Martin, sampler; Curt Enos, sampler and HRS information; Annette Sackmann, air sampling trainer; Otavio Silva, air and soil sampler; Patty Roberts, air and soil sampler; and Wes McCall, air and soil sampler.



WASTE SITE TRACKING #: MO0616
PREPARED BY: R. OVERFELT

ECOLOGY & ENVIRONMENT FIT MARCH 1988
SOURCE: USGS 7.5' BONNE TERRE
& FLAT RIVER, MO QUADS. 1982

FIGURE 1-1: SITE LOCATION

SECTION 2: SITE DESCRIPTION AND HISTORY

2.1 SITE DESCRIPTION

The Big River Mine Tailings site covers approximately 600 acres (Appendix A; Plates 1 and 3). It consists mainly of mine tailings ranging from 0 to more than 100 feet deep (EAP 1981). An active sanitary landfill and landfill office are located on the south end of the site. The landfill is operated by the St. Francois County Environmental Corporation (SFCEC) which has a state permit to fill approximately 60 acres (Hudwalker 1988). There are six monitoring wells installed around the landfill. The well logs for these wells are included as Appendix G. These wells are drilled to the base of the tailings. The average thickness of the tailings calculated from the well logs is approximately 50 feet. The majority of the site is situated within a horseshoe meander of the Big River (Plate 3). Therefore, the site is bordered by Big River on its west, north, and east sides. Residential areas and the town of Desloge are adjacent to the site to the south and southeast.

In order to simplify referencing specific areas on site, the three main areas discussed will be referred to as the meander area, the landfill area, and the St. Joe Minerals property. The landfill area and St. Joe Minerals property make up the southwest and southeast sections of the site, respectively, while the meander area consists of all property north of these areas within the Big River meander (Plate 3).

The site is the result of 30 years (1929 to 1958) of stockpiling lead mining wastes from a mine/mill operation located on the southern edge of the site (Novak 1980). After processing the lead ore, the tailings were transported to a designated disposal location on the site via a slurry pipeline. At the time of deposition, the material was about 50 percent water, and ponded areas would form on site, hence the name "tailings pond". Because the tailings are porous and highly permeable in most instances, the ponds dried up rapidly. There is only one small ponded area located on the west side of the site that always contains water (Plate 1). Other areas temporarily pond after heavy rainfall events but rapidly dry up. The vast majority of the site consists of dry, unvegetated tailings; therefore, it will be referred to as a tailings pile.

The site was brought to the attention of the EPA in 1977, after an estimated 50,000 cubic yards of the tailings slumped into Big River during a heavy rainfall. The tailings contain elevated levels of lead, cadmium, and zinc as well as other metals of concern. Because the tailings consist of powder, silt, and sand-sized particles, they are easily eroded via water and wind. Due to the proximity of the site to the Big River and to the town of Desloge, there were major concerns about the site's influence on the surface water and sediment quality of Big River as well as ambient air quality on and off site.

Photo 1 illustrates the area of the 1977 major tailings collapse into the Big River (Appendix F). This was taken during the 1988 Preliminary Assessment (PA) reconnaissance. Photo 2 illustrates tailings erosion on top of the pile at the major area of collapse. Photo 3, taken during the 1988 PA reconnaissance, illustrates the proximity of site to Big River on the east side as well as the migration of wind blown tailings. A strong west/northwest wind was transporting the tailings in a east/southeast direction toward the town of Desloge during the January 1988 PA reconnaissance. The predominate winds that transport the tailings appear to be from the southwest, west, and northwest. This can be concluded by the dune-like migration of the tailings that is apparent on site. The primary migration appears to be from west to east, although the prevailing wind in the area is from the south (SCS 1981). Some south to north migration is evident, however, most migration appears to be west to east. This is particularly evident in the relatively flat, unvegetated, and most elevated portion of the meander area. This area lies directly west of the major collapse area and extends approximately 2,000 feet north, 1,500 feet south, and 2,000 feet west. The topographic map in Appendix H illustrates this area. Photo 4 illustrates the barchan-type dunes and ripples that have formed in this elevated portion of the meander area. The wind fence in the photo was emplaced by SFCEC to aid in prevention of the erosion. The fencing has had minimal effect, and much of it is in need of repair. Other areas on site that release tailing particulates readily to the ambient air are the landfill operations area and the huge tailings pile located on St. Joe Minerals property that is elevated 75 to 100 feet above the adjacent tailings (Photo 5). Photo 6 was taken from the top of the large St. Joe Minerals property pile and illustrates the meander area bordering Big River to the west and farmland to the east. Howard Wood, owner of the farm property to the east of the site, stated that he never had to apply agricultural lime to his property, because so much of the tailings material blows from the site and is deposited on his fields.

Tailings have been transported by surface water erosion to Big River in many areas along the perimeter of the site bordering Big River. Section 3 documents the history of these major areas. Some have been stabilized, and some are actively transporting tailings or in direct contact with the river. During the LSI reconnaissance of the river and site border, the areas where tailings are obviously being transported into the river by surface water erosion or areas where tailings are in contact with the river were documented. These areas are illustrated on Plate 3. Photos 7 and 8 illustrate two of these areas on the west side of the site. During the reconnaissance, it became obvious that a large portion along the northern border of the site had tailings in contact with the river; therefore, this area was marked on Plate 3. Photo 9 illustrates one of these numerous areas along the north perimeter. Photo 10 shows tailings in contact with the river at the east bend on the east side of the site. The bank is very steep and undercut by the river which releases additional tailings. Tailings at this location constantly exceed their angle of repose and fall into the river.

The on-site landfill is also considered a serious problem for two reasons. First, the activity around the landfill operations continuously creates dusty conditions and releases additional heavy metal-laden particulates to the ambient air. Workers on site are constantly exposed to tailings dust. The second reason for concern is the leachate production from the landfill. Landfill leachate is typically low pH and contains large quantities of organic material. This condition could possibly dissolve and mobilize heavy metals bound in the tailings. Therefore, these metals could easily migrate to the shallow ground water and to Big River. Results from a leachate sample taken during the LSI confirms that this problem does exist.

During the LSI, several previously unknown site features were documented. The most significant of these features include a drainage tunnel, artesian wells, and a swimming area.

A drainage tunnel approximately 10 feet wide, 15 feet high, and 1,500 feet long runs under the southwest corner of the site. The tunnel entrance (Photo 11) is located approximately 300 feet southeast of the landfill office (Plate 3). The tunnel trends southeast/northwest and exits at an opening (Photo 12) approximately 200 feet southeast of the west Desloge river access (Plate 3). Water flowing through the tunnel then drains directly into the Big River. In an interview with landfill manager Bryant AuBuchon, E & E/FIT learned that the tunnel was built by St. Joe Minerals. It was used to divert surface water drainage from a tributary to Big River that once traversed and drained the south part of the site. This former tributary has obviously been filled with tailings. E & E/FIT did not perform a reconnaissance through the drainage tunnel due to safety restrictions; however, AuBuchon confirmed the actual path from his experience.

The area near the drainage tunnel entrance is approximately 50 feet lower in elevation than the adjacent access road and landfill area to the north, due to the thickness of the tailings (Photo 13). Because the landfill operators had a problem with ponding water in an area approximately 200 feet north of the tunnel (Photo 14), a culvert was installed under the access road that drains from this ponded area to the drainage tunnel entrance (Photo 13). Also, a constant flow of landfill leachate seeps into the drainage tunnel in the area (Photo 15). One other notable feature near the drainage tunnel entrance is another drainage tunnel that once drained an area on the tailings pile from a drainage tower (Photo 16). This opening is approximately 20 feet north of the drainage tunnel and appears to trend in a north/south direction underneath the tailings. This tower drainage tunnel drains into the drainage tunnel leading to Big River. It appears that the tower drainage tunnel contributes a significant amount to tailings runoff.

AuBuchon stated that during heavy rainfall events, a significant amount of tailings is carried through the drainage tunnel and deposited into Big River. E & E/FIT observed that the bottom of the tunnel near the entrance was lined with tailings at least one to two feet thick (Photo 11). It is obvious that the landfill leachate also flows through the tunnel and into Big River. Therefore, E & E/FIT sampled the leachate and tailings at the tunnel entrance and the water at the tunnel exit in order to characterize the contaminants in the water and sediment entering Big River via the tunnel.

While performing a reconnaissance near Owl Creek just west of the site, the E & E/FIT discovered four artesian wells. In an interview with Bryant AuBuchon, it was determined that these were actually former exploratory borings installed many years ago by St. Joe Minerals in order to determine the areal and vertical extent of the lead ore deposits. Apparently, the borings were never plugged after installation. These borings are cased with two-inch diameter steel casing that rises one to two feet above the ground surface. Ground water conditions in the site vicinity apparently have created artesian conditions in these borings (Photo 17). All of these artesian wells were located near the east bank of Owl Creek, north of the abandoned railroad spur, and south of the Owl Creek and Big River confluence. Two of the artesian wells are located at sample location 324 (Plates 2 and 3), and two of the wells are located at sample location 301 (Plates 2 and 3). All of these wells were producing several gallons of water per minute. This water flows directly into Owl Creek which drains into Big River. The E & E/FIT sampled one well at each location.

The E & E/FIT also determined during the LSI that a large tailings sandbar on Big River located on the northwest side of the site is used as a swimming and fishing area for the landfill workers and their friends (Plate 3). A road to access this swimming area had recently been constructed before the LSI fieldwork. AuBuchon confirmed that the area is used for swimming and fishing. The E & E/FIT sampled the surface water and sediment at this location.

It is important to realize that all of the major tailings piles in this former mining region are contributing to the contamination entering Big River and its tributaries, and that all are potentially impacting the ambient air. Consequently, the problem is regional and cannot be attributed to only one waste pile. However, the Big River Mine Tailings site (Big River pile) is unique in several ways that make it more detrimental to the environment. Because it borders Big River on three sides and is elevated above the river, tailings directly enter Big River via wind and water erosion as well as by undercutting of the tailings by the river. None of the other piles in the area are situated on Big River. As of 1980, an estimated 90,000 cubic yards of tailings have been eroded into the Big River from the site (Novak and Hasselwander 1980). E & E/FIT has observed active deposition of tailings into the river and areas on site where tailings are continuously in contact with Big River. Another notable difference about the site is that it was deposited on relatively flat topography. Therefore, as the pile of tailings accumulated, it became topographically elevated above the surrounding area. With no vegetation to stabilize the elevated areas, tailings are more easily transported to the ambient air. This occurs over much of the site; however, the large, flat, elevated area in the east-central portion of the meander area is the most severely eroded. The topographic map of the site included in Appendix H illustrates this elevated area. Tailings constantly migrate from west to east in this area creating dune features typical of aeolian deposits. Photos 3 and 4 illustrate erosion in this portion of the meander area. Other large tailings piles, such as the Leadwood and Federal piles (See Section 2.2), were deposited in valleys of dammed tributaries. As they were deposited, they filled in these valleys. While some elevated areas exist on these piles and on other tailings piles in the area, due to the size of the Big River site and relative elevation, it appears to have greater potential to create significant tailings particulate releases to the ambient air. Air monitoring of individual tailings piles is needed to confirm or refute these observations.

The on-site landfill is another unique site characteristic. No landfills are known to exist in other tailings piles. Complications associated with the landfill were discussed previously in this section. Consequently, while the metals contamination in the area cannot be attriubted to one mining waste source, the Big River site appears to contribute a disproportionate share of the contamination due to its specific characteristics.

2.2 SITE HISTORY

The Big River Mine Tailings site is located in an area known as the Old Lead Belt. The Old Lead Belt is located entirely in St. Francois

County and covers an area of approximately 110 square miles (USGS 1988).

Lead was first discovered in southwestern Missouri in the early 1700s. Until the 1860s, mining in the area was restricted to shallow workings from pits or trenches. In 1864, the St. Joseph Lead Company purchased 964 acres and began mining in Bonne Terre, Missouri. Plates 1 and 2 illustrate the towns and mining waste piles of the Old Lead Belt. Diamond-bit core drilling of the area began in 1869 and determined lead rich ore deposits existed under the towns of Bonne Terre, Desloge, Flat River, Leadwood, and Elvins. As many as fifteen lead companies operated in the area from the late 1800s to early 1900s. However, by 1933, all of the properties in the area had been acquired by the St. Joseph Lead Company. The St. Joseph Lead Company is presently known as the St. Joe Minerals Corporation. The St. Joseph Lead Company operated mine/milling operations at Bonne Terre from 1864 to 1961, at Desloge (Big River Mine Tailings site) from 1929 to 1958, and at Leadwood from 1915 to 1962. Mining activity in the area began to decrease in the 1950s and 1960s as the ore deposits were depleted and with the discovery of the Viburnum Trend (New Lead Belt) which had higher grade ore. The Federal Division of the St. Joseph Lead Company was the last mine to close in the Old Lead Belt in 1972 (USGS 1988).

This area was the nation's largest producer of lead from 1907 to 1953. Approximately eight million tons of lead were produced. Mining wastes or tailings were produced and disposed of in piles directly on the land surface. Early mining methods produced coarse tailings (known locally as chat) from mechanical separators that concentrated the ore. As technology improved chemical separators were used that produced fine-grained tailings. The majority of the Big River site consists of fine-grained tailings. However, both methods produced wastes that contain elevated metals levels. An estimated 250 million tons of tailings were produced in the Old Lead Belt. The Big River drainage basin which drains the Old Lead Belt is estimated to contain 3,000 acres of tailings. Tailings from these waste piles are easily transported and released to surface water bodies and ambient air via wind and water erosion. Plates 1 and 2 illustrate the major tailings piles that make-up the Old Lead Belt wastes as well as the tributaries of Big River that drain them.

The St. Joe Minerals Corporation (formerly St. Joseph Lead Co.) owned and operated the mining and milling operation that produced the tailings at the Big River site. In 1972, the corporation donated the majority of the site, 502 acres, to St. Francois County (Novak 1980). Approximately 100 acres, which is located directly east of the present landfill, is still owned by St. Joe Minerals (Hudvalker 1988; Plate 3).

After acquisition of the 502 acres, St. Francois County leased the land to the St. Francois County Environmental Corporation (SFCEC) (AuBuchon 1987). In 1973, the non-profit SFCEC established a sanitary landfill on approximately 60 acres of the southwest section of the mine tailings pile (EAP 1981; Hudvalker 1988). AuBuchon (1987) stated that the landfill accepts typical residential refuse and debris, and that the refuse is not separated into specified cells. The landfill operation has four full-time employees: AuBuchon and three heavy equipment operators. Hudvalker and Associates, Inc., a consulting engineering firm located in Farmington, Missouri, has administered landfill operations and maintenance of the tailings pile since 1985 (Hudvalker 1988).

Part of the 100-acre area on the east side of the site owned by St. Joe Minerals Corp. is currently leased to the Morgan and White Company (Plate 3). Morgan and White use tailings and chat from this portion of the site for mixing asphalt and sell the tailings for agricultural lime. The number of workers at Morgan and White varies. There are three full time workers; however, during the peak asphalt season (April through September), there are up to five workers on site.

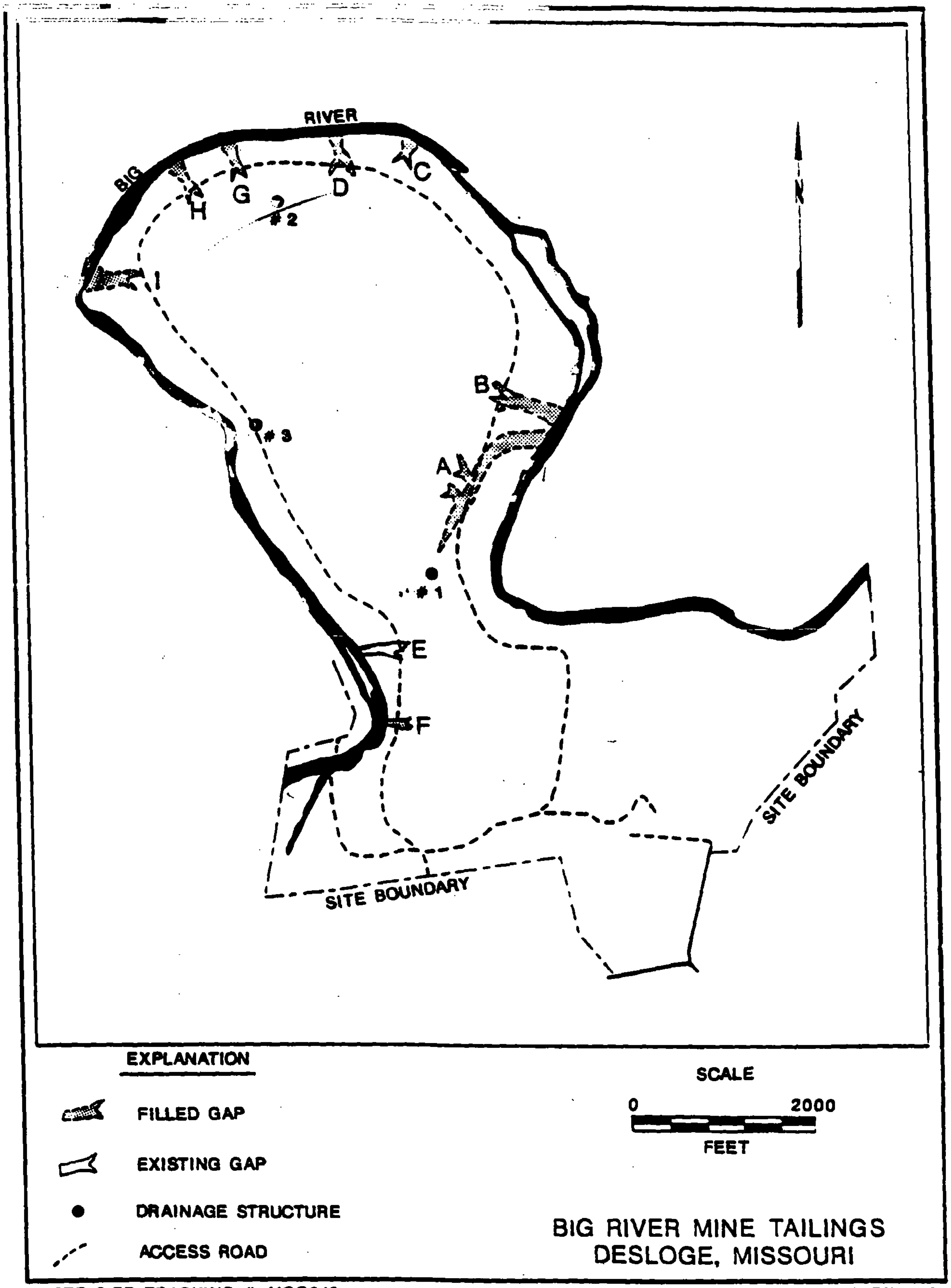
Marvin Hudvalker of Hudvalker and Associates, Inc., was present during the January 1988 PA reconnaissance. He stated that mine tailings were used as daily cover on the landfill trash, and that when a cell is filled, a one-yard thick clay cover is applied, and grass is planted. During the PA reconnaissance, the filled landfill cells were noted to have a continuous cover and the area was relatively clean.

A review of the Missouri Department of Natural Resources (MDNR) files regarding the landfill revealed that the landfill operation was very inadequate before Hudvalker and Associates took over administration. The facility was cited numerous times for various violations. Photographs from repeated inspections of the landfill depict large amounts of refuse with no cover or vegetated cap (Burris 1988).

According to a 1977 University of Missouri-Columbia (UMC) report, the area experienced a severe storm event involving the section of the tailings pile known as Gap A, adjacent to the Big River on the southeast side of the meander area (Figure 2-1). This portion of the mine tailings pile became supersaturated and collapsed, releasing its contents into the Big River (Appendix F; Photo 1). Although the exact quantity of mine tailings that washed into the river is not known, estimates suggest that the quantity may have been as much as 50,000 cubic yards (Hudwalker 1988; Figure 2-1). When MDNR discovered this catastrophic event, they requested that the EPA Surveillance and Analysis team (SVAN) conduct an extensive investigation of the Big River. The SVAN conducted a survey in late 1977, and the general findings, based on aquatic population density and diversity, were that the Big River was degraded by the mine tailings that entered the river. The degradation was mainly the result of physical changes in the benthic zone of the river rather than chemical toxicity of the river water (EAP 1981).

In 1980, the Missouri Department of Conservation (MDC) submitted evidence that some fish sampled downstream from the tailings pile contained elevated lead levels (EAP 1981). This report concluded that the high concentrations of lead were found in the edible tissue of fish found in the Big River downstream from the location where mine tailings had entered the river during the 1977 rupture. The highest concentration, 1.30 parts per million (ppm), was found in sample nine from four golden red-horse fish collected immediately downstream from the collapsed Desloge tailings pile. The World Health Organization (WHO) dietary limit for lead is 0.3 ppm (Czarneski 1984).

As a result of these findings, the state of Missouri issued a press release cautioning local residents not to eat bottom-feeders taken from a 50-mile stretch of the Big River from the city of Leadwood (near the Desloge tailings pile) downstream to Washington State Park (Gale et al. 1982). Since 1980, numerous research projects have focused on the impact of the mine tailings piles in the Old Lead Belt on the Big River. Results of various studies are presented in Section 3.



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Source: Novak 1980

Figure 2-1: Major Erosional Features

By December 1981, St. Joe Minerals Corporation, under a cooperative agreement with the state of Missouri, began limited remedial action on the pile in an effort to fill the erosional gaps and stabilize the pile (Mattson 1987). Many smaller erosional events have been documented since the massive 1977 release. Section 2.3 details the past and present erosional problems as well as the efforts undertaken to stabilize the pile.

In the spring of 1985, the Desloge Tailings Task Force was organized to deal with the existing problems of the Desloge Mine Tailings site. The Task Force, organized by St. Joe Minerals, consisted of representatives from St. Joe Minerals, the landfill, and MDNR, as well as local officials and others. Specific Task Force activities are detailed in Section 2.3. The Task Force focused on three primary objectives:

1. Provide adequate site supervision to ensure proper repair and maintenance.
2. Develop and implement short-term measures to stabilize the site.
3. Develop a long-term stabilization plan for the site.

Landfill authorities requested a permit from the state of Missouri to expand operation into 200 additional acres of the tailings pile. In January 1987, as a result of this proposed expansion, the MDNR requested that six monitoring wells be installed around the existing landfill to determine whether the ground water contained significant quantities of landfill leachate (Plate 3). The well logs for these six monitoring wells are included as Appendix G. Water samples were taken from the wells during the LSI. Table 2-1 summarizes the pertinent site history events as well as stabilization efforts.

2.3 STABILIZATION EFFORTS

After the massive release of mine tailings into the Big River in 1977, efforts to stabilize this mine tailings pile were initiated. A number of remedial efforts have been accomplished. Reports from several agencies detail the problems that exist at the site and present solutions to these problems.

Table 2-1
Site History and Stabilization Efforts

Date	Chronology of Pertinent Site Events
1929-1958	Mining occurred and tailings were deposited in slurry form.
1973	St. Joe Minerals Corporation donated 502 acres to St. Francois County. St. Francois County leased the land to the St. Francois County Environmental Corporation which opened the existing landfill.
1977	Collapse of tailings in Gaps A and B; SVAN reports degradation of Big River due to influx of tailings during collapse.
1980	Missouri Department of Conservation determined elevated Pb levels in bottom-feeding fish and issued a press release cautioning local residents not to eat these fish.
1981	St. Joe Minerals began remedial activity in an attempt to stabilize the tailings.
1983	Gaps G and H were formed by overtopping of the retaining berm.
1984	1,500 feet of wind fencing installed.
1985	Desloge Tailings Task Force was orgainzed. Gap I was formed by overtopping. Burns and McDonnel long-term stabilization plan. Twenty acres near Gap I were seeded. This area appears to be growing well today. Installation of an additional 2,000 feet of wind fencing.
1986	10,000 Black Locust trees planted; mostly near Gap I.
1987	Monitoring wells installed around landfill. Some 15,000 Black Locust trees planted near Gap G. Some 20,000 feet of wind fencing installed.
1988 (Jan)	E & E/FIT Preliminary Assessment reconnaissance.
(May)	E & E/FIT Limited Site Inspection.
1990	E & E/FIT Listing Site Inspection.

A comprehensive report prepared in 1980 for MDNR by the UMC College of Engineering characterizes the major environmental concerns at the site including water and wind erosion and the apparent hazard of constructing a landfill in the tailings pile. The UMC investigation concluded that the tailings pile contained numerous points where tailings are entering the Big River due to water erosion. The UMC team designated six gaps, which were labeled alphabetically around the pile starting on the southeast side (Figure 2-1). Erosional Gaps G, H, and I developed after the report was completed and have been labeled as they occurred. Areas where tailings are eroding into the river via water erosion or where tailings are in direct contact with the river were noted during the LSI. These areas are illustrated on Plate 3.

Two of the original drainage structures placed by the mining company are illustrated in Photos 7 and 18 (Appendix F). These concrete drainage structures were constructed to drain the water from off the tailings pile and divert it into Big River. During the E & E/FIT PA site reconnaissance in January 1988, it was noted that drainage structure #1 near Gap A was totally collapsed and was no longer functional. According to the UMC report, drainage structure #1 became blocked, leading to the massive erosion which occurred in 1977 at Gaps A and B. The UMC report recommended that the major erosional gaps be filled with a suitable fill material and the area be reshaped to reduce further erosion. Further, the report suggested that the drainage structure located near Gap A be altered to minimize the chance for overflow (Novak and Hasselwander 1980). As Photo 18 illustrates, no further stabilization efforts had been conducted at drainage structure #1 as of July 1990, during the LSI fieldwork.

Wind erosion and the associated blowing of lead-laden dust is also a major concern (Appendix F; Photos 3 and 4). As tailings accumulate and their angle of repose is exceeded, they collaspe and fall into the river. Wind erosion is generally from west to east, which produces a continuous movement of the tailings toward the east. Because the tailings are a very fine, dolomitic sand or silt, sufficient wind velocity creates a tailings dust cloud. During the January 1988 site reconnaissance, this occurrence was observed to be a serious problem (Photo 3). A dust plume originating from the site appeared to be transporting dust at least one mile to the southeast. Wind speeds on that day included gusts up to 35 miles per hour.

The UMC report recommended that a study be undertaken to assess the possibility for plant growth to be established on the pile to control wind erosion. Plant life is very difficult to establish in this environment for several reasons:

- o A serious nutrient deficiency exists in the tailings;
- o Wind erosion prevents establishment of seedlings;
- o Moisture cannot be retained, especially on the slopes, due to the porous nature of the tailings; and
- o The lead content of the tailings may cause plant sterilization, preventing reseeding by existing plants.

Because of these deleterious conditions, natural plant growth on the majority of the pile is almost nonexistent. Thus, experimentation was suggested as an attempt to establish a method for maintaining a vegatative cover.

The UMC report considers the on-site landfill to be a serious potential problem. The liquid runoff (leachate) that results from a landfill is typically low in pH and contains large quantities of organic material. If these conditions exist, it is very possible that heavy metals could be leached from the tailings and transported to the Big River and shallow ground water at the site. In the UMC report, tests were conducted by extracting mine tailings with nitric acid, distilled water, and ethylenediaminetetra-acetic acid (EDTA). The nitric acid extraction represents the total quantity of metals in the tailings. The distilled water extraction represents what is released by the movement of rain water through the tailings. The EDTA extraction represents the potential for extraction by landfill leachate (Table 2-2). Metals that are extracted by landfill leachate would also be chemically bound by organics and might remain in solution after entering a body of water such as the Big River. During the reconnaissance, the area where landfilling was complete and soil cover was applied was observed to be much more stable than the adjacent mines tailings. However, the benefits of soil cover are offset by the potential for landfill leachate to release lead and other metals from the tailings (Novak and Hasselwander 1980).

These three problems of water erosion, wind erosion, and the landfill are the primary concerns at the Desloge tailings pile. When the UMC report was submitted in 1980, no remedial action had begun. However, St. Joe Minerals Corporation began remedial activities in 1981.

Table 2-2
Metals Analyses of Tailings
Big River Mine Tailings Desloge, Missouri
University of Missouri-Columbia College of Engineering

	Clay (µg/g dry)			Sand (µg/g dry)		
	Water	EDTA	HNO_3	Water	EDTA	HNO_3
Lead	20	2,200	2,400	26	720	850
Cadmium	ND	3.2	14	ND	5.8	25
Zinc	3.4	220	680	14	230	1,000

Source: Novak and Hasselwander 1980

NOTE:
ND: Not detected.
Water: Represents rainfall through tailings.
EDTA: Ethylenediaminetetra-acetic acid and represents landfill leachate through tailings.
HNO_3: Nitric acid and represents total metal content in tailings.

In December 1981, St. Joe Minerals Corporation began filling Gaps A, B, C, and D. This remedial action was completed in January 1982 (Mattson 1987). C.G. Mattson, St. Joe Minerals Corporation Project Manager, provided a summary of the remedial activity and maintenance performed after the initial work on Gaps A, B, C, and D to the date of the EPA PA.

According to Mattson, inspections have been performed at least once per month from December 1981 by St. Joe Minerals and/or the engineer for the landfill. Inspections also are made after or during heavy rainfall events. The inspections consists of confirming that all drainage structures are functional and that no observable defects have occurred in the retaining berm.

In April 1983, two small gaps, designated Gaps G and H, were formed when unusually heavy rainfall overtopped the retaining berm (Figure 2-1). The gaps were filled and a 22-inch steel pipe drainage structure was placed in each. In October 1984, 1,500 feet of fence was placed along the base of the large tailings pile on St. Joe Minerals property, and the area north of the fence was seeded, fertilized, and covered with straw mulch. This fence was built to reinforce a dune formed by a wind fence placed in 1980.

In April 1985, Gap I was formed when heavy rainfall topped the retaining berm. The gap was filled and a 22-inch steel pipe drainage structure was established. At the same time, 2,000 feet of snow fence was placed in the area of the break to build up the retaining berm with wind-blown material. The open channel spillway cut that drains the pond area was deepened and a diversion ditch was cut across natural ground to keep water from flowing into the Gap I area (Figure 2-1). A diversion dike was also built through natural ground so that water diverted by the landfill operation would not flow into Gap E (Figure 2-1).

In October 1985, the approximately 20 acres of tailings that comprise the major portion of the Gap I drainage area were fertilized and seeded. During the January 1988 FIT reconnaissance, it was apparent that the vegetation in this particular area was growing well and had helped stabilize the area. It should be noted that this area is flat and stable relative to other steep sloping, dune-like areas that also exist on the tailings pile. The condition of this area was similar during the July 1990 LSI.

In 1985, the Desloge tailings Task Force contracted the engineering firm Burns and McDonnel, Inc., to develop a long-term stabilization plan. The investigation and report were funded 25 percent by the landfill corporation and 75 percent by St. Joe Minerals. The Burns and McDonnel (B & M) proposal was highly criticized because it included creating several ponds on the tailings pile to control surface runoff (B & M 1987). Because of the proven instability of the tailings, the plan to create ponds on the pile was not considered a satisfactory solution. In March 1986, 10,000 Black Locust trees were planted on the Desloge tailings area; some 7,500 of them were planted in the Gap I drainage area that was sewn in October 1985. During the reconnaissance, it was apparent that the seeding of Black Locust in this area was very successful. Some trees were approximately 12 feet tall. In February 1987, 15,000 Black Locust trees were planted on the approximately 15 acres of tailings that form the drainage area for Gap G. These areas were inspected during the LSI, and the vegetation attempts appeard to be successful in the Gap I area and moderately successful in the Gap G area.

In September and October 1987, some 20,000 feet of wind fencing was installed on the upper portion of the tailings area. During the FIT reconnaissance it was noted that much of this fencing was damaged or blown down due to a recent storm. Reconstruction of the fencing, as well as reinforcement, were planned. It was obvious that the wind fencing was controlling some movement of the sand-like material, but it is ineffective during stronger winds (Mattson 1987). It should be noted that at the time of the LSI, most of the wind fencing was damaged and, therefore, ineffective.

In April 1987, the Soil Convervation Service proposed some stabilization plans for the site to the Desloge Mine Tailings Task Force. They suggested diverting the surface drainage away from critical erosion areas and planting some test plots to determine what methods might be best for revegetation. Plans in 1988 were to carry out revegetation test plot experiments in an attempt to determine what plants and planting methods are best suited to the mine tailings. No known further stabilization efforts had been completed or undertaken during the period from the 1988 PA to the 1990 LSI activity. No additional areas were vegetated and it was noted during the LSI that most of the wind fencing was in need of repair.

2.4 SITE CONTACTS

Persons associated with the operation and regulation of the site include the following:

Marvin Hudwalker
Professional Engineer
Hudwalker and Associates, Inc., Consulting Engineers
Farmington, Missouri
(314)756-6775

Bryant AuBuchon
Landfill Manager
St. Francois County Environmental Corporation
Desloge, Missouri
(314)431-4768

C.G. Mattson
Project Manager
St. Joe Minerals Corporation
Irvine, California
(714)975-5269

Greg Reesor
Superfund Contact
U.S. EPA
726 Minnesota Avenue
Kansas City, Kansas
(913)551-7695

Also see Appendix C for additional site contacts and property owners associated with the site sampling.

SECTION 3: PAST INVESTIGATIONS

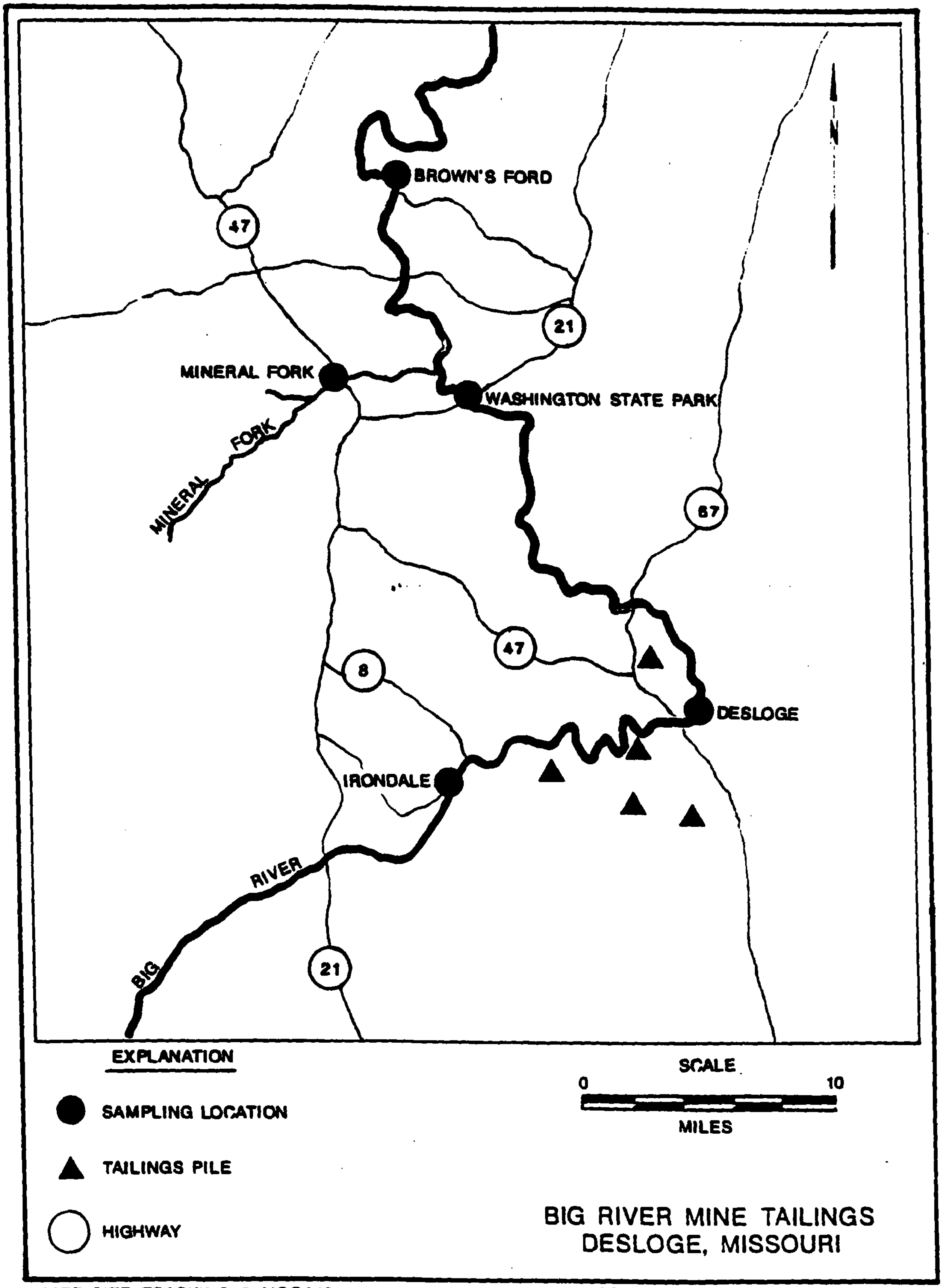
Numerous investigations regarding the effects of mine tailings on the Big River have been completed since the massive erosional event in 1977. This section will address the significant results of this research.

3.1 METALS IN BIG RIVER WATER AND SEDIMENT

In a study conducted by the National Fisheries Research Laboratory (NFRL), the metals content in river water and sediment was measured at different locations along the Big River (Figure 3-1). The Irondale and Mineral Fork sampling locations were considered control areas while Desloge, Washington State Park, and Brown's Ford sites are 5 miles, 37 miles, and 60 miles, respectively, downstream from the Desloge Mine tailings pile.

Water sampling was done during low, medium, and high stream flow. Total metals and dissolved metals were measured for lead, cadmium, and zinc. The highest total lead (0.68 milligrams/liter [mg/l]) occurred at Washington State Park, and the highest dissolved lead (0.026 mg/l) occurred at Brown's Ford (Table 3-1).

Sediments samples were collected from corresponding locations on the Big River (Table 3-2). Total sediment lead concentrations were highest in Desloge (2215.0 milligrams/kilogram [mg/kg]) and tended to decrease with distance downstream. This value is similar to the lead content found in the tailings at the Desloge pile. Total lead concentration was lowest (49.6 mg/kg) at Irondale. Concentrations at Mineral Fork were substantially higher than at Irondale, though they were lower at Mineral Fork than at other locations. This is probably attributable to the past lead mining or ongoing barite mining activities in the Mineral Fork watershed. These sampling results show how the mine tailings had affected the benthic zone of the Big River at the Desloge mining pile and for several miles downstream (Table 3-2; Schmitt 1982).



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SOURCE: SCHMITT 1982

Figure 3-1 NFRL Study Sample Locations on Big River

Table 3-1
Metals Concentrations in Water Samples Collected
in the Big River
Big River Mine Tailings Site
Desloge, Missouri

Location/ Stage	Flow (CFS)	Lead D	Lead T	Cadmium D	Cadmium T	Zinc D	Zinc T
Mineral Fork							
Low	29.6	0.005	0.009	0.001	0.001	<0.01	<0.01
Med.	160.0	0.006	0.005	0.001	0.001	<0.01	<0.01
High	505.0	0.005	0.009	0.001	0.001	<0.01	<0.01
Brown's Ford							
Low	95.6	0.005	0.043	0.001	0.001	0.02	0.03
Med.	650.0	0.007	0.084	0.001	0.001	0.01	0.03
High	11900.0	0.026	0.440	0.001	0.001	0.05	0.17
Washington State Park							
Low	70.2	0.009	0.091	<0.001	0.001	0.01	0.04
Med.	490.0	<0.005	0.140	<0.001	<0.001	0.01	0.07
High	11395.0	0.021	0.680	<0.001	<0.004	-.--	0.22
Desloge							
Low	45.3	0.020	0.041	0.002	0.004	0.31	0.36
Med.	298.0	0.010	0.085	0.001	0.001	0.06	0.11
High	932.0	0.012	0.110	0.002	0.004	0.10	0.16
Irondale							
Low	7.1	0.005	0.005	0.001	0.001	<0.01	<0.01
Med.	160.0	0.005	0.005	0.001	0.001	<0.01	<0.01
High	300.0	0.005	0.005	0.001	0.001	<0.01	<0.01

Source: National Fisheries Research Laboratory Report (Schmitt 1982).

Note: CFS = Cubic feet per second.
D = Dissolved Metals.
T = Total Metals.
Reporting unit is mg/l.

Table 3-2
Metals Concentrations in Sediment Samples
Collected in the Big River
Big River Mine Tailings Site, Desloge, Missouri

Location	Lead	Cadmium	Zinc
Irondale	49.6	1.62	64.9
Desloge	2,215.0	19.96	1,658.4
Washington State Park	1,843.4	10.79	704.3
Brown's Ford	1,438.3	6.55	484.5
Mineral Fork	291.5	2.52	369.7

Source: National Fisheries Research Laboratory Report (Schmitt 1982).
NOTE: Adjusted total sediment metals concentrations (ug/g dry weight).

3.2 METALS IN AQUATIC BIOTA

Several past studies have focused on the elevated metal levels in the Big River aquatic biota.

In the report prepared by the NFRL, cray-fish, fresh water mollusks, and fish were sampled. The sample locations were the same as for surface water and sediments. In crayfish samples, lead and cadmium levels were elevated at Desloge, Washington State Park, and Brown's Ford. The highest lead concentration (140 micrograms/gram [μg/g]) occurred at Desloge. The lead concentration in crayfish was 1.4 μg/g at Irondale and 2.7 μg/g at Mineral Fork. Since crayfish feed on aquatic macrophytes and detritus, they can accumulate sediment-bound toxins.

Pocketbook mussels were collected at all the locations except Desloge, where none could be found. Results were listed by mean concentrations. Results showed the highest mean lead concentrations at Brown's Fork ranging from 310 to 490 μg/g in soft tissue and 18 to 19 μg/g in the shell. Lead levels at Washington State Park were from 200 to 310 μg/g in soft tissue and 8 to 22 μg/g in the shell. The control sample at Irondale had mean lead levels of 2.16 μg/g in soft tissue and 0.76 μg/g in the shell.

The results of fish samples collected in the Big River vary with fish types (Table 3-3). Bottom-feeders, such as catfish and the Redhorse sucker, tended to have higher concentrations of metals than fish such as the smallmouth bass that do not feed on bottom sediment.

Table 3-3
Metals Concentration in Edible Portions
of Fish in the Big River
Big River Mine Tailings, Desloge, Missouri

Location/ Species	Lead	Cadmium	Zinc
Mineral Fork			
Smallmouth bass	0.19	0.01	13.97
Yellow bullhead	0.13	0.02	5.67
Redhorse sucker	0.08	0.01	13.42
Brown's Ford			
Smallmouth bass	0.21	0.01	4.50
Flathead catfish	0.29	0.02	12.24
Redhorse sucker	0.63	0.01	11.67
Washington State Park			
Smallmouth bass	0.27	0.01	9.49
Flathead catfish (4)	12.00	0.34	23.00
Redhorse sucker	0.43	0.01	9.38
Mixed suckers	0.38	----	----
Desloge			
Smallmouth bass	0.05	0.01	11.73
Channel catfish	0.13	0.03	5.12
Redhorse sucker	0.57	0.03	16.15
Mixed sucker	0.79	----	----
Irondale			
Smallmouth bass	0.01	<0.01	13.28
Flathead catfish	0.06	0.06	6.75
Redhorse sucker	0.02	0.01	9.32
Mixed sucker	0.07	----	----

Source: National Fisheries Research Laboratory Report (Schmitt 1982).

NOTE: Means of two samples (individual fish) unless otherwise indicated. Reporting unit is ug/g wet weight.

The lead content in the Redhorse sucker was greater than the 0.3 µg/g dietary limit recommended by the World Health Organization (WHO): 0.57 µg/g at Desloge, 0.43 µg/g at Washington State Park, and 0.63 µg/g at Brown's Ford. The lead concentrations at Irondale and Mineral Fork were well below the WHO limit (Table 3-3; Schmitt 1982.)

Research conducted on fish over a five-year period by the University of Missouri-Rolla (UMR) confirms there results. UMR research shows that over a five-year period, the lead concentrations in suckers from the Big River near the lead tailings pile have consistently exceeded the WHO limit (Gale et al. 1982).

These results suggest that mine tailings have raised lead levels in the benthic zone of the Big River and in the bottom feeders that live in this zone of the river. This study also suggests that the tailings have had little effect on the heavy metals content in the river water. However, the LSI sampling results have determined that the surface water in Big River does contain elevated levels of metals which are attributable to the site.

3.3 MINE TAILINGS FOR USE AS AGRICULTURAL LIME

UMR research determined that the possible use of mine tailings as agricultural lime may be acceptable. It also stated that caution should be taken because some older tailings piles have much higher concentrations of lead than more recently developed piles. It should also be noted that plant uptake studies have indicated that both lettuce and radishes tend to accumulate some lead and cadmium when tailings were mixed with soil as agricultural lime (Wixon et al. 1983)

3.4 PARTICULATES IN AMBIENT AIR FROM TAILINGS IN AREA

MDNR collected air quality data near Flat River, Missouri, approximately two miles southeast of the site. MDNR used one Hi-vol sampler located approximately 2,000 feet north of the St. Joe Park Tailings Pile (Federal Pile) near Flat River (Plate 1). Data was collected for a three-year period, 1981 to 1983. Monitor filters taken during the initial sampling period of January through August 1981 were analyzed for lead. They were analyzed for total suspended particulates only. No additional filters in the three-year period were analyzed for lead. The total suspended particulate (TSP) annual geometric mean in 1981 was 50.55 micrograms/cubic meter ($\mu g/m^3$); 1982 was 35.47; and 1983 was 47.43 $\mu g/m^3$ (MDNR 1981). The National Ambient Air Quality Standard (NAAQS) for the annual geometric mean of TSP is 75 $\mu g/m^3$ (CFR 1987). The results of the lead analyses for the first three quarters of 1981 were January to March 0.14 $\mu g/m^3$, April to June 1.09 $\mu g/m^3$, and July to August 0.17 $\mu g/m^3$ (MDNR 1981). The NAAQS primary standard for lead in a calendar quarter is 1.5 $\mu g/m^3$ (CFR 1987). These results are all within the standards for air quality and are adequate for southerly winds. Because the prevailing winds in this part of the country vary from season to season or month to month, additional Hi-vol monitoring devices situated around the tailings pile would have been more effective than one unit (USDC 1979). A background or control Hi-vol sampler was not used; therefore, no control data is available for comparisons. The Hi-vol air monitoring data collected during the LSI included a much more complete study and analysis. These results are discussed in Section 7.4.

3.5 E & E/FIT PREVIOUS INVESTIGATIONS

PA site reconnaissance was conducted in January 1988. Site conditions at that time were documented in the PA report submitted May 17, 1988, to EPA. Much of the background material from the PA has been updated and is included in this report. During the PA reconnaissance, 35 mile per hour westerly winds were observed transporting tailings material off site. Photographs taken during this PA thoroughly document this air release.

A limited site investigation that included surface sampling of the tailings and background soils was conducted May 16, 1988. Nine samples, including a duplicate, were collected on site, and three background soil samples were collected near a gravel road 2.5 miles northwest of the site. Concentration ranges of on-site samples were 880 to 1,400 mg/kg of lead, 8.4 to 19 mg/kg of cadmium, and 370 to 1,100 mg/kg of zinc. Concentrations of background samples were 410 to 570 mg/kg of lead, undetected cadmium, and 97 to 99 mg/kg of zinc. Tailing concentrations were elevated above these background samples; however, the background concentrations were considered very high. This probably is due to the collection of the background samples adjacent to a gravel road. Tailings are used for road material in the area; therefore, dust from the road may have elevated the adjacent soil. The LSI sampling yielded much lower metals concentrations in background surface soil.

SECTI 4. SUMMARY OF WASTE SOURCE AND CHARACTERISTICS

It has been determined that the 600-acre mine tailings located at the Big River Desloge Tailings site contain significant amounts of lead, cadmium, and zinc. The tailings from the pile are migrating into the river and ambient air via water and wind erosion. Therefore, these heavy metals constituents are contaminating the river, air, and possibly the ground water. This section will discuss the three heavy metals of primary concern (lead, cadmium, and zinc), their characteristics, potential hazards, and relevant EPA Maximum Contaminant Levels (MCL). Detailed waste characteristics for these metals as well as arsenic, cobalt, and nickel are included in Appendix I.

Lead exists in nature mainly as lead sulfide (galena). Other common forms are lead carbonate (cercissite), lead sulfate (anglesite), and lead chlorophosphates (pyromorphite). Stable complexes result from the interaction of lead with the sulflydryl, carboxyl, and amine coordination site found in living matter. The toxicity of lead in water is affected by pH, hardness, organic materials, and the presence of other metals. The aqueous solubility of lead ranges from 500 micrograms/liter (µg/l) in soft water to 3 µg/l in hard water (EPA 1976).

Lead is a toxic metal that tends to accumulate in the tissues of humans and other animals. Although seldom seen in the adult population, irreversible brain damage is a frequent result of lead intoxication in children. This most commonly results from the ingestion of lead-containing paint found in older homes. The major toxic effects of lead include anemia, neurological dysfunction, and renial impairment. The most common symptoms of lead poisoning, which usually develop slowly, are anemia, severe intestinal cramps, paralysis of nerves (especially the arms and legs), loss of appetite, and fatigue. The MCL established for lead in drinking water is 50 µg/l and proposed 5 µg/l (EPA 1991). The National Ambient Air Quality Primary Standard for lead in the air in a calendar quarter is 1.5 $\mu g/m^3$ (CFR 1987).

Cadmium occurs mainly as a sulfide salt, frequently in association with zinc and lead ores (EPA 1976). Accumulation of cadmium in soils in the vicinity of mines and smelters may result in high local concentrations in nearby waters. Cadmium is deposited and accumulated in various body tissues. Cadmium may function in or may be an etiological factor for various human pathological processes including testicular tumors, renal dysfunctions, hypertension, arteriosclerosis, growth inhibition, chronic diseases of old age, and cancer (EPA 1976). The MCL established for cadmium in drinking water is 10 µg/l and proposed at 5 µg/l (EPA 1991).

Zinc is usually found naturally as a sulfide, and it is often associated with other metals, especially lead, copper, cadmium, and iron. It is used in galvanizing processes and in preparation of alloys. Zinc is essential and beneficial in human metabolism. Community water supplies tested have contained 11 to 27 mg/l without harmful effects. The toxicity of zinc compounds to aquatic animals is modified by environmental factors. An increase in temperature and reduction in dissolved oxygen increases the toxicity of zinc for fish. Toxic concentrations of zinc compounds cause adverse changes in the morphology and physiology of fish (EPA 1976). No primary MCL for zinc has been established.

Arsenic, nickel, and cobalt were also detected in the ground water near the on-site landfill. The MCLs for arsenic and nickel are 50 µg/l and 100 µg/l, respectively. No MCL for cobalt has been established.

Mean concentrations of lead, cadmium, zinc, cobalt, nickel, and arsenic were calculated from the fourteen tailings samples collected on site during the 1990 LSI. Mean concentrations are 2,215 mg/kg lead, 21.7 mg/kg cadmium, 1,044 mg/kg zinc, 15.4 mg/kg cobalt, 15.8 mg/kg nickel, and 7.6 mg/kg arsenic.

The tailings area has been established to be approximately 600 acres. The average thickness of the tailings is approximately 46 feet based on an evaluation of contours from a 1908 USGS map (before tailings deposition) compared to the current topographic elevation. Well logs also verify that the tailings are approximately 50 feet thick. Therefore, the overall volume of waste was calculated to be approximately 44,528,000 cubic yards.

5.1 SITE VICINITY AND AIR PATHWAY CONSIDERATIONS

There are several people working on site and numerous people residing in the area surrounding the site. The landfill operation employs four full-time personnel. The Morgan and White facility has three full-time employees and may have up to five during April to Septem-ber. Therefore, there are seven people that work on site year round. The nearest individual residing off site is at the Kyle residence, located 100 feet south of the southwest side of the site.

Population of the surrounding site area was determined using topographic maps, aerial photographs, US Census Bureau data, and the Graphical Exposure Modeling System (GEMS). Table 5-1 lists these results.

Table 5-1
Population Surrounding the Site in Four-mile Radius

Distance from site (miles)	Population
0 - 1/4	52
1/4 - 1/2	235
1/2 - 1	2,399
1 - 2	11,443
2 - 3	6,469
3 - 4	238

Sources: USGS 1982, St. Francois 1983, EPA 1989, U.S. Census 1991

Resources in the area include the adjacent Big River and commercial agriculture. The Big River is recognized by MDNR for uses that include livestock watering, wildlife watering, swimming, boating, and aquatic life (fishing etc.) (Hovland 1988). The E & E/FIT observed numerous individuals fishing and swimming in Big River at and downstream of the site. It should also be noted that during the LSI, it was determined that landfill employees had recently built an access road on site leading to a large tailings sandbar that employees use for swimming and fishing. This area is located on the west side of the meander area and is illustrated on Plate 3. Howard Wood owns the farm that lies across the river on the east side of the site. Wood uses the land for livestock grazing and hay production. Wood stated that he does not need to apply agricultural lime to his fields due to the significant amount of tailings that blow from the site and are deposited on his property. No terrestial or aquatic sensitive environments exist within a four-mile radius of the site (Dickniete 1990).

5.2 TOPOGRAPHY AND SURFACE WATER CONSIDERATIONS

The Big River Mine Tailings site lies on the eastern side of the Ozark highlands in St. Francois County, Missouri. The major physical features in the area are the St. Francois Mountains to the south, the Farmington Plain to the east, and the dissected topography of the Salem Plateau located to the north (SCS 1981). The site is between these major features on the floodplain of the Big River.

The Big River Mine Tailings site is a mounded pile of tailings that slopes from the middle toward the river boundary. Therefore, drainage on the east, north, and west sides of the site is directly into Big River. Section 3 discusses in detail site drainage as well as past and present problems. Refer to the detailed topographic map of the site included in Appendix H for specific site drainage patterns. Some of the drainage on the south end of the site enters the on-site tunnel and is transported to Big River.

The majority of the site is bordered by Big River. There are numerous areas along this perimeter where tailings constantly erode into the river. Therefore, the tailing wastes are easily transported to the river and in many areas are continuously in contact with the river.

The tailing material is processed dolomite powder, silt, and sand-sized material. Because the tailings are very porous and permeable, they will not retain water through infiltration. Also, tailings are devoid of organic nutrients. Therefore, plant growth is very difficult. Most of the site is unvegetated.

The Soil Conservation Service describes the majority of the site as Psamments soils. This unit consists of deep, nearly level to gently rolling, excessively drained, newly formed soil in tailings ponds. These soils are formed in crushed dolomite material from lead mining. Permeability is rapid, and surface runoff is slow to medium although most precipitation is absorbed into the surface. The available water capacity is low. The natural fertility is very unbalanced, and careful fertilization is required to make the soil suitable for any plant growth. The organic matter is also very low. Some areas have been seeded to grasses and legumes, but results are poor. These soils are generally unsuitable for growing grasses, shrubs, and trees, unless intensively managed (SCS 1981).

The area where natural vegetation occurs on site consists mainly of Caneyville silt loam except for a small area on the southwest portion of the site where Gasconade, flaggy, silty, clay loam occurs.

Caneyville silt loam has 2 to 5 percent slopes and is moderately deep and well drained. This soil occurs on convex ridgetops. The surface layer is a dark-brown silt loam about five inches thick. Surface runoff is slow to medium. Available water capacity is low (SCS 1981).

Gasconade flaggy, silty, clay loam has 9 to 35 percent slopes, is excessively drained, and occurs on uneven side slopes. The surface layer is a very dark-brown flaggy, silty, clay loam about eight inches thick. The subsoil is dark-brown very flaggy, silty, clay about five inches thick. Permeability is moderately slow, and surface runoff is rapid. Available water capacity is very low (SCS 1981).

All of the soils on site are underlain by hard-bedded Bonneterre dolomite (SCS 1981).

As stated in Section 5.1, the Big River is officially recognized for uses that include swimming, boating, fishing, livestock watering, and wild-life watering (Howland 1988). E & E/FIT observed many local individuals swimming and fishing in the Big River at the site and downstream. There are no drinking water intakes on Big River within 15 miles downstream of the site. However, there is an intake on Big River in Jefferson County, at least 60 river miles from the site (Price 1991).

There are no sensitive environments or critical habitats within one mile downstream of the site (Dickniete 1990).

5.3 HYDROGEOLOGY AND GROUND WATER CONSIDERATIONS

The regional and site specific hydrogeology is very complex due to the past mining activities. Hundreds of miles of abandoned underground mine shafts are now filled with ground water. It is estimated that 100,000 exploratory borings were also drilled in the Old Lead Belt (USGS 1988). It is assumed that most of these borings were never properly sealed. Consequently, the mining activity in the region has significantly altered ground water flow and has left the ground water more susceptible to contamination. A comprehensive, regional ground water study was beyond the scope of the LSI. However, the USGS office in Rolla, Missouri, is currently conducting a ground water study of the site and surrounding area.

The shallow ground water on site was characterized during the LSI using several sampling methods. This included sampling of monitoring wells, installing and sampling Geoprobe temporary wells, sampling springs, and sampling artesian wells. It was determined that the shallow ground water is in contact with the tailings. Monitoring wells drilled to the base of the tailings directly around the landfill had static water level (SWL) measurements ranging from 30.5 to 45.75 feet below the ground surface. These monitoring wells (UG-1, DG-3, and DG-2) were emplaced in areas where the tailings are thickest. Monitoring well DG-5, located at a lower elevation near the Big River, had a SWL of 4.25 feet below the ground surface. When the SWL is compared to the total depth of the well, which is drilled to the base of the tailings, it is apparent that shallow ground water is in contact with the tailings. Well logs for the monitoring wells are included in Appendix G. Four Geoprobe temporary wells had SWLs ranging from 9 to 12 feet below the ground surface. It can also be concluded from these SWL measurements that the shallow ground water is in contact with the tailings. This is also confirmed by the numerous springs or seeps found along the perimeter of the site and Big River boundary. Several of these springs were sampled during the LSI.

Several artesian wells located approximately 800 to 1000 feet west of the southwest border of the site were sampled. The wells are actually unsealed exploratory borings. The surface contact of these wells is topographically 60 to 80 feet lower than the southwest side of the site. Results from the samples collected indicated that contaminated shallow ground water from the site is influencing these artesian wells. Results from all of the ground water samples collected are discussed in Section 7.3.

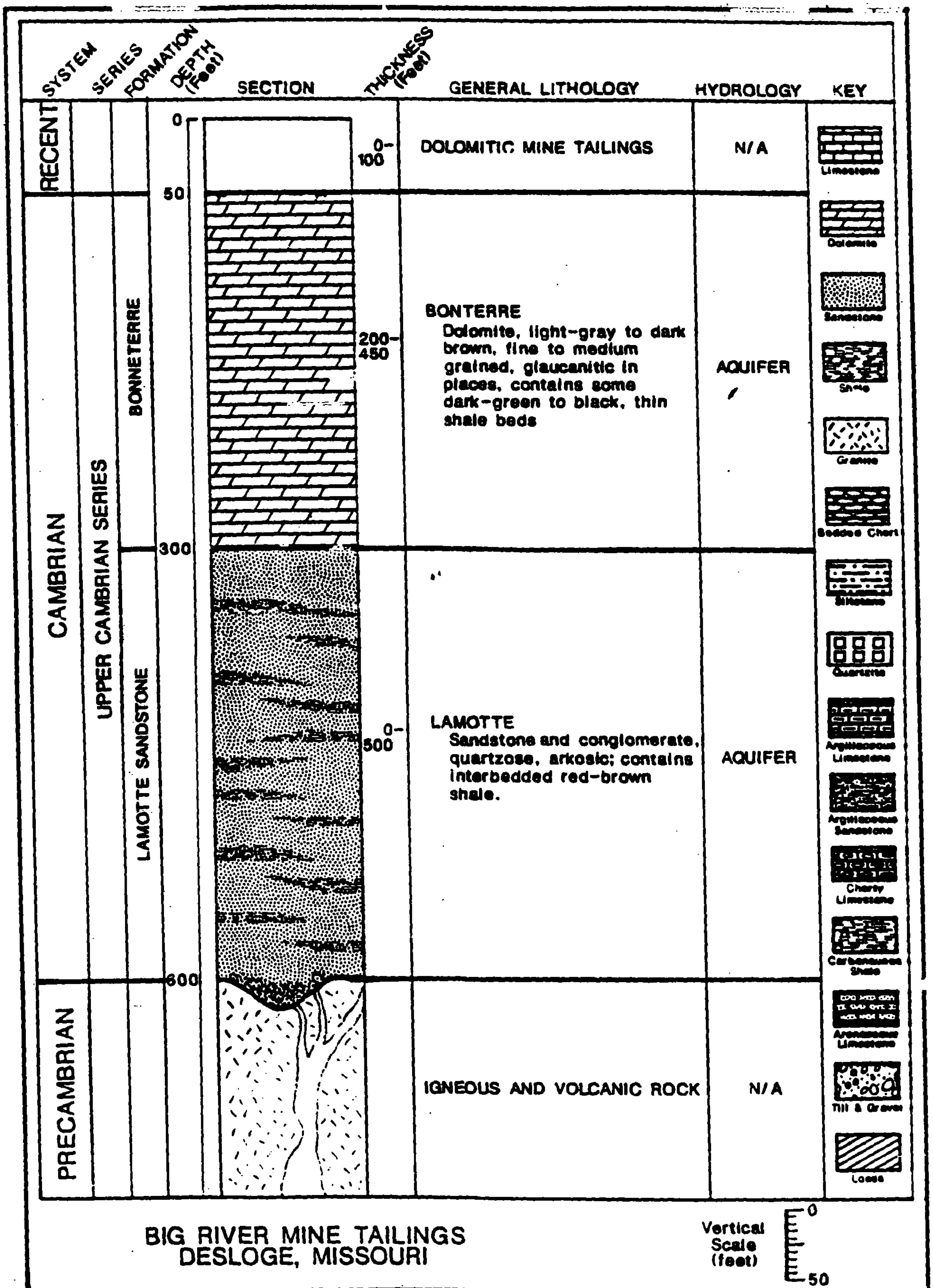
The site is underlain by Precambrian-age felsites and granites, which are overlain by rock units of the Upper Cambrian series (Buckley 1908; MDGSWR 1961). Figure 5-1 depicts the general stratigraphy of the site vicinity.

The Upper Cambrian Series rock units consist of in ascending order the Lamotte Formation; the Bonneterre Formation; the Elvins Group, which contains the Davis and Derby-Doerun formations, and the Potosi and Eminence formations. The Elvins Group and the Potosi and Eminence formations will not be considered in this report because they are topographically higher than the Big River Mine Tailings site (Buckley 1908; MDGSWR 1961).

The Lamotte Formation is predominantly a quartzose sandstone that grades laterally in many places into arkose and conglomerate (MDGSWR 1961). The formation is approximately 300 feet thick in the study area (Buckley 1908). The Lamotte aquifer is a regional drinking water source (MDGSWR 1983).

The Bonneterre Formation is typically a light-gray, medium to fine-grained, medium-bedded dolomite, although it consists of relatively pure limestone in some areas (MDGSWR 1961). The formation is approximately 350 feet thick in the study area and the principal source for the lead mining in the area that occurred in the late 19th and early to mid 20th centuries. The Bonneterre aquifer is also a regional drinking water source (MDGSWR 1983).

The area ground water aquifers that are topographically lower than the site are the Bonneterre and Lamotte formations. The Flat River Water District serves the towns of Desloge, Elvins, Flat River, Leadington, River Mines, and Ester, Missouri. The approximate population served is 11,000. The Big River Mine Tailings site is adjacent to the town of Desloge and is within two miles of Flat River. The Flat River Water District's water supply comes from the Bonneterre Formation via a sealed, abandoned mine shaft, located approximately two miles south of the site in River Mines, Missouri; and from the Lamotte Formation, via a



WASTE SITE TRACKING NO.: MO0616
PREPARED BY: C. WILLIAMS

ECOLOGY & ENVIRONMENT FIT APRIL 1988
SOURCE: MDGSWR 1961

Figure 5-1: Generalized Stratigraphic Column

well located approximately 3,000 feet east in Desloge, Missouri, that is pumped from 410 feet.

The typical shallow ground water flow around the site is assumed to be toward the river. Several springs around the site area flow into the Big River.

An unknown number of private drinking water wells are used in the area. The nearest drinking water well is located on site at the landfill office. This well is reported to be 216 feet deep. Sample results (sample 307) indicate that water from this well is also being influenced by the site (Section 7.3).

Other municipalities that use ground water for drinking and are within a four-mile radius of the site include Leadwood, Bonne Terre, and Terre DuLac. Table 5-2 lists information on municipal wells in the area.

Table 5-2
Municipal Ground Water Usage
in Four-Mile Radius
Big River Mine Tailings site
Desloge, Missouri

Water District	Munici-palities Served	Popu-lation Served	Well Identific-ation	Total Depth (feet)	Formation	Distance From Site
Flat River	Flat River Desloge Elvins Leadington Ester River Mines	4,443 3,581 1,548 238 1,038 414	#1 Sealed mine shaft #2	432 410	Bonneterre Lamotte	~ 2 miles 3000 ft.
Lead-wood	Leadwood Gumbo	1,371 ~ 90	#1 #2	700 790	Unknown Unknown	~ 2.5 miles ~ 2.5 miles
Bonne Terre	Bonne Terre E Bonneterre	3,797	#1 #2	746 720	Lamotte Lamotte	~ 1.5 miles ~ 1.5 miles
Terre DuLac	Terre DuLac	~2,000	#1 #2 #3	1,030.5	Unknown Unknown Unknown	~ 3.5 miles ~ 3.5 miles ~ 3.5 miles

Sources: Tille 1988; Hedgeworth 1988; Warren 1988; Johnson 1987a; Degonia 1988.

SECTION 6: FIELD ACTIVITIES

The Big River Mine Tailings LSI field work was conducted August 21 through 29, 1990. Sample series #CSXCR was assigned to all samples. The E & E/FIT members and their field assignments were: Bob Overfelt, team leader and sampler; Chris Williams, Site Safety Officer and sampler; Sharon Martin, sampler; Curt Enos, sampler and HRS information; Annette Sackmann, air sampling trainer; Otavio Silva, air sampler; Patty Roberts, air sampler; and Wes McCall, air sampler.

The field activities varied slightly from the work plan; the number of samples collected was increased substantially. Because of the size of the site and the other tailings piles in the surrounding area, it was necessary to increase the number of samples in order to fully characterize the site and help establish attribution.

Additional soil and tailings samples were added in order to characterize the soil at each Hi-vol air sampler location and to more accurately establish average background concentrations.

Sediment and surface water samples were added to help establish attribution. Therefore, several more samples were collected upgradient and downgradient of the site. Also, any major tributary that could contribute significantly to the water quality of Big River was sampled.

Additional ground water samples were taken to better characterize the shallow ground water on site and in the vicinity. The Geoprobe was used to install four temporary wells along the north perimeter of the site. Numerous springs were found and sampled along the river bank at the site. Some private wells adjacent to the site were also sampled.

The number of air samples was increased because one additional Hi-vol was used and the sampling period was extended from five to six days.

Additional Quality Assurance/Quality Control (QA/QC) samples were also submitted in order to meet the necessary requirements. All sampling was conducted in accordance with the Region VII E & E/FIT Quality Assurance Project Plan. All samples were submitted for total metals analyses. Water samples were also submitted for dissolved metals analyses. All samples were delivered to EPA Region VII Laboratory on July 30, 1990.

6.1 SOIL AND TAILINGS SAMPLING

Thirty samples were collected on site and in the surrounding area. Samples are summarized in Table 6-1, and locations are depicted on Plates 1 and 3. Fourteen tailings samples, including one duplicate, were collected on site. A soil sample was collected at each of the four off-site Hi-vol locations. Five background soil samples, including a duplicate, were collected from three locations several miles west of the site. Four soil samples were collected from three private residences and a day care center, all of which are within 1,500 feet of the southern site border. Four soil samples were collected at intermediate distances (one to two miles) around the site.

The majority of the samples (001 through 026 and 030) were composite samples consisting of five aliquots, one collected every 3 feet over a 15-foot linear distance. All of these samples were collected with a stainless steel spoon at a depth of 0 to 6 inches.

Samples 027, 028, and 029 were collected from a boring at surface sample location 009 at depths of 5 to 6 feet, 10 to 11 feet, and 15 to 16 feet, respectively. These samples were collected using the Geoprobe and the Probe-drive soil sampler.

6.2 SEDIMENT AND SURFACE WATER SAMPLING

Because sediment and surface water samples were collected concurrently at the same sampling location, they will be discussed together. Surface water samples were collected first to avoid introducing disturbed sediment into the water. There were 21 sampling locations, including one duplicate sample location; 22 surface water and 22 sediment samples were collected. Sediment samples are summarized in Table 6-2, and surface water samples are summarized in Table 6-3. Plates 2 and 3 illustrate the sampling locations. Two background locations on the Big River were sampled several miles upstream of the site: one on the tributary that drains the Leadwood tailings pile and one downgradient of the Leadwood tributary and upgradient of the site. Two locations were sampled on Owl Creek. Eight locations, including a duplicate, were sampled on Big River where the site borders the river. Five locations downgradient of the site on Big River were also sampled. A location was sampled on Flat River, Terre Bleue Creek, and Turkey

Table 6-1
Soil and Tailings Sample Summary
Big River Mine Tailings Site
Desloge, Missouri
E & E/FIT; July 1990
Sample Series CSXCR

Sample #	Location	Property Owner
001	From residence ~750 ft S of SW edge of site	Kennedy
*002	On site near center of river meander area	County
*003	On site in SW section of river meander area	County
*004	On site in W central section of river meander area	County
*005	On site in N central section of river meander area	County
*006	On site in NE section of river meander area at hi-vol 3 location	County
*007	On site in E central section of river meander section	County
*008	Duplicate of sample 007	County
*009	On site in SE section of river meander area	County
*010	On site in SE section of site	County
*011	On site S central section at hi-vol 4, near landfill office	County
012	Background ~4 miles W of site at hi-vol 7 location	Glore
013	~1 mile W/SW of site at hi-vol 6 location	Pratte
014	~1.25 miles E of site at hi-vol 5 location	Callahan
015	~1,500 ft E of site at hi-vol 1 and 2 locations	Wood
016	~2 miles W of site at SE corner of Leadwood Cemetery residence	Banks
017	Background ~6 miles NW of site and 0.25 mile S of Hwy. 47	Stoffel
018	Background ~4.5 miles NW of site in Terre Du Lac Development	Whitehead
019	Duplicate of sample 018	Whitehead
020	Background ~6 miles W of site ~1,000 ft NW of Huff Cemetery	Valley
*021	On site at leachate seep area at S edge of property near well DG-3	County
022	~100 ft S of site near landfill office	Kyle
023	~2 miles E of site and ~0.5 mile E of Big River/Flat River confluence	Bullock
024	~0.75 mile N of site and ~1 mile S of Bonne Terre	McDowell
025	~2,000 ft W of site near Murrill Cemetary	Weible
026	From Day Care Center playground ~1,500 ft S of site	Forrester
*027	On-site boring ~150 ft E of met station, 5 to 6 ft depth	County
*028	On-site boring ~150 ft E of met station, 10 to 11 ft depth	County
*029	On-site boring ~150 ft E of met station, 15 to 16 ft depth	County
030	~1,000 ft SE of site at SW corner of Oak and 8th streets Residence	Goff

* Tailings Sample

Note: All samples were composite samples consisting of five aliquots and were collected from a depth of 0 to 6 inches except samples 027, 028, and 029. These samples were collected with the Geoprobe from an on-site boring at varying depths. All samples were requested to be analyzed for total metals. See Plates 1 and 3 for sample locations. See Appendix C for addresses of property owners.

Table 6-2
Sediment Sample Summary
Big River Mine Tailings Site
Desloge, Missouri
E & E/FIT; July 1990
Sample Series CSXCR

Sample #	Location
100	Background from Big River at Hwy. U bridge ~0.5 mile W of Irondale
101	Background from Big River ~1 mile downstream of the Hwy. 8 and Big River intersection
102	From tributary to Big River that drains Leadwood tailings pile, taken N of Leadwood ~800 ft upgradient of Big River confluence (stainless steel spoon)
103	From Big River ~1 mile downstream of Leadwood river access
104	From Big River on W side of site at W bend in river ~600 ft downstream of W Desloge river access
105	From Big River on W side of site ~0.5 mile downstream of W Desloge river access
106	From Big River on NW side of site at swimming area
107	From Big River on NE side of site ~0.9 mile downstream of swimming area (collected with shovel)
108	From Big River on E side of site ~0.5 mile upstream of major collapse area
109	From Big River on E side of site where major collapse occurred in 1977
110	From Owl Creek on N side of abandoned RR spur (collected with spoon)
111	From Owl Creek ~30 ft upgradient of Big River confluence (collected with spoon)
112	From Big River ~3,500 ft downstream of major collapse area (collected with shovel)
112D	Duplicate of sample 112
113	From Big River ~1,500 ft upstream of the N Desloge river access (collected with shovel)
114	From Big River ~0.75 mile upstream of the Hwy. 67 bridge over Big River (collected with shovel)
115	From Flat River ~300 ft upgradient of the Big River confluence (collected with spoon)
116	From Big River ~5 miles downgradient of the site and ~2.75 miles downstream of Flat River confluence
117	From Turkey Creek ~1,500 ft upgradient of the Big River confluence (collected with spoon)
118	From Terre Bleue Creek ~750 ft upgradient of the Big River confluence (collected with spoon)
119	From Big River ~10 miles downstream of the site and ~2.5 miles downstream of the Hwy. K bridge
120	From Big River ~15 miles downstream of the site and ~0.5 mile upstream of the Hwy. E bridge

Note: All samples were composite samples consisting of three aliquots and collected from a depth of 0 to 6 inches. Samples were collected with an Eckman Dredge unless otherwise noted. All samples were requested to be analyzed for total metals. All samples were collected on the waterway or from public access points. A corresponding 200-series surface water sample was collected at every sediment location (Table 6-3). See Plates 2 and 3 for sample locations.

Table 6-3
Surface Water Sample Summary
Big River Mine Tailings Site
Desloge, Missouri
E & E/FIT; July 1990
Sample Series CSXCR

Sample #	Cond (μmhos)	pH	Temp (°C)	Location
200	170	6.96	24	Background from Big River at Hwy. U bridge ~0.5 mile W of Irondale
201	170	7.23	27	Background from Big River ~1 mile downstream of the Hwy. 8 bridge and Big River intersection
202	550	7.20	26	From tributary to Big River that drains Leadwood tailings pile, taken N of Leadwood ~800 ft upgradient of Big River confluence
203	200	7.48	25	From Big River ~1 mile downstream of Leadwood river access
204	290	7.27	23	From Big River on W side of site at W bend in river ~600 ft downstream of W Desloge River access
205	280	7.63	23	From Big River on W side of site ~0.5 miles downstream of W Desloge River access
206	260	7.42	25	From Big River on NW side of site at swimming area
207	380	7.33	28	From Big River on NE side of site ~0.9 mile downstream of swimming area
208	360	7.44	29	From Big River on E side of site ~0.5 mile upstream of major collapse area
209	370	7.45	29	From Big River on E side of site where major collapse occurred in 1977
210	550	7.33	18.5	From Owl Creek on N side of abandoned RR spur
211	245	7.60	26	From Owl Creek ~30 ft upgradient of Big River confluence
212	290	7.29	25	From Big River ~3,500 ft downstream of major collapse area
212D	290	7.29	25	Duplicate of sample 212
213	290	7.55	26	From Big River ~1,500 ft upstream of the N Desloge river access
214	350	7.31	23	From Big River ~0.75 mile upstream of Hwy. 67 bridge over Big River
215	550	8.0	23	From Flat River ~300 ft upgradient of the Big River confluence
216	340	7.26	27	From Big River ~5 miles downgradient of the site and ~2.75 miles downstream of Flat River confluence
217	650	7.58	23	From Turkey Creek ~1,500 ft upgradient of the Big River confluence

Table 6-3 (Continued)
Surface Water Sample Summary
Big River Mine Tailings Site
Desloge, Missouri
E & E/FIT; July 1990
Sample Series CSXCR

Sample #	Cond (µmhos)	pH	Temp (°C)	Location
218	205	7.34	27	From Terre Bleue Creek ~750 ft upgradient of the Big River confluence
219	315	7.46	25	From Big River ~10 miles downstream of the site and ~2.5 miles downstream of Hwy. K bridge
220	310	7.4	26	From Big River ~15 miles downstream of the site and ~0.5 mile upstream of the Hwy. E bridge

Note: All samples are requested to be analysed for total and dissolved metals. A corresponding 100-series sediment sample was collected at every surface water sample location (Table 6-2). All samples were collected on the waterway or from public access points. See Plates 2 and 3 for sample locations.

Creek, which are major Big River tributaries. For Hazard Ranking System (HRS) scoring purposes, the farthest downstream location was 15 miles from the site.

The sediment and surface water samples were either collected at public access points on the stream or from a johnboat.

The sediment samples were composite samples consisting of three aliquots, one collected every 5 feet over a 15-foot linear distance. Samples were collected using either an Eckman Dredge, a shovel, or a stainless steel spoon. Table 6-2 indicates if a tool other than the Eckman Dredge was used. A shovel was used when gravel on the river bottom prevented dredge use. A stainless steel spoon was used for some tributary samples.

After collection of surface water samples, specific conductivity, pH, and temperature were recorded in the field. The surface water samples were also preserved in the field to a pH <2 with 1:1 nitric acid, and then were placed in a cooler and iced to 4°C.

6.3 GROUND WATER SAMPLING

Ground water samples were collected from monitoring wells, springs, Geoprobe temporary wells, artesian wells, and private wells on site and in the vicinity. Twenty-one ground water samples were collected. Six quality assurance samples were also collected. Table 6-4 summarizes the ground water samples collected, and locations are depicted on Plates 2 and 3. Five springs, including one background spring, were sampled around the site perimeter. The background spring was located across the river from the site. Four samples were collected from Geoprobe temporary wells that were installed along the north perimeter of the meander area.

Two artesian wells located just west of the site near Owl Creek were sampled. According to AuBuchon, the artesian wells are former exploratory borings installed many years ago by St. Joe Minerals. Apparently the borings were never properly plugged after installation. Several of these pipes are present in the vicinity.

Two drinking water wells were sampled. A sample was collected from the on-site well located at the landfill office. A sample was collected from a private well at a residence located approximately 750 feet south

Table 6-4
Ground Water Sample Summary
Big River Mine Tailings Site
Desloge, Missouri
E & E/FIT; July 1990
Sampl Seri s CSXCR

Sample #	Well Depth	Cond (µmhos)	pH	Temp (°C)	Location
300	---	600	7.38	22	From spring on W boundary of site at W bend in river ~600 ft downstream of W Desloge River access
301	un-known	550	7.16	17	From artesian well ~25 ft E of W bank of Owl Creek and ~50 ft N of abandoned RR spur
302	---	600	7.25	28	From spring on NE boundary of site ~0.75 mile upstream of major collapse area
303	---	1,100	7.07	28	From spring on E boundary of site at major collapse area
304	---	600	7.57	25	From spring on E arm boundary of site ~0.75 mile downstream of major collapse area
305	---	2,100	10.62	21	From tributary to Big River carrying effluent from RESCO products, taken ~500 ft downstream of N Desloge River access
306	---	1,400	7.39	25	From leachate seep area at S central boundary of site near well DG-3
307	216	550	6.92	17	From landfill office well, SWL ~63 ft
308	200-300	680	6.97	18	From private well at Kennedy residence ~750 S of SW edge of site
309	10.75	1,400	6.56	18	From on-site MW DG-5 at E bend in river, SWL was 4.25 ft
309D	10.75	1,400	6.56	18	Duplicate of sample #309
310	37.5	900	6.78	15	From on-site MW UG-1 N of landfill in S central river meander area, SWL was 26 ft
311	45.75	1,100	6.56	17	From on-site MW DG-3 at S border of site, SWL was 44.5 ft
312	30.5	700	6.45	16	From on-site MW DG-2, E of landfill SWL was 25.5
314	9	470	7.15	25	From on-site Geoprobe-TW on W side of meander area near pond, SWL was 7 ft
315	12	420	7.05	25	From on-site Geoprobe-TW on NW side of meander area, SWL was 9 ft
316	12	600	6.93	20	From on-site Geoprobe-TW on N side of meander area, SWL was 9 ft
317	12	700	7.11	20	From on-site Geoprobe-TW on NE side of meander area, SWL was 9 ft
318	---	550	7.04	17	From background spring on opposite river bank from site at the W bend in river
319	---	650	7.54	19	From NW end of drainage tunnel ~300 ft SE of W Desloge River access
320F	---	---	---	---	Trip Blank (total metals only)
321F	---	---	---	---	Field Blank
322F	---	---	---	---	Field Blank
323F	---	---	---	---	Rinsate of disposable Teflon bailers
324	un-known	700	7.10	15	From artesian well ~20 ft E of Owl Creek and 100 ft S of Owl Creek and Big River confluence
324F	---	---	---	---	Rinsate of Geoprobe pipe
325F	---	---	---	---	Acid Blank (total metals only)

MW = monitoring well;
TW = temporary well;
SWL = Static Water Level (measured from top of protective steel casing of MW).

Note: All samples are requested to be analyzed for total and dissolved metals except for samples 320F and 325F, which were submitted for total metals only. All samples were collected on site or from the river waterway, except for sample 308 which was taken from the Kennedy residence. Sample 313 was not used. Sample 305 was believed to be a small spring when sampled, but it was later discovered to be a small tributary. See Plates 2 and 3 for sample locations.

of the site.

While on site, it was discovered that a drainage tunnel exists beneath the site. The tunnel extends from an opening located approximately 300 feet southeast of the landfill office and trends southeast/northwest to an exit opening near the west Desloge River access. The tunnel is approximately 1,500 feet long. The E & E/FIT learned from AuBuchon that the tunnel was built by St. Joe Minerals and was used to divert surface water drainage from a tributary to Big River. The E & E/FIT sampled a leachate seep that drains into the southeast entrance of the tunnel and also collected a sample from where water exits at the northwest end of the tunnel before it enters Big River.

Ground water sample 305 initially appeared to be a spring when it was sampled; however, it was determined later to be a small tributary to Big River. The tributary drains part of the RESCO Products property. The water appeared very turbid and white in color and had a pH of 10.62. This tributary is apparently being influenced by operations at the RESCO Products property. It is known that a large quarry exists on the RESCO property.

Five ground water samples, including one duplicate, were collected from four of the six monitoring wells. Two of the monitoring wells were dry. The following table lists information regarding the monitoring well sampling.

Monitoring Well Information

Well #	Total Depth	Depth to Static Water Level (ft)	Water Height (ft)	Volume Purged (gal)	Sample #
UG-1	37.5	26	11.5	3.5	310
DG-1	Dry	--	--	--	--
DG-2	30.5	25.5	5	1.5	312
DG-3	47.75	44.5	1.25	0.3	311
DG-4	Dry	--	--	--	--
DG-5	10.75	4.25	6.5	4.5	309, 309D

The monitoring wells were purged using disposable polyethylene bailers. The wells were purged of three volumes or until dry. After purging, the wells were allowed to recharge for approximately 24 hours before sampling. The bailers were rinsed with deionized water before sampling.

Immediately after collection of ground water samples, specific conductivity, pH, and temperature were recorded (Table 6-4). The ground water samples were preserved to a pH <2 with 1:1 nitric acid, and then were placed in a cooler and iced to 4°C.

Six QA/QC samples were submitted: two field blanks, a trip blank, an acid blank, a rinsate sample of a bailer, and a rinsate sample of Geoprobe pipe.

6.4 AIR SAMPLING

The E & E/FIT performed a general reconnaissance of the site and surrounding area on July 21, 1990, and determined placement of the Hi-vol air samplers. Six locations were chosen. On July 22, 1990, seven Hi-vol samplers were set up (Plate 1). One location had co-located Hi-vols in order to collect a replicate sample. Six of the Hi-vols were powered by 3,500 watt, gasoline-powered generators, and one Hi-vol, located just north of the landfill office, was plugged into an electrical outlet. Two Hi-vols were placed on site, and five were placed off site. One Hi-vol was set up on the north end of the site, and one was set up at the landfill office area where daily traffic can be heavy. Three Hi-vols, in two locations, were set up to the east in a downwind direction. The predominant wind direction transporting tailings in the area was determined to be from the west to the east with some southwest and northwest influence. One Hi-vol was set up to the west in between the Leadwood tailings pile and the site. One remote background Hi-vol was set up to the west of the site and to the northwest of the Leadwood tailings pile. The locations of the Hi-vols are as follows:

- Hi-vol 1 and 2 - Across Big River approximately 1,500 feet east of the site.
- Hi-vol 3 - On site in the northeast section of the river meander area.

- Hi-vol 4 - On site in southwest section approximately 150 feet north of landfill office.
- Hi-vol 5 - Approximately 1.25 miles east of the site, near Hwy. 67 and Big River intersection.
- Hi-vol 6 - Approximately 1 mile west-southwest of the site, between Leadwood pile and the site.
- Hi-vol 7 - Approximately 4 miles west of the site.

All Hi-vol locations are illustrated on Plates 1 and 3. The Hi-vol samplers were placed on stands, making them 6 feet above the ground surface in order to characterize the air quality in the breathing zone.

A Campbell Scientific Portable Meteorological Station was placed on site in the south section of the meander area (Plates 1 and 3). The station continuously collected wind speed, wind direction, temperature, relative humidity, and barometric pressure.

The Hi-vol samplers were operated for approximately 12 hours each day for six consecutive days. The samplers were run for the 12-hour period of noon to midnight to accommodate diurnal changes.

Forty-seven air samples, including a field blank for each day, were collected from six locations over a six-day sampling period (Table 6-5). Sampling began on July 23, 1990, and ended on July 28, 1990. A sample was not collected from Hi-vol 5 on July 23, 1990, because the Hi-vol was not functioning properly. Sample 406 was submitted for analysis; however, it cannot be used as comparable data because the sampler ran for 24 hours due to a timer malfunction. All air samples were submitted for total metals analyses.

Table 6-5
Air Sample Summary
Big River Mine Tailings
Desloge, Missouri
E & E/FIT; July 1990
Sample Series CSXCR

Sample #	Location	Date Collected	Property Owner
400	Hi-vol #1	7-23-90	Wood
402	Hi-vol #2	7-23-90	Wood
403	Hi-vol #3	7-23-90	County
404	Hi-vol #4	7-23-90	County
*405	Hi-vol #5 (not submitted)	7-23-90	-----
*406	Hi-vol #6	7-23-90	Pratte
407	Hi-vol #7	7-23-90	Glore
408	Field Blank	7-23-90	-----
409	Hi-vol #1	7-24-90	Wood
410	Hi-vol #2	7-24-90	Wood
411	Hi-vol #3	7-24-90	County
412	Hi-vol #4	7-24-90	County
413	Hi-vol #5	7-24-90	Callahan
414	Hi-vol #6	7-24-90	Pratte
415	Hi-vol #7	7-24-90	Glore
416	Field Blank	7-24-90	-----
417	Hi-vol #1	7-25-90	Wood
418	Hi-vol #2	7-25-90	Wood
419	Hi-vol #3	7-25-90	County
420	Hi-vol #4	7-25-90	County
421	Hi-vol #5	7-25-90	Callahan
422	Hi-vol #6	7-25-90	Pratte
423	Hi-vol #7	7-25-90	Glore
424	Field Blank	7-25-90	-----
425	Hi-vol #1	7-26-90	Wood
426	Hi-vol #2	7-26-90	Wood
427	Hi-vol #3	7-26-90	County
428	Hi-vol #4	7-26-90	County
429	Hi-vol #5	7-26-90	Callahan
430	Hi-vol #6	7-26-90	Pratte
431	Hi-vol #7	7-26-90	Glore
432	Field Blank	7-26-90	-----
433	Hi-vol #1	7-27-90	Wood
434	Hi-vol #2	7-27-90	Wood
435	Hi-vol #3	7-27-90	County
436	Hi-vol #4	7-27-90	County
437	Hi-vol #5	7-27-90	Callahan
438	Hi-vol #6	7-27-90	Pratte
439	Hi-vol #7	7-27-90	Glore
440	Field Blank	7-27-90	-----
441	Hi-vol #1	7-28-90	Wood
442	Hi-vol #2	7-28-90	Wood
443	Hi-vol #3	7-28-90	County
444	Hi-vol #4	7-28-90	County
445	Hi-vol #5	7-28-90	Callahan
446	Hi-vol #6	7-28-90	Pratte
448	Hi-vol #7	7-28-90	Glore
449	Field Blank	7-28-90	-----

* Because of Hi-vol malfunctions, these samples will not be used.

Note: All samples were requested to be analyzed for total metals. The high volume samplers were run for a 12-hour sample period from 1200 hours to 2400 hours for each sample. Sample numbers 401 and 447 were not used. See Plates 1 and 3 for sample locations.

SECTION 7: ANALYTICAL RESULTS

In general, the analytical data results from the Big River Mine Tailings site were acceptable. However, some data were coded.

<u>Data Qualification Code</u>

U = The material was analyzed for but was less than the measurement detection limit. The associated number is the detection limit.

J = The data are reported but are not valid by approved QC procedures. The numerical value is an estimated quantity.

I = The sample data are invalid. No value is reported.

The complete explanation for coded data is included in Appendix D with the data transmittal.

7.1 SOIL AND TAILINGS

The metals of primary concern in the soil and tailing samples are arsenic, cadmium, cobalt, lead, nickel, and zinc. The presence and concentrations of these metals will be discussed in this section; the analytical results are summarized in Table 7-1. The complete data transmittal is included in Appendixes D and E.

Because the site is located in the Old Lead Belt, it is difficult to establish background concentrations for natural soils. It is known that in this area, tailings have been used for agricultural lime on fields, mixed in asphalt for paving roads, spread on gravel roads, and used for fill material. These practices all are mechanisms for the dispersal of contaminants. Aeolian influences also spread contamination as metals-laden dust and tailings are deposited on downgradient soils via wind erosion. Howard Wood, property owner of the farm adjacent to the east side of the site, stated during the LSI that he has never had to lime his fields because of the tailings material that has been deposited on his property via wind erosion. Another reason that background concentrations may be difficult to establish is that the Bonneterre Formation underlying the site contains heavy metal

Table 7-1
Selected Metals in Soil and Tailings Samples
Big River Mine Tailings Site
Desloge, Missouri
E & E/FIT: July 1990
Sample Series CSXCR

Sample (mg/kg)	Arsenic	Cadmium	Cobalt	Lead	Nickel	Zinc
*001	6.3	1.2U	14	130 J	9.4U	65
*002	14	21	13	1000 J	18 J	950
*003	7.7	14	11	1100 J	15 J	570
*004	8.1	20	11U	1400 J	8.5 U	840
*005	8.6	8.4	14	930 J	15 J	370
*006	9.6	19	27	1500 J	20 J	870
*007	9.4	28	15	1700 J	12 J	1200
*008	2.1U	30	13	1600 J	14 J	1300
*009	9.7	13	12	1300 J	16 J	610
*010	14	79	42	13000 J	37 J	4300
*011	6.5	24	10 U	970 J	9.0 J	1200
b-012	9.3	1.3 U	16	65 J	10 U	35
013	6.9	1.2 U	15	450 J	9.6 U	42
014	6.2	1.3 U	16	85 J	17 J	57
015	8.2	3.2	16	370 J	11 J	180
016	13	6.0	13 U	940 J	10 U	490
b-017	9.5	1.2 U	14	64 J	9.5 U	66
b-018	7.2	4.8	16	1500 J	12 J	370
b-019	6.8	5.3	18	1600 J	12 J	390
b-020	6.2	1.2 U	12 U	76 J	9.4 U	67
*021	2.3 U	16	19	1500	20	760 J
022	2.2 U	270	16	650	8.8 U	13000 J
023	2.1 U	2.1	12	190	15	140 J
024	2.3 U	1.2 U	12 U	99	9.2 U	98 J
025	3.1 U	1.6	18	130	12 U	53 J
026	2.3 U	25	13	1300	9.6	1100 J
*027	2.4 U	11	38	2500	36	630 J
*028	2.1 U	10	10 U	1600	9.5	510 J
*029	7.0 J	11	11 U	910	9.1 U	510 J
030	7.6 J	7.9	23	2200	21	430 J

b = Background Sample
* = Tailings Sample
J = Data reported but not valid by approved QA/QC procedures
U = Less than measurement detection limit, the associated number is the detection limit.

Note: See Table 1 and Plates 1 and 3 for sample locations and the data transmittal in Appendix D for complete analytical results.

mineralization (lead ore) outcrops. Some surface soils in the area were formed from weathered Bonneterre and may naturally contain elevated concentration of metals. These factors were all taken into account when off-site sampling was conducted. An attempt was made to sample only soil that visually appeared to be indigenous and not influenced by road construction, fill activities, or other artificial interferences.

Five background samples, including a duplicate, were collected from several miles west of the site in areas where influence from wind erosion and deposition from the site or the Leadwood tailings pile would be minimal. Three of these samples (012, 017, and 020) were collected from pastureland, and two samples (018 and 019), including the duplicate, were collected from a residence in the Terre Du Lac subdivision. The three samples collected from pastureland had mean concentrations of 8.3 mg/kg arsenic, 10 mg/kg cobalt, 68.3J mg/kg lead, and 56 mg/kg zinc. Nickel and cadmium were undetected. (Note: A J code will only be associated with the mean value if a significant amount (>25%) of the data used to calculate the mean are J-coded.) However, the samples collected at the Terre Du Lac residence (018 and 109) had elevated concentrations of most metals with means of 7.0 mg/kg arsenic, 5.05 mg/kg cadmium, 17 mg/kg cobalt, 1,550 J mg/kg lead, 12 J mg/kg nickel, and 380 mg/kg zinc. Because the location where samples 018 and 019 were collected is not undisturbed soil, they are not comparable to the pastureland samples; therefore, the samples will not be considered representative of background conditions.

Fourteen tailings samples, including a duplicate, were collected from ten locations on site to characterize the level of metals concentrations in the surface (0-6") of the pile. However, three subsurface tailings samples (027, 028, and 029) were collected at one location (surface sample 009 location) in order to characterize the subsurface. The ranges and mean concentrations of metals in the tailings samples on site are arsenic ranging from undetected to 14 mg/kg; 7.6 mg/kg mean; cadmium ranging 8.4 to 79 mg/kg, 21.7 mg/kg mean; cobalt ranging undetected to 42 mg/kg, 15.4 mg/kg mean; lead ranging 910 to 13,000 J mg/kg, 2,215 J mg/kg mean; nickel ranging undetected to 37 J mg/kg, 15.8 J mg/kg mean; zinc ranging 370 to 4,300 mg/kg, 1,044 J mg/kg mean. It should be noted that sample 010 collected from the east area of the site, contained the highest concentrations of metals and significantly raised the mean concentrations. In a study performed by UMR, in which 74 surface tailings samples were collected over the entire tailings site, the mean lead concentration was 2,077 mg/kg, the mean cadmium concentration was 26 mg/kg, and the mean zinc concentration was 1,226 mg/kg (Wixon 1983). Therefore, the mean values established from the LSI sampling are similar to the UMR study. When comparing the background concentrations of cadmium, lead, nickel, and zinc in soil to the tailings, it is obvious that the tailings contain extremely elevated concentrations of these metals. The arsenic and cobalt concentrations do not appear to be significantly elevated in the tailings when compared to background concentrations. Arsenic and cobalt concentrations are discussed herein because ground water samples collected on site exhibited elevated levels of these metals.

The four subsurface tailings samples (009, 027, 028 and 029) were collected at 0 to 6 inches, 5 to 6 feet, 10 to 11 feet, and 15 to 16 feet, respectively. Concentrations of cobalt, lead, and nickel increased significantly from the 0 to 6 inches to the 5- to 6-foot interval. The following concentrations were reported:

Sample #	Depth (feet)	Cobalt (mg/kg)	Lead (mg/kg)	Nickel (mg/kg)
009	0-.5	12	1,300 J	16 J
027	5-6	38	2,500	36
028	10-11	10 U	1,600	9.5
029	15-16	11 U	910	9 U

At the 10- to 11- and 15- to 16-foot intervals, metal concentrations appear to return to values similar to or less than the concentrations reported in surface sample depths. This could indicate that these metals have migrated down from the upper five feet, resulting in even higher concentrations at this depth. However, much more sampling and characterization of the subsurface is needed to draw any definitive conclusions. Arsenic and zinc concentrations did not vary significantly with depth.

Soil or tailings samples were collected at each Hi-vol air sampler location in order to establish metals concentrations at those locations and to verify a zone of influence in which the deposition of tailings via wind erosion occurs. Additional samples were also collected from each direction surrounding the site to aid in the determination of this zone of influence.

Hi-vol sampler location 3 (sample 006) and Hi-vol sampler 4 (sample 011), both located on the tailings have been considered in the tailings results discussion. Also, Hi-vol sampler location 7 (sample 012) has been discussed as a background.

Based on the limited sampling conducted, the most significant area of influence from the site appears to be toward the east and southeast. The nearest resident is approximately 100 feet south of the site on the southwest edge where sample 022 was collected. Results from sample 022 indicated 270 mg/kg cadmium, 16 mg/kg cobalt, 650 mg/kg lead, and 13,000 J mg/kg zinc. These are the highest cadmium and zinc concentrations of any soil or tailings sample collected. Arsenic and nickel were reported as undetected. Results from a sample (026) collected from a day care center playground located approximately 1,500 feet south of the site detected cadmium at 25 mg/kg, cobalt at 13 mg/kg, lead at 1,300 mg/kg, nickel at 9.6 mg/kg, and zinc at 1,100J mg/kg. Arsenic was undetected. Sample 030 was collected approximately 1,000 feet south of the site at a private residence and results indicate 7.6 J mg/kg arsenic, 7.9 mg/kg cadmium, 23 mg/kg cobalt, 2,200 mg/kg lead, 21 mg/kg nickel, and 430 J mg/kg zinc. The two residential samples and the day care center sample have very high concentrations of lead, cadmium, and zinc that are comparable to concentrations found in tailings samples. Therefore, it can be concluded that this area south of the site has been and is currently being influenced by the site.

Sample 015 was collected approximately 1,500 feet east of the site at the co-located Hi-vol sampler locations 1 and 2. Results from sample 015 found arsenic at 8.2 mg/kg, cadmium at 3.2 mg/kg, cobalt at 16 mg/kg, lead at 370 J mg/kg, nickel at 11 J mg/kg, and zinc at 180 mg/kg. The elevated levels of lead, cadmium, and zinc at this location also indicate that this area east of the site is being influenced by the site. Sample 014 was collected at Hi-vol sampler location 5, approximately 1.25 miles east of the site, and sample 023 was collected approximately two miles east of the site to determine if the soils in these areas have been influenced by the site. Lead concentrations in samples 014 and 023 were 85 J mg/kg and 190 mg/kg, respectively. These lead concentrations are relatively low in comparison to the tailings samples. Other metals of concern were also found at relatively low concentrations. Results of samples 014 and 023 indicate that the soils are not significantly influenced at these locations.

Soil samples 001, 025, and 024 were collected approximately 750 feet southwest of the site, approximately 2,000 feet west of the site and approximately 0.75 miles north of the site, respectively. The concentrations of metals of concern in these three samples are not significantly above background. Therefore, it appears that the soils on the west and north sides have not been influenced at the sampling locations. Perhaps if more soil sampling was performed within a few hundred feet of the site, an area of influence could be established; however, much more sampling would be required to accurately define the entire zone of influence.

Two samples (016 and 013) were collected at locations between the Leadwood tailings pile and the site. These samples were reported to contain lead at 450 J mg/kg in 013, and at 940 J mg/kg in 016. Other metals of concern were also significantly elevated. This could be the result of natural conditions or tailings deposition via wind erosion from the Leadwood pile. However, it is most likely attributable to transport of tailings to that location for fill or construction purposes. Sample 016 was collected at a cemetery where tailings may have been used for fill. Sample 013 was taken in a pasture adjacent to a newly constructed residence where tailings were used as base for part of the drive.

A total of 30 soil or tailing samples were collected to establish background concentrations, determine concentrations present in the on-site tailings, and characterize an area or zone of influence where tailings have migrated off site via wind erosion and elevated the concentrations of metals in the soils. Establishing natural background concentrations in this area of regional mining activity and widespread varied usage of tailings is difficult. However, three samples from apparently undisturbed soil in pastures west of the mining area contained consistently low levels of lead and other heavy metals. The 14 tailing samples collected on site confirmed the presence of elevated levels of lead (up to 13,000 J mg/kg). Samples of soil collected from around the site indicate that the soils to the south and east at distances of at least 1,500 feet from the site are being influenced most significantly. Off-site areas exhibiting elevated levels of metals include lawns of private residences and a playground of a day care center.

7.2 SEDIMENT AND SURFACE WATER

It should be emphasized that the heavy metals contamination associated with the area near the site is a regional problem. Consequently, a limited regional sampling plan of surface water and sediment was implemented in order to assess the relative impact of the Big River Mine Tailings site on the Big River. The sampling plan was designed to establish attribution of heavy metals contamination from the major tributaries that drain tailing-contaminated basins into Big River. To achieve this objective, background sampling began approximately 16.5 miles upstream of the site location and continued to approximately 15 miles downstream of the site. The discussion of the sample results will begin at the furthest upstream location and consider the impact of the regional mining wastes as the Big River progresses downstream.

Sediment and surface water samples were collected concurrently at the same location; therefore, data results of both media will be discussed together. Metals of concern in the sediment include arsenic, cadmium, cobalt, lead, nickel, and zinc. Cadmium, lead, and zinc are the primary and most widespread contaminants in the sediment while arsenic, cobalt, and nickel were found generally at much lower concentrations but occur at elevated concentrations sporadically. These metals will only be discussed when elevated levels are found. Lead and zinc were the only metals of concern found at elevated levels in the surface water. Tables 7-2 and 7-3 list the selected heavy metal results found in the sediment and surface water, respectively. Sediment samples have 100-series numbers, and surface water samples are assigned the corresponding 200-series number. A total of 21 locations, including a duplicate, were sampled for sediment and surface water.

Two background sample locations (100, 200 and 101, 201) upgradient of any mining wastes were collected from Big River. Refer to Plates 2

Table 7-2
Selected Metals in Sediment Samples
Big River Mine Tailings Site
Desloge, Missouri
E & E/FIT; July 1990
Sample Series CSXCR

Sample (mg/kg)	Arsenic	Cadmium	Cobalt	Lead	Nickel	Zinc
*100	4.4 J	1.1 U	11 U	1.1 U	9.0 U	21 J
*101	5.5 J	1.1 U	11 U	1.4	9.1 U	53 J
102	2.5 U	140	12 U	10,000	9.8 U	6,500 J
103	30 J	46	13 U	720	10 U	1,900 J
104	2.2 U	130	11 U	5,500	8.9 U	6,600 J
105	6.2 J	21	11 U	1,700	10	840 J
106	8.3 J	42	12 U	1,600	9.3 U	2,200 J
107	9.0 J	88	12 U	3,600	12	4,500 J
108	2.2 U	59	11 U	1,300	9.6	2,600 J
109	6.4 J	24	12 U	1,300	13	1,100 J
110	5.5	32	52	540	59	1,900
111	6.7	6.3	10 U	350	13	400
112	11	63	13 U	3,100	12	3,300
112D	6.4	120	12 U	3,400	9.8 U	6,700
113	18	16	12 U	2,500	12	810
114	7.9	28	12 U	3,800	11	1,800
115	21	18	16	3,500	18	970
116	7.1	14	12	1,200	13	1,000
117	11	37	44	8,700	58	1,500
*118	2.2 U	1.0 U	10 U	4.4	5.8	7.7U
119	5.5 J	6.1	11 U	610	13	370
120	4.5 U	3.7 U	1.1 U	680	8.6 U	290

* Background Sample
J - Data reported but not valid by approved QC procedures
U - Less than measurement detection limit, the associated number is the detection limit.

Note: See Plates 2 and 3 for sample locations and the data transmittal in Appendix D for complete analytical results. A corresponding 200-series surface water sample was collected at every sediment location (Table 7-3).

Table 7-3
Selected Metals in Surface Water Samples
Big River Mine Tailings Site
Desloge, Missouri
E & E/FIT; July 1990
Sample Series CSXCR

Sample (µg/l)	Lead		Zinc	
	Total	Dissolved	Total	Dissolved
* 200	3.0 U	3.0 U	20 U	20 U
* 201	3.0 U	3.0 U	74	20 U
202	61	23	1,300	1,200
203	15	3.0 U	44	20 U
204	37	3.3 U	81	44
205	29	3.0 U	74	41
206	32	3.0 U	84	56
207	34	3.9 U	100	68
208	33	4.0	98	68
209	31	4.5	98	86
210	6.0	3.0 U	42	20 U
211	26	3.0 U	62	34 U
212	29	4.4	120	100
212 D	28	4.8	130 U	99
213	30	5.4	130	110
214	27	5.7	150	130
215	32	16	120	130
216	49	9.5	130	100
217	22	11	34 U	31 U
* 218	3.0 U	3.0 U	20 U	20 U
219	26 J	8.2 J	91	62
220	49 J	11 J	70	39

* Background Samples
J - Data reported but not valid by approved QA/QC procedures
U - Less than measurement detection limit, the associated number is the detection limit.

NOTE: See Plates 2 and 3 for sample locations and the data transmittal in Appendix D for complete analytical results. A corresponding 100-series sediment sample was collected at every surface water sample location (Table 7-2).

and 3 for sample locations. Samples 100 and 200 were collected approximately 16.5 miles upstream of the site near Irondale, Missouri. Sediment sample 100 contained arsenic at 4.4 J mg/kg and zinc at 21 J mg/kg; cadmium, cobalt, lead, and nickel were undetected. No metals of concern were detected in surface water sample 200. Samples 101 and 201 were collected approximately 9.7 miles upstream of the site. Sample 101 contained arsenic at 5.5 J mg/kg, lead at 1.4 mg/kg and zinc at 53 J mg/kg with cadmium, cobalt, and nickel reported below detection limits. Only total zinc at 74 µg/l was found in surface water sample 201. These samples indicate the very low metals concentrations found in the Big River upgradient of the mining district.

The tributary that drains the Leadwood Tailings pile to Big River is the farthest major tributary upstream that contributes a significant amount of metals contamination to Big River (Plate 2). Samples 102 and 202 were collected from this tributary approximately 800 feet upgradient of its Big River confluence. Sediment sample 102 contained high concentrations of cadmium at 140 mg/kg, lead at 10,000 mg/kg, and zinc at 6,500 J mg/kg. Surface water sample 202 contained 61 µg/l total and 23 µg/l dissolved lead, as well as 1,300 µg/l total and 1,200 µg/l dissolved zinc. The next downstream location sampled on Big River (103,203) was located approximately halfway between the Leadwood tributary confluence and the Owl Creek confluence with Big River. Sediment results of sample 103 detected 30 J mg/kg arsenic, 46 mg/kg cadmium, 720 mg/kg lead, and 1,900 J mg/kg zinc. Surface water sample 203 contained 15 µg/l total lead and 44 µg/l total zinc with no detects in the dissolved metals analysis. The elevated metals in the sediment and the elevated total lead in the surface water at this location on Big River is directly attributable to the Leadwood tributary.

Owl Creek is the next tributary along the river that contributes some heavy metal contamination. Its confluence with Big River is approximately 500 feet upgradient of the Big River tunnel discharge confluence (See Plate 3). Owl Creek does not directly drain a tailings pile; however, it does contain tailings in its sediment. The source of these tailings appears to be an abandoned railroad spur which crosses Owl Creek just southwest of the site (See Plate 3). The railroad bed is constructed primarily of tailings, some of which have apparently eroded and entered Owl Creek. Two locations were sampled along Owl Creek. Samples 110 and 210 were collected just north (downgradient) of the abandoned railroad spur. Sediment sample 110 contained arsenic at 5.5 mg/kg, cadmium at 32 mg/kg, cobalt at 52 mg/kg, lead at 540 mg/kg, nickel at 59 mg/kg, and zinc at 1,900 mg/kg. Surface water sample 210 contained 6.0 µg/l total lead and 42 µg/l total zinc. Samples 111 and 211 were collected on Owl Creek approximately 30 feet upgradient of the Big River confluence. Concentrations of metals in sediment sample 111 were much less than sample 110 with arsenic at 6.7 mg/kg, cadmium at 6.3 mg/kg, cobalt undetected, lead at 350 mg/kg, nickel at 13 mg/kg, and zinc at 400 mg/kg. Surface water sample 211 detected total lead at 26 µg/l and total zinc at 62 µg/l. The metals concentrations in sediment sample 110 are probably higher because it was taken adjacent to the railroad spur where tailings directly enter Owl Creek. The metals concentrations in the Owl Creek water are probably higher near the confluence of Big River due to the significant amount of ground water entering Owl Creek directly from the numerous artesian wells along its east bank. Water from these wells contains elevated concentrations of metals. Results of the artesian well samples are discussed in Section 7.3 and are listed in Table 7-4. Although Owl Creek does contribute heavy metals to Big River, a comparison of its sediment and surface water metal content suggests it is only a minor contributor.

The previously discussed tunnel that runs under the site and discharges near the West Desloge River Access is the next contributor of tailings, surface water, ground water, and landfill leachate to the Big River. The water, leachate, and sediment (tailings) at the entrance and at the exit opening were sampled and found to contain elevated levels of metals. Sample 021 was collected from the entrance of the tunnel and is discussed in Section 6.1. No sediment was available at the tunnel exit; therefore, no sample was collected. Leachate samples 306 and 319 collected at the entrance and exit openings of the tunnel, respectively, are discussed in Section 7.3.

In an interview with landfill manager Bryant Aubuchon, the E & E/FIT learned that this tunnel transports a significant amount of tailing and surface water into Big River during major storm events. Also landfill leachate constantly flows into the tunnel. It is also assumed that some ground water is discharged through the tunnel. A thorough reconnaissance of this tunnel is needed to determine if any other significant seeps are present or whether any other tunnels drain into it. This tunnel is potentially one of the major sources of contaminants entering the river.

Samples 104 and 204 were collected on Big River approximately 400 feet downstream of the tunnel discharge confluence. These samples were also collected upgradient of any areas around the site where tailings are directly in contact with the river or are entering it via water erosion. Results of sediment sample 104 detected a significant increase of metals with 130 mg/kg cadmium, 5,500 mg/kg lead, and 6,600 J mg/kg zinc. Surface water sample 204 contained 37 µg/l total lead, undetected dis-solved lead, 81 µg/l total zinc, and 44 µg/l dissolved zinc. This sig-nificant increase in heavy metals in the Big River sediment and surface water directly downgradient of the tunnel discharge strongly suggests the tunnel as the source. Additionally, the extremely high concentrations of dissolved zinc found in the leachate seep at the tunnel entrance and in the water at the tunnel exit may be attributable to the first elevated dissolved zinc concentrations in Big River in sample 204.

A total of eight samples, including a duplicate, were sampled at seven locations on the river and around the tailings pile. It should be noted that during the sampling of the Big River numerous areas where tailings are in contact with the river and are easily transported into the river via water erosion were observed. The major areas that were observed are illustrated on Plate 3. Also, numerous ground water seeps or springs originating from the tailings were observed draining directly into Big River. Four of these seeps were sampled and found to contain elevated metals. The seep sample results are discussed in Section 7.3. The range and mean values of the metals of concern in the eight sediment samples (104, 105, 106, 107, 108, 109, 112, and 112D) collected on the Big River adjacent to the site are: arsenic, undetected to 11 mg/kg, 5.9 J mg/kg mean; cadmium, 21 mg/kg to 130 mg/kg, 68.4 mg/kg mean; lead, 1,300 mg/kg to 5,500 mg/kg, 2,687 mg/kg mean; nickel, undetected to 13 mg/kg, 7.1 mg/kg mean; zinc, 840 J mg/kg to 6,700 mg/kg, 3,480 J mg/kg mean. After comparing upstream sediment samples with the extremely elevated concentrations in these samples, it is obvious that the Big River Mine Tailings site is affecting the benthic zone of the river by significantly increasing the heavy metals content and physically altering it with the introduction of thousands of cubic yards of tailings. Surface water samples at these seven locations were also elevated. The following is the range and mean for the eight surface water samples: total lead 28 μg/l to 37 μg/l, 31.6 μg/l mean; total zinc 74 μg/l to 120 μg/l, 81.9 μg/l mean; and dissolved zinc 41 μg/l to 100 μg/l, 70.2 μg/l mean. Dissolved lead was undetected in these samples until sample 208. Samples 208, 209, 212, and 212D had dissolved lead ranging from 4.0 to 4.8 μg/l and a mean concentration of 4.4. μg/l.

A clear pattern of increasing concentrations of lead and zinc in the surface water is evident at each of these locations in a downstream progression. The impact of the site on the surface water is particularly evident in the dissolved lead fraction, which increases from undetected to 4.8 μg/l and in dissolved zinc which increases from 44 μg/l to 100 μg/l progressively downstream along the border of the site.

Samples were collected at approximately 0.75 miles (113, 213) and at approximately 1.5 miles (114, 214) downstream of the eastern edge of the site. The bottom of the river was observed to be lined with tailings along this section. Results of the metals in sediment samples 113 and 114 were very similar to the sediments around the site. Surface water samples 213 and 214 were found to contain increasing dissolved lead at 5.4 μg/l and 5.7 μg/l, respectively, as well as increases in dissolved zinc at 110 μg/l in samples 213 and 130 μg/l in sample 214.

The Flat River is the next major tributary downstream that drains tailings piles into Big River. The confluence of Flat River and Big River is approximately 2.75 miles downstream of the east edge of the site. Flat River drains the Federal tailings pile (the largest one in the Old Lead Belt) as well as the Elvins and National tailings piles (See Plate 2). Samples 115 and 215 were taken from Flat River approximately 300 feet upgradient of this confluence. Sediment sample 115 contained 21 mg/kg arsenic, 18 mg/kg cadmium, 16 mg/kg cobalt, 3,500 mg/kg lead, 18 mg/kg nickel, and 970 mg/kg zinc. Surface water sample 215 detected total lead at 32 μg/l, dissolved lead at 16 μg/l, total zinc at 120 μg/l, and dissolved zinc at 130 μg/l. These sample results verify that Flat River is another major contributor of heavy metal contamination to Big River.

Samples 116 and 216 were collected on Big River approximately 5 miles downstream of the site and approximately 2.5 miles downstream of the Flat River confluence. Sediment sample 116 contained arsenic at 7.1 mg/kg, cadmium at 14 mg/kg, cobalt at 12 mg/kg, lead at 1,200 mg/kg, nickel at 13 mg/kg, and zinc at 1,000 mg/kg. Surface water sample 216 contained 49 µg/l total lead, 9.5 µg/l dissolved lead, 130 µg/l total zinc, and 100 µg/l dissolved zinc. It is evident that though the heavy metals in the sediment are still elevated at this location the concentrations have decreased substantially. This phenomenon is probably due to the river's ability to transport large quantity of tailings from the site. Most sediments are transported during high flow (high velocity) events. Therefore, as the flow and velocity decreases in the river, the majority of the sediments fall out of suspension and are deposited in the river bottom. Consequently, the highest concentrations of heavy metals (as well as the heaviest tailings deposition) are found within two to three miles downstream of the Big River Mine Tailings site. A statistical sampling is needed to verify this assumption. The surface water at the sample 216 location has apparently been elevated by the addition of the Flat River contaminants. Total lead increased from 27 µg/l in 214 to 49 µg/l in 216; dissolved lead increased from 5.7 µg/l in 214 to 9.5 µg/l in 216.

Samples 118 and 218 were collected from Terre Bleue Creek, approximately 750 feet upgradient of the Big River confluence. The confluence of Terre Bleue Creek and Big River is approximately 8.5 miles downstream of the site. A sample was collected at this location because Terre Blue is a major tributary to Big River, even though it has no tailings piles in its drainage basin. Therefore, it was considered a background location. Sediment sample 118 contained 4.4 mg/kg lead and 5.8 mg/kg nickel, while all other metals of concern were below detection limits. No metals of concern were detected in surface water sample 218. These results indicate that background conditions exist on Terre Bleue Creek.

Samples 119 and 219 were collected on Big River approximately 10 miles downstream of the site. Results of sediment sample 119 detected arsenic at 5.5 J mg/kg, cadmium at 6.1 mg/kg, lead at 610 mg/kg, nickel at 13 mg/kg, and zinc at 370 mg/kg. Surface water sample 219 results indicated 26 J µg/l total lead, 8.2 J µg/l dissolved lead, 91 µg/l total zinc, and 62 µg/l dissolved zinc. These results indicate that heavy metal concentrations in sediment and surface water are decreasing downstream; however, they remain elevated.

Turkey Creek is the farthest downstream tributary to Big River that drains a tailings pile in the Old Lead Belt. It drains at least the west section of the Bonne Terre pile. An abandoned rail spur follows the creek north from the town of Bonne Terre. This spur is constructed of tailings that were observed to be in contact with Turkey Creek in several locations. It appears that tailings are easily eroded off of the spur and deposited into the creek. Samples 117 and 217 were collected from Turkey Creek approximately 1,500 upgradient of the Big River confluence. Sediment sample 117 contained 11 mg/kg arsenic, 37 mg/kg cadmium, 44 mg/kg cobalt, 8,700 mg/kg lead, 58 mg/kg nickel, and 1,500 mg/kg zinc. Surface water sample 217 detected total lead at 22 µg/l, dissolved lead at 11 µg/l, and zinc was undetected for total and dissolved; however, the detection limits are elevated to 34 U µg/l and 31 U µg/l, respectively. Therefore, it can be concluded Turkey Creek is also contributing significantly elevated sediment and surface water to Big River.

The farthest downstream samples (120 and 220) collected on Big River were taken approximately 15 miles downstream of the site and approximately 1.25 miles downstream of the Turkey Creek confluence. Results of sediment sample 120 indicate lead at 680 mg/kg and zinc at 290 mg/kg. All other metals of concern were undetected. Surface water sample 220 detected total lead at 49 J µg/l, dissolved lead at 11 J µg/l, total zinc at 70 µg/l, and dissolved zinc at 39 µg/l. It appears that the Big River sediment and surface water are influenced by Turkey Creek when a comparison is made of the data upgradient (119, 219) and downgradient (120, 220) of the Turkey Creek confluence.

An evaluation of the data collected along more than 30 miles of the Big River and its tributaries confirms the assumption that the heavy metal contamination is a regional problem. The data indicate that the major sources contributing to the contamination other than the site include the Leadwood pile tributary, Owl Creek, Flat River, and Turkey

Creek. However, the data also indicate that the Big River site is the major source of tailings that physically enter the river. This is substantiated by the extremely elevated levels of heavy metals found in the river sediments at the site and directly downstream. Other sources contribute heavy metal-laden tailings, but the data suggests that they do not contribute to nearly the same extent as the Big River Mine Tailings site.

The data also indicated that the tributaries draining other mining waste areas contain substantial amounts of lead and zinc in their surface water. Without an analysis of average annual streams flow for each tributary compared to Big River as well as a comparison of average contaminant levels in these tributaries and Big River, it is difficult to assess exactly what percentages each source releases to Big River. Although, for site assessment purposes, the data do establish relative elevated levels of heavy metals along Big River. Therefore, it is obvious that the Leadwood tributary, upgradient of the site, elevates the heavy metal content of the river water above background, but it is also apparent that the Big River Mine Tailings site elevates the heavy metal content in the river water even higher than the Leadwood tributary. For example, dissolved lead increases from undetected in sample 203, downstream of the Leadwood tributary and upstream of the site on Big River, to 4.8 µg/l in sample 212D on the east side of the site. Dissolved zinc similarly in-creases from undetected in sample 203 to 99 µg/l in sample 212D. Similar increases of contaminants occur downstream of the Flat River and Turkey Creek confluences.

The LSI has successfully determined the major sources of contamination entering Big River throughout the site area. Although a much more extensive study of the impact of the entire Old Lead Belt on the Big River drainage basin may be necessary to fully characterize the severity and extent of the regional contamination.

7.3 GROUND WATER

The objectives of the ground water sampling were to characterize the shallow ground water in the tailings on site, as well as the drinking water well at the on-site landfill office and at a nearby residence. Characterization of the regional ground water would require the consideration of each mining waste source. The many miles of open mine shafts created during the mining activities are now filled with ground water. These conditions have certainly altered the natural movement and chemical characteristics of the region's ground water. The U.S. Geological Survey office in Rolla, Missouri is currently conducting a ground water study focusing on the site and regional conditions. Therefore, the focus of the E & E/FIT LSI was limited to the characterization of site-specific ground water conditions.

Because the tailings are a product of mainly carbonate rock and because the underlying Bonneterre Formation is dolomite, the pH of the local ground water is normally slightly alkaline. This condition generally restricts the mobility of metals. Theoretically, significant migration of metals in the ground water should be minimal. However, because landfill leachate characteristically produces organic chelating agents that can solubilize metals, the possibility of the on-site landfill producing leachate and mobilizing the metals in the tailings is a major concern (Novak and Hasselwander 1980). Consequently, sampling was conducted in an attempt to consider the influence of the landfill as well as the tailings to the on-site ground water.

Metals of concern detected in the ground water samples include arsenic, cadmium, cobalt, lead, nickel, and zinc. Concentrations of arsenic, cobalt, and nickel in the soil, tailings, and sediment samples have mainly been considered for comparison due to their elevated presence in some of the on-site ground water samples. Ground water sampling included five springs, four Geoprobe temporary wells, two artesian wells, two private drinking water wells, four monitoring wells, a tunnel, and a leachate seep. See Plates 2 and 3 and Table 6-4 for sample locations and Table 7-4 for sample results.

Four of the spring samples were collected from locations along the perimeter of the site bordering Big River. One background spring was sampled across Big River opposite the site. Shallow ground water is present in the large mound of tailings that lie directly on top of the Bonneterre Formation. Because the tailings are very porous and highly permeable, numerous springs or seeps are present along the edges of tailings bordering Big River. These springs drain directly into the river. The springs that were sampled were located and sampled during a

Table 7-4
Selected Metals in Ground Water Samples
Big River Mine Tailings Site
Desloge, Missouri
E & E/FIT; July 1990
Sample Series CSXCR

Sample	Arsenic		Cadmium		Cobalt		Lead		Nickel		Zinc	
(µg/l)	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.	Tot.	Diss.
300	10U	10U	5.5	5.0U	50U	50U	250J	N/A I	40U	40U	3400	1900
301	10U	10U	5.0U	5.0U	50U	50U	36J	33 J	53	60	180	190
302	10U	10U	5.0U	5.0U	50U	50U	86J	N/A I	40U	40U	98	27
303	21	10U	190	5.0U	85	50U	14000J	N/A I	92	40U	9100	65
304	10U	10U	5.0U	5.0U	50U	50U	63J	20 J	40U	40U	200	160
305	10U	10U	5.0U	5.0U	50U	50U	5.1J	N/A I	40U	40U	20U	20U
306	10U	10U	5.0U	5.0U	400	400	330J	29 J	310	320	8900	6400
307	10U	10U	5.0U	5.0U	50U	50U	17J	14 J	40U	43	140	140
308	10U	10U	5.0U	5.0U	50U	50U	3.0U	N/A I	40U	40U	26	31
309	59	37	6.9	5.0U	50U	50U	680J	4.1U	61	40U	850	520
309D	59	37	8.0	5.0U	50U	50U	650J	3.3U	49	40U	830	550
310	25	17	5.0U	5.0U	50U	50U	23J	3.0U	40U	40U	94	290
311	64	34	11	5.0U	50U	50U	5000J	3.0U	64	40U	530	20U
312	110	10U	37	27	350	360	9300J	60	680	620	26	23000
314	14	10U	5.0U	5.0U	85	55	1700J	74	83	43	470	170
315	14	10U	8.6	5.0U	56	50U	3800J	9.3	70	40U	560	20U
316	46	10U	30	5.0U	170	50U	8200J	46	170	40U	2500	450
317	85	51	26	5.0U	53	50U	10000J	3.0U	60	40U	1400	20U
318	10U	10U	5.0U	5.0U	50U	50U	63J	28	52	86	180	160
319	10U	10U	5.0U	5.0U	50U	50U	43J	4.4U	40U	40U	170	450
320F	10U	---	5.0U	---	50U	---	N/A I	---	40U	---	20U	---
321F	10U	10U	5.0U	5.0U	50U	50U	N/A I	3.0U	40U	40U	20U	20U
322F	10U	10U	5.0U	5.0U	50U	50U	3.2J	3.0U	40U	40U	20U	20U
323F	10U	10U	5.0U	5.0U	50U	50U	N/A I	3.0U	40U	40U	20U	20U
324	10U	10U	5.0U	5.0U	50U	50U	37J	28	51	88	160	170
324F	10U	10U	5.0U	5.0U	50U	50U	N/A I	3.0U	40U	40U	27	20U
325F	10U	---	5.0U	---	50U	---	N/A I	---	40U	---	20U	---

Tot. = Total
Diss. = Dissolved
J - Data reported but not valid by approved QA procedures.
U - Less than measurement detection limit, the associated number is the detection limit.
I - Invalid sample data - value not reported/not available.
Note: See Plates 2 and 3 and Table 6-4 for sample locations and the data transmittal in Appendix D for complete analytical results. Samples 320F and 325F were submitted for total metals analyses only. Sample #313 was not used.

reconnaissance of the site perimeter conducted on the Big River in a johnboat. Samples 300, 302, 303, and 304 were collected from the on-site springs. Sample 300 was collected from a spring on the west side of the site near the landfill. Analyses of sample 300 found total lead at 250 J μg/l, dissolved lead was invalid (N/A I), total zinc at 3,400 μg/l, and dissolved zinc at 1,900 μg/l. Note that many of the ground water sample lead results have been invalidated due to the matrix spike recovery being out of control limits and that most other lead results are J coded due to the blank rule. The dissolved zinc concentration in sample 300 was 10 times greater than any of the other spring samples. All of the other springs were a significant distance from the landfill, which suggests that the landfill may be influencing the ground water at this location.

Sample 302, collected from a spring on the northeast edge of the site, contained 86 J μg/l total lead, invalid dissolved lead, 98 μg/l total zinc, and 27 μg/l dissolved zinc. Sample 303, taken near the major collapse area on the east side of the site, contained 21 μg/l total arsenic, undetected dissolved arsenic, 190 μg/l total cadmium, undetected dissolved cadmium, 85 μg/l total cobalt, undetected dissolved cobalt, 14,000 J μg/l total lead, invalid dissolved lead, 92 μg/l total nickel, undetected dissolved nickel, 9,100 μg/l total zinc, and 65 μg/l dissolved zinc. The presence of arsenic, cadmium, cobalt, and nickel only in the total analysis and not in the dissolved as well as the high total lead and zinc concentrations in sample 303 indicates this sample may have contained significant suspended sediment. Sample 304 was collected near the east edge of the site and contained 63 μg/l total lead, 20 J μg/l dissolved lead, 200 μg/l total zinc, and 160 μg/l dissolved zinc. It can be concluded from these sample results that the numerous springs or seeps flowing from the site into Big River transport significant quantities of total and dissolved lead and zinc, further elevating metals levels in the Big River water.

Sample 318 was collected from a spring on Big River across from the west side of the site and was assumed to be a background location. However, analytical results reported total lead at 63 J μg/l, dissolved lead at 28 μg/l, total nickel at 52 μg/l, dissolved nickel at 86 μg/l, total zinc at 180 μg/l, and dissolved zinc at 160 μg/l. These high concentrations could represent natural ground water conditions or that the site or past mining activities, has influenced the shallow ground water across Big River. The constituents and concentrations in sample 318 are comparable to the results on ground water samples collected from the artesian wells (samples 301 and 324). Lead, nickel, and zinc were the only metals detected in these three samples, and the concentrations are similar. All three samples were also collected in the same general area. Therefore, it is possible that the source of the contamination at these three locations is the same.

The two artesian wells (samples 301 and 324) are approximately 1,000 feet west of the southwest edge of the site along the east bank of Owl Creek. As previously discussed, these wells are actually abandoned exploration borings that were drilled by the mining company in order to vertically characterize zones of mineralization in the Bonneterre Formation. Therefore, it can be assumed that the borings extend into the Bonneterre; however, total depths are unknown. Topographically, these wells are at least 60 feet below the southwest portion of the site (USGS 1982). Refer to the topographic map of site in Appendix H. Therefore, shallow ground water from the elevated tailings may be influencing this area as it migrates from the site. Sample 301 contained total lead at 36 J µg/l, dissolved lead at 33 J µg/l; total nickel at 53 µg/l, dissolved nickel at 60 µg/l; total zinc at 180 µg/l and dissolved zinc at 190 µg/l. Results from sample 324 were very similar with total lead at 37 J µg/l, dissolved lead at 28 µg/l; total nickel at 51 µg/l, dissolved nickel at 88 µg/l; total zinc at 160 µg/l and dissolved zinc at 170 µg/l. Again, these concentrations are very similar to sample 318.

The four Geoprobe temporary wells (samples 314, 315, 316, and 317) were installed along the northwest, north, and northeast areas of the tailings. They were emplaced in the tailings in these areas in order to characterize the shallow ground water in an area that is probably not influenced by the landfill. The well locations are approximately 25 to 35 feet lower topographically than the thicker portions of the tailings pile immediately to the south. All of the metals of concern were detected in the total metals analysis; however, the results discussion will focus on the dissolved metals only. The concentrations of total metals in the samples are extremely high and are more of a reflection of the inability of the Geoprobe well point (screen) to filter out a substantial amount of the suspended solids. Therefore, a significant amount of the finer grained tailings entered the screen and were collected in the total metals sample. Table 7-4 lists the total metals results: Dissolved metals detected in sample 314 include 55 µg/l cobalt, 74 µg/l lead, 43 µg/l nickel, and 170 µg/l zinc. Lead at 9.3 µg/l was the only dissolved metal detected in sample 315. Dissolved metals in sample 316 included 46 µg/l lead and 450 µg/l zinc. Arsenic at 51 µg/l was the only dissolved metal found in sample 317. The dissolved metals concentrations found in these samples, with the exception of the invalid dissolved lead samples, are similar to the concentrations found in the springs sampled (302, 303, and 304) on site, in areas not adjacent to the landfill.

A total of five samples, including a duplicate, were collected from four monitoring wells. There are six monitoring wells around the landfill; however, two were dry. The monitoring wells were installed in 1987, at MDNR request, in order to monitor the shallow ground water around the landfill. Samples 309, 309D, 310, 311, and 312 were sampled from monitoring wells on the north, east, and south edges of the landfill (See Plate 3). Total metals concentrations are extremely high and variable in the monitoring well samples, probably due to suspended solids, as with the Geoprobe temporary well samples. Therefore, only dissolved metals results will be discussed. Table 7-4 lists total metals results for comparison. Arsenic and zinc were the only dissolved metals detected in samples 309, 309D, 310, and 311. In these samples, dissolved arsenic ranged from 17 µg/l to 37 µg/l, with a mean of 31.2 µg/l, and dissolved zinc ranged from un-detected to 550 µg/l, with a mean of 340 µg/l. However, in sample 312, located on the east edge of the landfill, dissolved metals detected include 27 µg/l cadmium, 360 µg/l cobalt, 60 µg/l lead, 620 µg/l nickel, and 23,000 µg/l zinc. These extremely elevated dissolved metals concentrations are very similar to the concentrations found in the landfill leachate seep (sample 306). Consequently, it appears that the landfill is influencing the ground water at sample 312 (well DG-2). Because sample 311 (well DG-3) is within 100 feet of the landfill leachate seep sample 306, it would be anticipated that the ground water in DG-3 would be similar to the leachate seep; however, results do not indicate this. This may be due to the fact that DG-3 was nearly dry, with only a 1.25 foot water column. Also, recharge to the well was very slow and did not exceed the 1.25 foot column. Hence, the water in DG-3 may not be representative of the ground water at that location.

The leachate seep sample 306 was collected at the entrance to the drainage tunnel into which it drains. The tunnel trends southwest/ northeast, is approximately 1,500 feet in length, and drains water from the south entrance to the north exit. Sample 319 was collected at the exit location. Water flow through the tunnel at the time of sampling was very slow but continuous. The leachate seep sample 306 contained 400 µg/l total cobalt, 400 µg/l dissolved cobalt, 330 J µg/l total lead, 29 J µg/l dissolved lead, 310 µg/l total nickel, 320 µg/l dissolved nickel, 8900 µg/l total zinc, and 6400 µg/l dissolved zinc. Cadmium was the only metal of concern that was not found at extremely elevated concentrations in sample 306, that was also found in sample 312 from monitoring well DG-2. The extremely high levels of dissolved cobalt, nickel, and zinc in samples 306 and 312 are indicative of landfill leachate mobilizing metals. Lead is also elevated in these samples, however, not as extremely. Results of sample 319, collected at the tunnel exit, indicate total lead at 43 J µg/l, undetected dissolved lead, total zinc at 170 µg/l, and dissolved zinc at 450 µg/l. Concentrations are much lower in sample 319, collected at the tunnel exit, probably due to dilution of the water as it is transported through the tunnel. Additional sampling of the leachate and the tunnel water is needed to fully characterize the tunnel water and determine the exact path of the leachate flow.

Two private drinking water wells were also sampled. Sample 307 was collected from the on-site landfill office well, and sample 308 was collected from the Kennedy residence, located approximately 750 feet south of the landfill office off site. Sample 307 contained 17 J µg/l total lead, 14 J µg/l dissolved lead, 43 µg/l dissolved nickel, 140 µg/l total zinc, and 140 µg/l dissolved zinc. Sample 308 is considered background and contained only 26 µg/l total zinc and 31 µg/l dissolved zinc. No total lead was detected in 308 and dissolved lead was invalidated. The landfill well is 216 feet deep, and the Kennedy well is between 200 and 300 feet deep; therefore, they are drawing from similar levels in the Bonneterre aquifer. The dissolved lead, nickel, and zinc found at elevated levels in the landfill well, but not in the Kennedy well, suggests that the site is influencing the deeper ground water on site. The proposed MCL for lead in drinking water is 5 µg/l; samples collected from the landfill well contained lead concentrations significantly above this level.

Sample 305 was taken from what was originally thought to be a spring but was later determined to be a tributary carring effluent from RESCO Products into Big River. RESCO operates a quarry at their facility. The only contaminant found in sample 305 was total lead at 5.1 J µg/l. However, the pH of the sample was 10.62. Further inquiry into RESCO operations is warranted. This sample was taken approximately 500 feet downstream of the North Desloge river access (Plate 3) and several miles downstream of the site. It was intended as a background location and, therefore, does not have any impact on the site study.

Six QA/QC samples were submitted. These included: two field blanks, a trip blank, an acid blank, a rinsate sample of a bailer, and a rinsate sample of Geoprobe pipe. All metals of concern were non-detected in these samples except for 3.2 J µg/l total lead in field blank sample 322F and 27 µg/l total zinc in sample 324F from the rinsate of the Geoprobe pipe.

It is evident from the data results that the shallow ground water over the majority of the site contains elevated levels of dissolved lead and zinc. A significant amount of the shallow ground water flows out of springs or seeps along the perimeter of the site. Most of these springs transport the contaminated water directly into Big River. It is also apparent from the data that the landfill leachate is mobilizing metals of concern. This is particularly conclusive in leachate sample 306 taken on the south edge of the landfill and monitoring well sample 312 from the east edge of the landfill area. Both of these samples contained extremely high concentrations of cobalt, lead, nickel, and zinc. Sample 312 also contained elevated cadmium. None of the other ground water samples collected on site contained comparable dissolved metal concentrations. Although spring sample 300, collected on the west edge of the landfill area, contained dissolved zinc at 1,900 µg/l; dissolved lead was invalidated for the sample. This indicates that the landfill may also be influencing the shallow ground water on the southwest edge of the site.

Three ground water samples (301, 324, and 318) were collected from two artesian wells and a spring that are all located to the west of the landfill area just off site. All of these samples contained significant amounts of total and dissolved lead, nickel, and zinc. The proposed MCL of 5 µg/l for lead is exceeded in all of these samples. The MCL for nickel is 100 µg/l. Dissolved nickel was found at 60 µg/l in 301, 86 µg/l in 318, and 88 µg/l in 324. Therefore, concentrations of nickel are very close to the MCL in samples 318 and 324. The landfill drinking water well (sample 307) contained dissolved lead at 14 J µg/l, dissolved nickel at 43 µg/l, and dissolved zinc at 140 µg/l. The proposed MCL for lead is exceeded in this well. It should be noted that the landfill well is located in the same general area, near the landfill, as the artesian wells and spring sample 318, and it contains the same contaminants as these samples.

7.4 AIR

The objectives of the air sampling effort were to determine if tailings are released to the ambient air on site and if they are migrating off site. On-site air quality is a concern as there are seven on-site workers (four landfill workers and three full-time workers at the Morgan and White facility). Additionally, many people use the site for all terrain vehicle recreation. The town of Desloge is adjacent to the site on the southeast side and many people reside to the south and east of the site. During a January 1988 site reconnaissance, the E & E/FIT observed a tailings plume migrating from the site to the east. Because the tailings consist of dust, silt, and sand-sized particles and no vegetation is present on a majority of the site, the tailings migrate readily via wind erosion in the same manner as sand dunes. There is an obvious west to east migration of the tailings due to wind erosion. The people potentially affected, the predominant wind direction, and the location of other tailings piles were the main factors considered in the placement of the Hi-vol samplers (Table 6-5).

Hi-vol samplers 1 and 2 were the co-located samplers and were set up approximately 800 feet east of the site. Refer to Plates 1 and 3 and Table 6-5 for Hi-vol locations. These samplers were set up directly downgradient of the major west to east movement of the tailings. Hi-vol 3 was set up on site in the northeast section. This sampler was set at this location to determine ambient air conditions on site and away from the heavy vehicle traffic area near the landfill. Hi-vol 4 was placed on site approximately 150 feet north of the landfill office. This location was chosen to determine on-site ambient air conditions in the vicinity of the landfill operations. Hi-vol 5 was located approximately 1.25 miles east of the site. This location was selected in order to monitor the ambient air in a downgradient direction at least one mile from the site. Hi-vol 6 was set up approximately one mile west-southwest of the site. This location was chosen to sample the ambient air between the Leadwood tailings pile and the site. Hi-vol 7 was placed approximately four miles west of the site. This location was chosen as a remote background location. All of the off-site Hi-vols were placed in relatively remote locations in pastures or grass-covered meadows in order to minimize the possibility of interference from adjacent areas.

A meteorological station was set up in an open area approximately in the middle of the site. Every 15 minutes, it recorded the wind direction, wind speed, temperature, barometric pressure, and relative humidity. The meteorological station collected data continuously from the start to the finish of the project.

The Hi-vol samplers were run from 1200 to 2400 hours each day for six consecutive days. It should be noted that wind speeds were very low for the majority of the sampling. Results would vary considerably in higher wind speed conditions.

The primary metals of concern detected were arsenic, cadmium, lead, and zinc. Table 7-5 summarizes the analytical results for the selected metals of concern. A complete list of metals detected is available in the data transmittal included as Appendix D. The analytical data results were reported in total micrograms (µg) per filter. Therefore, these values have been converted to micrograms per cubic meter ($\mu g/m^3$) by division with the sample volume collected and were also adjusted to

Table 7-5
Selected Metals in Air Samples ($\mu g/m^3$)
Big River Mine Tailings Site
E & E/FIT; July 1990
Sample Series CSXCR

Date and Sample #	Hi-Vol Sampler	Arsenic	Cadmium	Lead	Zinc
7/23/90					
400	#1	0.001U	0.001U	0.008	0.014
402	#2	0.001U	0.001U	0.020	0.019
403	#3	0.001U	0.001U	0.015	0.011
404	#4	0.003	0.006	0.569	0.261
405	#5	NA	NA	NA	NA
406	#6	NA	NA	NA	NA
*407	#7	0.001U	0.001U	0.008	0.015
408	Field Blank	-----	-----	-----	-----
7/24/90					
409	#1	0.001U	0.001	0.030	0.024
410	#2	0.001U	0.000U	0.046	0.028
411	#3	0.001U	0.001	0.057	0.035
412	#4	0.001U	0.008	0.802	0.380
413	#5	0.001U	0.001	0.054	0.058
414	#6	0.001U	0.001	0.027	0.020
*415	#7	0.001U	0.000U	0.020	0.022
416	Field Blank	-----	-----	-----	-----
7/25/90					
417	#1	0.001U	0.001	0.011	0.026
418	#2	0.001U	0.001	0.023	0.025
419	#3	0.001U	0.003	0.044	0.036
420	#4	NA	NA	NA	NA
421	#5	0.001U	0.000U	0.127	0.031
422	#6	0.001U	0.000U	0.020	0.020
*423	#7	0.001U	0.000U	0.006	0.033
424	Field Blank	-----	-----	-----	-----
7/26/90					
425	#1	0.001U	0.001	0.053	0.050
426	#2	0.001U	0.001	0.068	0.047
427	#3	0.001U	0.001	0.082	0.053
428	#4	0.001U	0.009	1.088	0.473
429	#5	0.001U	0.000U	0.100	0.043
430	#6	0.001U	0.001	0.036	0.024
*431	#7	0.001U	0.000U	0.013	0.027
432	Field Blank	-----	-----	-----	-----

Table 7-5 (Continued)
Selected Metals in Air Samples (μg/m^3)
Big River Mine Tailings Site
E & E/FIT; July 1990
Sample Series CSXCR

Date and Sample #	Hi-Vol Sampler	Arsenic	Cadmium	Lead	Zinc
7/27/90					
433	#1	0.001U	0.001	0.027	0.040
434	#2	0.001U	0.001U	0.024	0.037
435	#3	0.002	0.004	0.294	0.171
436	#4	0.001U	0.004	0.429	0.232
437	#5	0.001U	0.000	0.050	0.482
438	#6	0.001U	0.000U	0.022	0.024
*439	#7	0.001U	0.000U	0.016	0.028
440	Field Blank	-----	-----	-----	-----
7/28/90					
441	#1	0.001U	0.001U	0.031	0.031
442	#2	0.001U	0.001U	0.016	0.024
443	#3	0.001U	0.001U	0.023	0.026
444	#4	0.001	0.001U	0.190	0.054
445	#5	0.001U	0.001	0.059	0.064
*446	#6	0.001U	0.001U	0.035	0.025
448	#7	0.002	0.008	0.066	0.069
449	Field Blank	-----	-----	-----	-----

* Background location for that day
N/A: No available data due to Hi-vol malfunction

Note: Locations 1 and 2 are duplicate samples. Concentrations of compounds detected in the field blanks were subtracted from the total sample weight prior to division of sample volume. Sample numbers 401 and 447 were not used. See Plates 1 and 3 and Table 6-5 for sample locations. See Appendix D for complete analytical results and Appendix J for calibration sheets, conversions of air data to μg/m^3 and windroses for each day.

standard temperature and pressure. Appropriate Hi-vol calibration sheets, calculations of standard volumes of ambient air for each Hi-vol sample, original data (μg/filter) for all metals, and concentrations in air μg/m^3 for all metals is available in Appendix J. A blank sample was also prepared each sampling period. If a metal was found above detection limits in the blank, then that amount was subtracted from the sample. If the metal was not detected in the sample blank, then one-half of the detection limit for that metal was subtracted from the sample.

The predominant wind for each sampling period was determined using the wind speed and wind direction data collected by the meteorological station. WROSE software by Bowman Environmental Engineering was used to construct a windrose which illustrates wind direction and wind speed for each day. Therefore, a background and a downwind direction can be determined for each day. A windrose for each day is included in Appendix J. Table 7-5 specifies a background Hi-vol location based on this data for each day.

It should be noted that after the Hi-vol samplers were set up and sampling had commenced, construction work using heavy equipment began approximately 500 to 750 feet south of Hi-vol 5, located approximately 1.25 miles east of the site. Several inconsistent results in samples from Hi-vol 5 are apparent in the data. Due to the noted interference from the construction work and the data results, sample results from Hi-vol 5 will be listed in Table 7-5, but will not be considered attributable to the site.

On July 23, 1990, the predominant wind direction was from southwest to northeast. Wind speed was between 3.3 to 5.4 meters per second (m/s) from this direction, Sample 407, collected at Hi-vol location 7 was chosen as the background sample. Sample 407 contained undetected arsenic and cadmium, 0.008 μg/m^3 lead, and 0.015 μg/m^3 zinc. Hi-vol 4 (sample 404) collected on site near the landfill office, was the only sample that contained metals at concentrations significantly over background. Sample 404 contained 0.003 μg/m^3 arsenic, 0.006 μg/m^3 cadmium, 0.569 μg/m^3 lead, and 0.261 μg/m^3 zinc. Samples from Hi-vol location 4 consistently had significant elevated metals results and in most cases were much higher than samples from Hi-vol 3, the other on-site Hi-vol. This is due to the routine landfill traffic and heavy equipment operation in the vicinity of the landfill. Dust from the everyday operations at the landfill obviously increases the suspended tailings particulates on the landfill portion of the site. No results are available for samples 405 and 406 from the Hi-vols 5 and 6, respectively, due to Hi-vol malfunction during the sampling period.

The predominant wind direction on July 24, 1990, was determined to be south/southeast based on the windrose evaluation. The wind speed was between 1.8 to 3.3 m/s the majority of the time from the predominant direction. Sample 415 collected at Hi-vol location 7 was chosen as the background sample. Sample 415 results indicated undetected arsenic and cadmium, lead at 0.020 $\mu g/m^3$, and zinc at 0.022 $\mu g/m^3$. Again the highest concentrations found were in sample 412 from Hi-vol 4. Sample 412 results detected cadmium at 0.008 $\mu g/m^3$, lead at 0.802 $\mu g/m^3$, and zinc at 0.380 $\mu g/m^3$. Concentrations of cadmium are also elevated to 0.001 $\mu g/m^3$ in Hi-vol 3 (sample 411) and Hi-vol 1 (sample 409). This data indicates that while wind speeds were relatively low, a sufficient amount of cadmium-laden particulates migrated off site and elevated sample 409 at Hi-vol location 1 which was approximately 800 feet east of the site.

The predominant wind direction on July 25, 1990, was from southeast to northwest. Predominant wind speeds were between 1.8 and 3.3 m/s about half of the sampling period and between 3.3 to 5.4 m/s the other half. Sample 423 collected at Hi-vol location 7 was chosen at background. Concentrations in sample 423 were undetected for arsenic and cadmium, 0.006 $\mu g/m^3$ lead, and 0.033 $\mu g/m^3$ zinc. Samples 417, 418, and 419 from Hi-vols 1, 2, and 3, respectively, had cadmium and lead concentrations elevated above background. Cadmium was found at 0.001 $\mu g/m^3$ in 417, at 0.001 $\mu g/m^3$ in 418, and at 0.003 $\mu g/m^3$ in 419. Lead was detected at 0.011 $\mu g/m^3$ in 417, at 0.023 $\mu g/m^3$ in 418, and 0.044 $\mu g/m^3$ in 419. No sample results from Hi-vol 4 were calculated due to Hi-vol malfunction. Considering wind direction, cadmium and lead appear to be migrating from the southeast area of the site to Hi-vols 1, and 2 off site.

The predominant wind direction on July 26, 1990, was determined to be from the south/southwest to north/northeast. The highest wind speeds were from the southwest between 3.3 to 5.4 m/s. Hi-vol location 7 (sample 431) was chosen as background. Results from sample 431 indicated undetected arsenic and cadmium, 0.013 $\mu g/m^3$ lead, and 0.027 $\mu g/m^3$ zinc. On-site Hi-vols 3 and 4 (samples 427 and 428) and downwind, off site, co-located Hi-vols 1 and 2 (samples 425 and 426) all contained elevated concentrations of cadmium, lead, and zinc during this sampling period. Sample 428 at Hi-vol 4 had the highest concentrations detected during the study with cadmium at 0.009 $\mu g/m^3$, lead at 1.088 $\mu g/m^3$, and zinc at 0.473 $\mu g/m^3$. Sample 426 collected at Hi-vol 2 contained 0.001 $\mu g/m^3$ cadmium, 0.068 $\mu g/m^3$ lead, and 0.047 $\mu g/m^3$ zinc. Sample 426 at Hi-vol 1 contained similar concentrations. The on-site and downwind results collected during this sampling period are conclusive evidence that a significant amount of heavy metal-laden particulates from the tailings are being released to the ambient air on site and are being transported at least 800 feet off site.

The predominant wind direction on July 27, 1990, was from west/southwest to east/northeast. The majority of the wind from this direction was in the range 3.3 to 5.4 m/s. Sample 439 at Hi-vol location 7 was used as the background for this sampling period. Results from sample 439 indicated undetected arsenic and cadmium, 0.016 $\mu g/m^3$ lead, and 0.028 $\mu g/m^3$ zinc. Both on-site Hi-vols 3 and 4 had elevated cadmium, lead, and zinc in their samples. Sample 435 (Hi-vol 3) contained 0.002 $\mu g/m^3$ arsenic, 0.004 $\mu g/m^3$ cadmium, 0.294 $\mu g/m^3$ lead and 0.171 $\mu g/m^3$ zinc. Sample 436 (Hi-vol 4) contained 0.004 $\mu g/m^3$ cadmium, 0.429 $\mu g/m^3$ lead, and 0.232 $\mu g/m^3$ zinc. Off-site, co-located Hi-vol locations 1 and 2 also had slightly elevated concentrations of cadmium, lead, and zinc. Hi-vol 1 (sample 433) contained 0.001 $\mu g/m^3$ cadmium, 0.027 $\mu g/m^3$ lead, and 0.040 $\mu g/m^3$ zinc; Hi-vol 2 (sample 434) contained similar concentrations. This data also concludes that tailings are being released into the ambient air on and off site.

On July 28, 1990, the wind direction varied from east to south to west. Therefore, a definite predominant wind direction is very difficult to determine. Refer to windrose 7-28-90 in Appendix J. It can be concluded that the wind was primarily from a southeast, south or southwest direction. Wind speed was mostly 1.8 to 3.3 m/s from the southeast and 3.3 to 5.4 m/s from the south and southwest. Hi-vol location 6 (sample 446) was chosen as background. However, because of the low wind speeds and the lack of a definite predominant wind direction, most of the samples this sampling period did not contain elevated levels of metals of concern. Sample 446 contained undetected arsenic and cadmium, 0.035 $\mu g/m_3$ lead, and 0.025 $\mu g/m^3$ zinc. Due to the wind direction, sample 448 at Hi-vol location 7 was apparently influenced by the Leadwood tailings pile during this period. Sample 448 contained 0.002 $\mu g/m^3$ arsenic, 0.008 $\mu g/m^3$ cadmium, 0.066 $\mu g/m^3$ lead, and 0.069 $\mu g/m^3$ zinc. These results reinforce the fact that this is a regional problem and not site specific. It should be noted that Hi-vol 4 (sample 444) located on the landfill area contained its lowest concentrations on this day. This is partly due to low wind speeds although the main factor was probably that July 28, 1990, was a Saturday. The landfill closed at noon that Saturday which was when sampling began. Therefore, the effects of the landfill daily operations can be realized when previous results are compared to these results. Sample 444 contained 0.001 $\mu g/m^3$ arsenic, undetected cadmium, 0.190 $\mu g/m^3$ lead, and 0.054 $\mu g/m^3$ zinc.

The LSI air monitoring study was conducted for six consecutive days from July 23 to 28, 1990. Samples were collected for a 12-hour sampling period each day from 1200 to 2400 hours. Wind speeds were low during the entire study period. However, sample results have concluded that the ambient air on site and at least 800 feet off site is being influenced by the Big River Mine Tailings site. Results from July 25, 26, and 27, 1990, contained significantly elevated concentrations of cadmium, lead and zinc in on-site Hi-vols 3 and 4 and in off-site, co-located Hi-vols 1 and 2. The highest concentrations of lead detected was 1.088 $\mu g/m^3$ in Hi-vol 4 on July 26. This does not exceed the National Air Quality Standard of 1.5 $\mu g/m^3$ in a calendar quarter; however, it is very significant when the low wind speeds during the sampling period are considered. It is highly probable that the 1.5 $\mu g/m^3$ standard is exceeded on site and off site during periods of higher wind velocities. Consequently, the greatest potential for exposure is to on-site workers and to residential areas bordering the site to the south and east.

Results from Hi-vol 4 which was placed in the landfill area, indicate that daily landfill operations further increase the amount of suspended particulates in the ambient air at the landfill. Concentrations of heavy metals were consistently higher at this location than any other. The sample (444) collected on the one day the landfill was closed contained the lowest concentrations for this location during the sampling period.

It should be noted that on the last day of sampling the winds were from a southerly direction and the remote, background, Hi-vol 7 sample contained elevated concentrations of metals of concern. This can be attributed to the Leadwood tailings pile that was located south/southeast of the Hi-vol. This emphasizes the fact that the air quality of the area is a regional problem. However, the Big River Mine Tailings site has characteristics that are unique and compound the problem. The site is the largest tailings pile in the area that was not deposited in valleys of dammed drainages. The Leadwood and Federal piles were deposited in this manner, resulting in their present day configuration. The Big River pile was placed on an area that was topographically similar or higher than the surrounding area. Consequently, after deposition of the tailings was complete at Big River, the site was significantly higher topographically than the adjacent area. As a result, particulates from the tailings are easily airborne even in low wind speed conditions. Other tailing piles are elevated or have portions that are above adjacent topography, but are not as large in surface area as the Big River tailings pile.

SECTION 8: SUMMARY AND CONCLUSIONS

The Big River Mine Tailings site is a 600 acre tailings disposal area. It was created during the operation of a lead mine/mill facility that operated between 1929 and 1958 in Desloge, Missouri. The Desloge facility was one of many that once operated in the area known as the Old Lead Belt. The Old Lead Belt encompasses an area of approximately 110 square miles, all of which is within St. Francois County. Numerous tailings piles that contain elevated levels of heavy metals exist throughout the Old Lead Belt. It is obvious that the heavy metals contamination of the surface water, ground water and air of the region has multiple sources. However, the Big River Mine Tailings site has several unique features that make it a major contributor of heavy metal contamination. The results of the LSI indicate that the site is releasing significant levels of heavy metals to the surface water, ground water, and air.

The site is a mounded pile of tailings that is bounded by the Big River on three sides. Because of its unusual location, adjacent to and elevated above Big River, tailings are constantly transported via wind and water erosion into the Big River. There are numerous areas along the perimeter of the site where the river is continuously in contact with the tailings. As a result of this physical setting, a castrophic release of tailings into Big River occurred in 1977. After a heavy rain, a portion of the tailings adjacent to the river on the east side became super saturated and released an estimated 50,000 cubic yards to the river. This was the largest of numerous documented releases. Smaller releases continue daily as the river undercuts and erodes the tailings. Analytical results of sediment and surface water samples collected from Big River and its tributaries verify that the site is a major contributor to heavy metal contamination of Big River.

Another unique feature of the site is the operation of a 60 acre municipal landfill on the southwest portion. Monitoring wells, private wells, abandoned wells, geoprobe temporary wells, springs along the site perimeter as well as leachate seeps, were sampled in order to characterize the ground water near the site. Results of the sampling indicate that elevated levels of heavy metals exist in the shallow ground water over the majority of the site. However, it is also apparent that the landfill leachate is mobilizing metals of concern. The leachate sample and sample 312 taken from a monitoring well adjacent to the landfill contained extremely high concentrations of metals of concern. The drinking water well located on site at the landfill office contained dissolved lead at 14J µg/l which exceeds the proposed MCL for lead.

Because the site is topographically elevated above the adjacent area and tailings are easily air borne via wind erosion, releases of tailings to the ambient air are frequent. A direct release was photo documented during the Preliminary Assessment reconnaissance in January, 1988. At that time, a large plume of tailings extending from the site and moving southeast approximately one mile was visible. Hi vol air samplers were utilized during the LSI to document the air releases. While wind conditions were not optimum, releases of tailings to the ambient air on site and at least 1,500 feet off site were documented. It appears that the daily routine landfill operations on site significantly increase the amount of suspended particulates released to the ambient air. Therefore, the landfill workers and residences adjacent to the site are at the highest risk of exposure from an air release.

The LSI of the Big River Mine Tailings site confirmed that heavy metals contamination in the Old Lead Belt is a regional multi-source problem and identified the Big River Mine Tailings site as a major contributor. The data as well as visual observations have documented heavy metal laden tailings releases to the ground water, surface water, and air from the site.

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