

WILDCAT BRANCH/ADDISON BRANCH MINES SITE

**Daniel Boone National Forest
Pulaski County, Kentucky**



Draft Engineering Evaluation/Cost Analysis

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ACRONYMS

AMD	Acid Mine Drainage
AML	Abandoned Mine Lands
ARAR	applicable or relevant and appropriate requirement
BMP	Best Management Practice
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DOE	U.S. Department of Energy
EE/CA	Engineering Evaluation/Cost Analysis
EKPC	East Kentucky Power Cooperative
ESI	Expanded Site Inspection
EM	Environmental Management
EPA	US Environmental Protection Agency
FY	Fiscal Year (US Government – October-September)
KDEP	Kentucky Department for Environmental Protection
NEPA	National Environmental Policy Act
NPL	National Priorities List
NRCS	Natural Resources and Conservation Service
OHV	Off-Highway Vehicle
O&M	Operation and Maintenance
PA	Preliminary Assessment
SARA	Superfund Amendment and Reauthorization Act
SMCRA	Surface Mining Control and Reclamation Act
SI	Site Inspection
SRB	Sulfate Reducing Bioreactor
TBC	to be considered (guidance)
USDA	United States Department of Agriculture
USDA FS	United States Department of Agriculture Forest Service
USDI OSM	United States Department of Interior Office of Surface Mining

EXECUTIVE SUMMARY

In accordance with the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA), the Daniel Boone National Forest has chosen to remediate the Wildcat Branch/Addison Branch Mines Site by conducting a set of non-time-critical removal actions.

This document is an Engineering Evaluation/Cost Analysis (EE/CA) for these actions at the Wildcat Branch/Addison Branch Mines Site (Site) in the London Ranger District of Daniel Boone National Forest, Kentucky. The Site is located within the Wildcat Branch and Addison Branch watersheds, which are sub-watersheds of the Cumberland River watershed and tributaries of Lake Cumberland. The EE/CA addresses contaminated water that is being released to the environment from mine pools associated with past deep mining activities and from seepage and runoff from mine waste piles and surface mines that were inadequately closed and reclaimed. The contamination results from acid mine drainage (AMD) that is characterized by low pH, excessive metals loading, and metals transport. Additionally, improper closure has caused stream sedimentation and associated degradation of aquatic resources and other beneficial uses, such as drinking water and recreation.

The objectives of the removal actions evaluated in this EE/CA are:

- Improving surface water quality by reducing or mitigating the release of AMD to Wildcat Branch, Addison Branch, their unnamed tributaries, and groundwater.
- The protection of aquatic life and habitat in Wildcat Branch and Addison Branch; and
- The control of contaminant migration from coal waste piles and mine openings to the surface water, including the Cumberland River, and to the underlying groundwater aquifer.

The Site is divided into 4 Areas, based on topography, location, and association by mine workings. Current descriptions of these areas are provided and past attempts to alleviate problems associated with AMD are presented. Sampling results obtained for the 2004 Preliminary Assessment (USDA 2004), 2008 Site Inspection (USDA 2008), and 2015 Expanded Site Inspection (USDA 2015) are presented to characterize the water quality and evaluate the potential human health and ecological risks. Potential removal actions are provided and evaluated according to standard CERCLA criteria, including effectiveness, implementability, and cost. These actions are then applied to AMD impacted locations within each of the 4 areas and evaluated to specific conditions.

The most promising and widely-applicable alternatives are waste material excavation and relocation to a repository, fly ash grouting of underground mines, In-Situ Bioremediation, Sulfate Reducing Bioreactors (SRBs), and AML Enhancement Rule removal of coal waste. These alternatives are the preferred removal actions at various locations within the 4 Areas. Remining is a desirable alternative for at least 1 location but its viability depends on the market value of the coal at the time of implementation and the ability to obtain required permits and approval to surface mine on National Forest System Lands. Depending upon the results of an on-going pilot study, an In-Situ Bioreactor could be the most desirable alternative at one location, with potential applicability in other deep mined areas. Fly ash grouting, Sulfate Reducing Bioreactors, and AML Enhancement Removal may be applicable and desirable at several locations. The Daniel Boone National Forest proposes to use an adaptive management approach to implement a variety of the recommended removal actions at applicable locations as funding, designs, materials, and other resources are available. The adaptive management approach will allow the Forest Service to make incremental improvements leading to various completed removal actions. Additionally, using adaptive management will allow the Forest Service to verify the effectiveness and costs of the implemented removal alternatives to inform future actions.

1. INTRODUCTION

This document is an Engineering Evaluation/Cost Analysis (EE/CA) for non-time-critical removal actions at the Wildcat Branch/Addison Branch Mines Site (Site) in the London Ranger District of Daniel Boone National Forest, Kentucky. In accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA), the United States Department of Agriculture Forest Service (USDA FS) has chosen to consider the remediation of the Wildcat Branch/Addison Branch Mines Site by conducting non-time-critical removal actions.

- This EE/CA is being performed by the USDA FS under its cleanup authorities (42 USC 9604(a), 7 Code of Federal Regulations (CFR) 2.60(m) and Federal Executive Order 12580). The purpose of this EE/CA is to evaluate technical approaches and recommend an alternative to minimize or eliminate any release or threat of release of a hazardous substance into the environment or impact on public health and welfare as outlined in 40 CFR 300.415(b)(2)(i)-(viii).
- This EE/CA has been prepared utilizing the U.S. Environmental Protection Agency (EPA) “Guidance on Conducting Non-Time-Critical Removal Actions under CERCLA” in accordance with the provisions of National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 CFR 300.415(b)(4)(i).
- The purpose of a removal action is to “abate, prevent, minimize, stabilize, mitigate or eliminate the release or the threat of a release” (40 CFR 300.415). The EE/CA for a removal action is intended to:
 - Satisfy environmental review requirements for removal actions;
 - Satisfy administrative record requirements for documentation of removal action selection; and
 - Provide a framework for evaluating and selecting alternative technologies.
- To meet those purposes, this EE/CA identifies objectives for the removal action and evaluates the effectiveness, implementability, and cost of various alternatives that may satisfy these objectives.

The Site is located within the Wildcat Branch and Addison Branch watersheds, which are sub-watersheds of the Cumberland River watershed. The Wildcat Branch watershed has been identified by the State Unified Watershed Assessment as a priority watershed / sub-basin and is listed in the Kentucky 305(b) Report to Congress as a 303(d)-listed stream as “impaired” for its intended uses (KDEP 2006). This listing was assigned because of low pH, heavy metals loading, and stream sedimentation resulting in degradation of aquatic resources and other beneficial uses. Additionally, the Nature Conservancy classifies this watershed as a “Critical Watershed” to conserve at-risk fish and mussel species.

The USDA Forest Service conducted a Preliminary Assessment (PA) of the Site in 2004 (USDA 2004) that assessed the threat posed by four primary waste source areas associated with coal mining operations conducted there beginning in the 1800’s and continuing for most of the 20th century. Additional sampling was then undertaken in support of a Site Inspection (SI), completed in 2008 (USDA 2008) and an Expanded Site Inspection (ESI), that was completed in 2015 (USDA 2015) to further assess the extent of hazardous substance and pollutant or contaminant releases within the project area.

1.1 SITE DESCRIPTION

The Wildcat Branch/Addison Branch Mines Site (Site) encompasses approximately 2636 acres (4.1 square miles) in Southeastern Kentucky and includes four primary waste source areas (A-D) that are associated with coal mining operations conducted from the 1800s to the 1970s (Figure1-1). The four

areas range in size from 363 acres for Area B to 960 acres for Area D. The Site is approximately five miles south of the community of Mount Victory, in Pulaski County, along Bear Wallow Ridge and located on the Hail, Kentucky USGS quadrangle. Its approximate center point is at 36°58'42.6" N, 84°25'05.2" W. Due to its relative proximity to the unincorporated community of Mount Victory, the Site is also commonly referred to as the Mt. Victory Mines Site.

The Site is part of the Cumberland River watershed, which is highly valued for its recreational usage and natural beauty but is also one of the areas within the Commonwealth of Kentucky most heavily impacted by acid mine drainage (AMD). The Cumberland River watershed straddles the border between Kentucky and Tennessee and covers about 18,000 square miles. The Cumberland River has been impounded and forms Lake Cumberland, a U.S. Army Corps of Engineers Flood Control and Recreational Reservoir. The area has a mean annual precipitation of 50 inches (127 cm), of which 15 inches (38 cm) is snowfall. Wildcat Branch and Addison Branch discharge to the Cumberland River upstream of Lake Cumberland.

Sub-watersheds affected by the AMD discharges from the Site are Wildcat Branch, located west of Bear Wallow Ridge, and Addison Branch, located southeast of the same ridge. These sub-watersheds cover approximately 2.60 square miles (1660 acres) and 1.49 square miles (950 acres), respectively (Figure 1-2). Both streams flow into the Cumberland River at approximate river miles 540 and 542 and contribute AMD to the River. A portion of a small, unnamed tributary to the Cumberland River northwest of Wildcat Branch and adjacent to Area A is included due to the presence of past mining activities, presence of AMD, and proximity to Wildcat Branch. Two additional small, unnamed tributaries to the Cumberland River, located between Wildcat Branch and Addison Branch are also included and assigned in part to each watershed. These small watersheds are split between Area C and Area D, and though there was no historical mining activity in this area, it is included due to the proximity to the mining impacted areas and potential use in mine reclamation activities.

The flow of AMD in dry and normal conditions is in the form of perennial seepages from many of the portals and adits of abandoned mines. During wet weather, there can be substantial surface flows from mine openings and through mine spoil piles. Streams receiving AMD are characterized by low pH, elevated concentrations of iron, manganese, aluminum, other heavy metals, and sulfates, and the accumulation of iron hydroxide ("yellow boy") on the stream bottoms. Aquatic life is absent from these reaches of the streams and tributaries.

1.2 SITE HISTORY

The Cumberland River region in Kentucky has been extensively mined for coal since the turn of the 20th century, using both surface mining and underground (deep) mining techniques. The deep mining activities created entries (portals / adits) along the various coal seam outcroppings in the steep slopes along the River and tributary streams. The waste materials from these mines were generally deposited in uncontrolled dumps near the mine entries. Surface mining operations left waste piles of overburden mixed with unrecovered coal over large areas, often called valley fills. The waste piles from both sources are unlined and uncapped.

The USDA FS began purchasing land in the Cumberland River watershed in the late 1930s. On these acquired lands, a number of coal mines were inadequately reclaimed after closure. These sites had both open and collapsed underground mine portals, large acid-forming mine waste piles, and many produced AMD. The areas were mined up until the late 1970s.

In the Wildcat Branch/Addison Branch Mines area, the primary coal seam is referred to locally as the Stearns #3 coal. This coal is similar in characteristics to low grade Stearns #2 seam coal, which has very

high sulfur content relative to other coal seams. Hard pockets of sulfurous material are found in the upper margin of this seam, which is topped by soft carboniferous shale. The Stearns #2 and #3 seams have historically produced AMD on a perpetual basis. This coal has variable chemistry, but pyrite-enriched zones (containing large amounts of sulfur) appear common in localized deposits and, where found in contact with surface water runoff and groundwater, produce very acidic flows with elevated heavy metal concentrations. When used as a fuel source for coal-fired power generation, the resulting sulfur dioxide emissions can exceed regulatory standards set by the Clean Air Act (CAA). These problems have forced the mining industry to suspend mining of this grade of coal.

1.3 SITE CHARACTERIZATION

The Wildcat Branch/Addison Branch Mines Site is considered as a single site that encompasses four source areas – Areas A, B, C, and D – and their watersheds (Figure 1-1). These areas include, but are not limited to 29 mine portals; various mine related ponds and impoundments; relics of the abandoned mine-related equipment and facilities; 50 acres of poorly vegetated strip mine disturbances; 23.5 acres of unvegetated spoil associated with deep mine faceups, surface mine benches and outcrops; and 4.5 acres of coal refuse. Approximately five miles of stream in the Wildcat Branch watershed have been impacted by AMD from mining activities and features, including approximately two miles of Wildcat Branch and 3 miles of tributaries. Approximately three miles of stream in the Addison Branch watershed have been affected by AMD, including 1.6 miles of Addison Branch and 1.4 miles of tributaries. An AMD impacted unnamed tributary to the Cumberland River located in Area A is approximately 0.4 miles in length.

Table 1-1 provides information for the four source areas including an estimate of the area covered by coal waste piles and hollow fills. All of the coal seams of interest were above the groundwater table, with the closest seam being about 20 feet above the water table in Area B, in the upstream portion of Wildcat Branch.

The four source areas are described in the following sections and shown in Figures 1-3 through 1-6.

1.3.1 Area A

Area A is located in the northwestern most portion of the Wildcat Branch watershed and spans approximately 737 acres from the headwaters of Wildcat Branch to the confluence with the Cumberland River (see Figure 1-3). Area A also includes a portion of a small, unnamed watershed that contributes directly to the Cumberland River. Approximately 150 acres are directly impacted by AMD-producing coal waste. Area A has been contour strip-mined in three large areas with residual mine development waste evenly-graded smooth to blend easily with the surrounding terrain and is generally composed of valley/hollow fills surrounded by high walls, which are the unreclaimed final cuts made by the stripping operation. However, the surface mined areas are only 50 to 60 percent vegetated with herbaceous, non-woody materials such as broomsedge, grasses, forbs and invasive weeds. As such, the surfaced mined areas are a continuing source of sediment and pollutants to Wildcat Branch, its tributaries, and to the Cumberland River. Area A also includes at least 5 ponds associated with mining or past reclamation projects that show varying impacts of AMD and the potential for failure.

Area A has been impacted by approximately 87 acres of underground mining and approximately 150 acres of surface mining. One deep mine operated by Mt. Victory Coal Company produced 113,665 tons of coal. Approximately 26 acres of coal reserves were mined by room and pillar method. Of the 230 coal pillars created, 127 were removed on retreat mining, leaving about 25 percent of the coal reserves within the mined area. This mine generates a substantial flow of AMD, where most of the mine effluent is surfacing at the location of the portals below the high wall and as seeps along the shoulder of the strip-mined benches below.

Area A was surface-mined by the Mount Victory Coal Company under Permit Number 4047-74. Mining

was last active in 1975. The bond of \$10,200 was forfeited on July 21, 1980, and the permit area was partially reclaimed by the Commonwealth of Kentucky in the spring of 1981. Approximately 74 acres in the northwest portion of Area A were surface mined by Wash Ridge Coal Company between the years of 1984 and 1990, under Permit Number 900-0016. The deep mine operated by Mount Victory Coal Company (Victory #3 Mine, Permit Number O3281) ceased production in 1977 and submitted the final mine map to the Kentucky Department of Mines and Minerals (now Division of Mine Permits) in August, 1980.

1.3.2 Area B – The Bear Wallow Complex

Area B, called the Bear Wallow Complex, contains about 363 acres located at the head of the east fork of Wildcat Branch, and is partially contiguous with Area A and Area C (see Figure 1-4). The entirety of Area B has been deep-mined to a large extent. The northern portion contains at least four portals, two of which were closed in 2014 using USDA FS AML safety funding. One of the open portals is 15 feet by 4 feet and drains a substantial flow of AMD. Additionally, this portion contains two acres of refuse up to three feet thick. The eastern section includes at least 3 open portals, 6 feet by 4 feet, and one acre of coal refuse in need of reclamation. Along the lower slopes facing Wildcat Branch, are numerous collapsed underground mine portals, four of which were closed in 2014 with USDA FS AML safety funding, and a contour strip bench. The southern portion of Area B is a wide contour bench and hollow fill that forms a large, flat area. One open portal (8 feet by 4 feet) is on the east side of the hollow that was an entry for the underground mine, and another portal (15 feet by 3 feet) is on the west side that provided entry to an underground mine that inter-connects with mine entries on the other side of a spur ridge to the south off Bear Wallow ridge, along an unnamed tributary to Wildcat Branch. There are approximately ten acres of barren to poorly-vegetated coal refuse at this location (hollow fill); including one shallow impoundment of AMD impacted water about 75 feet by 150 feet in extent.

Area B has been impacted by approximately 200 acres of underground mining and approximately 80 acres of surface mining. The southern and western portions in Area B were deep mined by the Cumberland River Coal Company, Mine #1 and Mine #2, which were last active in 1976. The four portals in the southeastern portion of Area B, opposite Mine #2 were from deep mine operations by the Mount Victory Coal Company's Victory Mine #1, which was also last active in 1976. The easternmost portion of Area B was deep-mined by the Blevins Coal Company and was last active sometime between 1950 and 1955. The northernmost portion of Area B was disturbed by deep mine operations in the Stokes Mines, which were last known to be active between 1950 and 1955. Additionally, 44.4 acres were surface mined (contour and auger) and 33 acres were underground mined by Wash Ridge Coal Company between 1985 and 1987, producing 38,000 tons of coal under Permit Number 900-0022, and 1.4 acres were surface mined by Rondo Coal Company in 1984, producing 8,400 tons of coal under Permit Number 900-0017.

1.3.3 Area C

Area C contains approximately 576 acres of the Wildcat Branch watershed, south of Area B and between Area A and the Addison Branch watershed (Area D), extending to the confluence with the Cumberland River. (See Figure 1-5). Area C also includes a small, unnamed tributary to the Cumberland River that is not impacted by historic mining, but is included due to its proximity to Area C and potential for use in reclamation activities. A deep mine face-up on the north bench has four portals, one of which collapsed and three that were closed in 2014 using USDA FS AML Safety funding, including one wildlife accessible closure. These entries inter-connect with entries adjacent to the hollowfill in Area B to the north. To the immediate east of these open portals, the area was stripped and augured in the mid-1980s and reclaimed. Two additional closed portals (also 4 feet by 12 feet) are located on the south bench. The remnants of a 25-foot by 25-foot concrete block building are also found here. The mine portals to the east and south of the drainage have been backfilled and the face-up areas returned to approximate original contour. Approximately four acres of bench and two acres of outslope are found at the northern portion of Area C. The bench is 100 to 200 feet wide and slopes gently. It was used as a coal stockpile area in addition to a

mine waste area. Outcrops are short, but steep. Bench and outcrop areas are becoming increasingly populated with scattered annual and perennial weeds, hardwood trees, and pine species due to recent successful revegetation efforts. The spoil is a mixture of sandstone, shale, and coal refuse with high acid producing potential (i.e., > 17 tons agricultural lime/1,000 tons of waste). This spoil pile is estimated to contain approximately 12,000 cubic yards of marketable coal refuse, however, mine seepage and precipitation are generating highly contaminated leachate that flows into Wildcat Branch and contributes to its status as a Kentucky 303(d) listed impaired stream.

Area C has been impacted by a total of approximately 50 acres of underground mining and approximately 12 acres of surface mining. The northeast portion of Area C was extensively deep-mined by the Cumberland River Coal Company and was last active in 1976. Deep mine operations on the north side of the hollow were known as Mine #2 and those on the south side of the hollow were known as Mine #1. This mine extends extensively into Area D to the southeast. Additionally, 7 acres, centrally located in Area C, were deep mined in 1985 by Dark Diamond, Inc., producing 5,000 tons of coal under Permit Number 900-5001, 2 acres located south of the main road were surfaced mined by T. Davenport in 1983 under Permit Number 900-0011, and 2 acres located north of the main road were surface mined by B. Perkins in 1984 under Permit Number 900-0013.

1.3.4 Area D

Area D contains approximately 960 acres, located in the Addison Branch watershed, and reaches 1.5 miles north from its confluence with the Cumberland River (see Figure 1-6). Extensive underground mining was performed in Area D, with multiple mining impacted areas, including at least eight open portals at four locations. Area D also includes a small, unnamed tributary to the Cumberland River that is not impacted by historic mining, but is included due to its proximity to Area D and potential for use in reclamation activities.

Area D has been impacted by approximately 215 acres of underground mining. The northernmost portion of Area D is immediately south of the Cumberland River Coal Company Mine #1 that extends into Area C and was last active in 1976. This area contains at least 3 portals. The furthest upstream portal has a high flow of AMD (>100 gpm) that discharges directly to Addison Branch. There are 2 impacted underground mining areas further downstream. The first area, above the confluence of the East and West Forks of Addison Branch and at the end of an old haul road, was mined by the Mt. Victory Coal Company in the mid 1960's. This area contains at least two open mine portals, of which the northern-most is about 8 feet by 4 feet. There is a concrete fan house, with a 3 feet by 3 feet opening about 150 feet to the south. One acre of coal refuse, scattered timbers, and other mining debris are also found here. The second, southernmost impacted area is below the confluence and was mined by Black Diamond Coal Company (formerly Addison Branch Coal Company) in the 1950's. This area contains at least three open portals, six metal mine cars, and one-half acre of coal refuse. The portal openings range in size from 6 feet by 4 feet to 15 feet by 4 feet and AMD drains steadily from the middle portal. It was here during a prescribed burn by the USDA FS in March 1996, that the coal refuse caught fire and burned from March to November that year.

1.4 PREVIOUS INVESTIGATIONS AND REMOVAL ACTIONS

1.4.1 Previous Investigations

The USDA FS conducted a PA of the Site in 2004 (USDA 2004) that assessed the threat posed by four primary waste source areas associated with coal mining operations conducted there during most of the 20th century. Additional site sampling was then undertaken in support of a Site Inspection (SI) report that was completed in 2008 (USDA 2008).

In 2006, BAT Associates prepared a draft EE/CA for the site that was never completed. Since the SI had limited sample data, it was determined that additional investigation was needed and the investigation areas

were re-evaluated and significantly expanded. Additional sampling was completed in 2010-2012, and a resulting Expanded Site Inspection (ESI) was completed in 2015 (USDA 2015).

1.4.2 Previous Removal Actions

The USDA FS and others have made efforts to reclaim the watershed and remediate the sources of AMD in the Wildcat Branch and Addison Branch Watersheds. The consensus among those involved with the restoration efforts is that the problems are complex, complete remediation will be costly, multiple removal actions at the various sources and sites must be considered together for a comprehensive solution, and long-term monitoring and maintenance must be performed.

Projects Nos. 1, 2, and 4 are all located within the Wildcat Branch watershed. All of these projects represent “at-source” or “passive” treatments of AMD, as they were designed to duplicate natural processes. They all required less long-term maintenance than more conventional active treatment systems that utilize neutralization by addition of a base, oxidation of ferrous iron by aeration, and removal of iron by precipitation. Some of these removal projects have been successful over the short term using this approach, while others have not. Project locations are shown in Figure 1-7.

1.4.2.1 - Project No. 1

Project No. 1 is located in Area C, which was first strip- and auger-mined for coal in the 1960s. Another mining company later re-permitted this area and opened an underground mine, which operated until the late 1980s.

Project No. 1 involved re-grading five acres of an acid-forming strip mine and underground coal mine development waste, which was inadequately reclaimed prior to acquisition of the property by the USDA FS. The re-grading was intended to establish favorable contours for improved drainage, followed by revegetation and construction of Best Management Practices (BMPs) for water treatment. Specific actions included: (1) blending agricultural lime with the mine waste to help neutralize high acidity (lime requirement of 17 tons/acre-foot; total potential acidity of about 45 ton/1,000 tons of waste); (2) construction of two small wetland basins and one anoxic limestone drain for remediation of AMD with pH 3.5 and total iron values greater than 100 ppm (mg/L); (3) construction of about 1,300 linear feet of limestone riprapped ditch with 13 riprap check dams to improve water quality by boosting pH values, precipitating heavy metals, and trapping sediment; and (4) covering of the mine waste with soil and revegetation.

Acid mine flows at the Project No. 1 location are seasonally intermittent, ranging from near zero to about 30 gallon/minute. Topsoil was obtained from various locations near the project for use in covering all exposed acid/toxic mine spoil to a sufficient depth to support revegetation.

The project was designed and constructed using USDA FS funds and was completed in Fiscal Year (FY) 1995. After 20 years, some of these restoration techniques continue to be successful. However, some techniques no longer work effectively due to lack of maintenance or because the iron coating on the limestone rock has minimized its buffering capacity. Additionally, no technique was built to manage the mine water flowing through the pile, except for short-term buffering by limestone rock, and, as discussed above, this mine water is laden with many contaminants. Seepage and precipitation are generating a highly contaminated leachate that flows into Wildcat Branch. Currently, the coal pile is vegetated by grasses, shrubs, and young hardwood and conifer trees.

1.4.2.2 - Project No. 2

Project No. 2, which is located in Area A, involved land treatment of a strip mine last active in June 1976,

on which the Reclamation Bond was forfeited in July 1980. The site was partially reclaimed in the spring of 1981, but the bond was not sufficient to re-establish vegetation and remedy pollution problems from AMD. The site had poor vegetative cover on the mine bench and slopes below due to exposed acid-forming/toxic mine development waste and the influence of AMD. This project involved construction of a number of drainage control/remediation technologies. These included:

- Construction of a pond/wetland basin for bio-remediation (rated at a flow of 30 gallons/minute);
- Construction of a pond to create a clean water source, the discharge from which passes through a buried anoxic limestone drain (ALD), to boost the alkalinity of the flow to the bio-remediation pond below;
- Reduction in the grade of steep slopes covered with mine spoil located on the down-slope of the highwall and on the mine bench to establish favorable contours for drainage and revegetation;
- Blending of agricultural lime with the mine spoil to buffer high acidity;
- Placement of quality topsoil as a cover of the mine spoil to support revegetation;
- Construction of ALD extending from draining mine portal (middle adit) to the bio-remediation pond;
- Construction of ditches lined with limestone and soda ash briquettes (Na_2CO_3) to boost alkalinity within the treatment pond; placement of two limestone diversion wells to receive anaerobic AMD via plastic pipe from near the bottom of the bio-remediation treatment pond in order to provide additional alkalinity, for the purpose of further promoting precipitation of heavy metals; and
- Construction of a principal diversion ditch to convey flow from the diversion wells to the stream below.

This project was designed and constructed using FS funds and was completed in FY 96. The above technologies have proven unsuccessful for a variety of reasons, including lack of funding for maintenance. Additionally, the technologies used are more suited to AMD with higher pH and lower metal loading than that encountered at Wildcat/Addison Branch.

1.4.2.3 - Project No. 4

Project No. 4, the most recent of these three projects, was undertaken in Area B with assistance from the U.S. Department of Interior's Office of Surface Mining (USDIO OSM). The project, known as "Wildcat Branch Mine Reclamation Project No. 4", was completed in July 1999. The USDA FS implemented this project at an un-reclaimed underground coal mine, which suspended operations in the 1950s prior to its acquisition by the USDA FS. The affected area was poorly vegetated due to the presence of exposed acid-forming/toxic mine spoil and AMD from two of the three open mine portals. Typically, the flow from the two portals is characterized by a pH of 2.6, 200 ppm iron, and 1200 ppm sulfate. The combined flow rate averages about 40 gallons/minute.

This project was designed and constructed to provide an environment capable of enhancing oxidation, hydrolysis, precipitation and complexation reactions for metal removal, as well as augment reductive/dissolution processes for alkalinity production. The objective of the project was to reduce the toxicity of the mine drainage in order to reduce impact on the downstream benthic communities and the dependent fishery population. In addition, two open mine portals were gated to keep the public out (i.e., to protect the trespassers from hazards of rock fall and potentially dangerous air quality), while maintaining their use by bats (including the Indiana bat, a threatened and endangered species).

In addition to improving water quality, another goal of this project was to revegetate about five acres of acid-forming/toxic mine spoil and treat the AMD. To accomplish this, the following tasks were completed:

- More than 3,000 cubic yards of acid/toxic mine spoil was removed, treated with agricultural lime to

- buffer acidity, buried and covered with soil in an adjacent repository;
- A plastic-lined aerobic lagoon (settling basin) connected to anoxic limestone under-drain was constructed;
- Three ponds in series with one another were constructed, one serving as a clean water source, one as a settling basin, and one as an aerobic wetland; and
- An abandoned collapsed wooden coal tipple/load-out structure was removed.

These activities required approximately 5,000 cubic yards of excavation and embankment construction. The settling basin and wetland were constructed with a successive alkaline producing system (SAPS) utilizing plastic pipe installed beneath a bed of crushed limestone in the lower pond to boost alkalinity of the mine drainage before discharge into Wildcat Branch. In addition the project required placement of approximately 1,000 cubic yards of riprap and other crushed stone products, installation of 528 linear feet of perforated PVC pipe, application of 150 tons of agricultural lime, and placement of 180 rolls of erosion control blanket.

Approximately \$115,000 was expended on this project. A Cooperative Agreement with USDI OSM (\$100,000 Grant) provided the primary financial support of the project.

Project No. 4 has yielded mixed results in the 15 years since its completion. The repository remains high and dry and appears to be functioning properly. Gates installed in 1999 were removed by vandals, so two of the three portals were closed in 2014 for safety purposes; however, the third was left open due to the large volume of AMD discharging from the opening. The alkaline producing system failed due to design flaws and lack of funding for maintenance and repairs.

1.5 SOURCES, NATURE, AND EXTENT OF CONTAMINATION

The primary sources of AMD are the coal and acid producing materials in the flooded mine chambers and the coal waste piles that lie within the watersheds of Wildcat Branch and Addison Branch. The water flowing from the mine portals and rock fractures and the seepage and runoff from waste piles is often an acidic, metal-laden leachate. The specific characteristics of this water can be highly variable depending upon the properties of the sulfide-bearing source materials, the types and concentrations of heavy metals, and the characteristics of the contacting water. Contaminated mine drainage generally has low pH and elevated concentrations of soluble iron, manganese, aluminum and lead. Contaminated mine drainage also typically has a high suspended solids concentrations as a result of ferric hydroxide precipitates and their associated slow settling velocity.

The AMD from the Site has adversely impacted water quality from where the drainage first enters Wildcat Branch and Addison Branch to their confluence with the Cumberland River. This is a total affected distance of approximately five (5) stream miles. Impacts are not as evident in the Cumberland River due to the dilution of the stream discharge by the high volume of river flow.

1.5.1 Solid Waste Sampling

The USDA FS has sampled coal waste piles in two locations within the area of concern. One survey was performed in the 1990s on coal refuse materials at the Site, for which measurements were made of total potential acidity and total neutralization potential. The second sampling event was performed at the Site on mine spoils in the 1990s. This event included analyses of several key parameters. The results of these surveys are available in the SI (USDA 2008) and are summarized below.

1.5.1.1 - Coal Refuse Samples

Coal refuse is the waste material separated from freshly-mined coal after it is excavated from the pit or

brought from underground. Coal refuse is commonly composed of carbonaceous shale, claystone, bone coal, and minor to substantial amounts of “good” coal (EPA 2000). In the Wildcat Branch/Addison Branch Mines Site, this refuse is usually pyritic and acid-forming (correspondence with G. Chalfant, 1/27/06). The coal refuse samples from the Site were evaluated using the acid/base account procedure which compares the total potential acidity (TPA) and total neutralization potential (TNP) to determine whether the material is potentially toxic. If the net acidity (i.e., TPA minus TNP) is five tons/1000 tons or more (CaCO₃ equivalent) then the material is considered toxic.

The net acidity for all samples is greater than the five-tons/kiloton threshold. Therefore, all of the materials tested are unsuitable for use as topsoil or for revegetation.. Moreover, successful revegetation of the waste piles from which the samples were taken will require the spoil materials to be isolated from contact with the root zone of the plants.

1.5.1.2 - Mine Spoils Samples

The second sampling of mine spoils at the Site was performed in conjunction with Project No. 4 at Area B (see Section 1.3.2.3 above). Mine spoils are the overburden strata (rock) broken up during the course of surface mining and replaced once the coal is removed. Particle sizes in the backfill (spoil) range widely, from clay-size to cobble and boulder (EPA 2000).

Spoils at two depths (0-in to 6-in and > 6-in below ground surface) were sampled and analyzed for selected parameters. In addition, testing determined that the relative availability of nutrients to plants at all depths was very good for aluminum, iron, and manganese, but low for calcium. Also, the projected lime requirement to raise the existing 2.4 pH of the soils to greater than 6.4 pH units was 23 tons per acre, for an assumed mixing depth of 6-inches. Complete analytical results are available in the SI (USDA 2008).

1.5.2 Groundwater Sampling

Groundwater conditions at the Site are not well documented and no groundwater samples were collected during the PA/SI. There are no domestic groundwater wells located within the Wildcat/Addison Branch Mines Site.

1.5.3 Sediment and Soil Samples

On November 16, 2004, BAT performed sediment and soil sampling within the four mine areas. BAT collected five sediment samples from the mine seeps and ten soil samples, at depths from 6”-12”, from various mining spoil areas located throughout the four waste areas. The locations of the samples are described in the SI report (USDA 2008). Sample locations were determined based on previous site reconnaissance, site visits and existing site conditions during this SI.

Analytical data indicate high concentrations of metals, particularly iron for the sediment samples. Iron levels range from 20,900 parts per million (ppm) in Area D to 259,000 ppm in Area B. Low pH and increased sulfate concentrations are also present in the sediment. These data indicate that the sediment at the mine seep locations has been impacted by AMD.

Data from the spoil/soil samples indicate high concentrations of iron and aluminum. The pH values were low, ranging from 4.9 to 2.3. Sulfates ranged from a non-detect in Area D (WB-P-09-01) to 49,200 ppm in Area C (WB-P-06-01). These data suggest that the coal spoil piles located throughout the four areas of concern contribute to the source of AMD within Wildcat Branch. Complete analytical results are available in the SI (USDA 2008).

In May 2009, a Geoprobe was used to collect continuous cores from the Area C coal refuse pile. The purpose was to define the quality (to burn for power production) and volume of the refuse in this pile. Analyses of the various cores were performed by East Kentucky Power Cooperative (EKPC) in Winchester, Kentucky. The ranges of results were as follows: 12.8% to 14.9% moisture, 31% to 55% ash, 2.4% to 5.8% sulfur, 4121 to 7371 BTU values “as received,” and 4724 to 8662 dry BTU values.

The EKPC also analyzed a composite sample of the same coal refuse material to determine trace elements on a dry basis. The purpose of this sample was to confirm that burning of this coal refuse would comply with their air quality permit at their fossil power plant. In summary the results were as follows: arsenic 11 mg/kg (or parts per million, ppm), barium 105 ppm, beryllium 60 ppm, chromium 36 ppm, copper 10 ppm, lead 26 ppm, manganese 46 ppm, mercury 0.25 ppm, vanadium 42 ppm and zinc 32 ppm. The remaining elements were below the detection limits.

1.5.4 Surface Water Sampling – 2008 Site Inspection

Several sampling studies have documented releases, especially of heavy metals and acidity, directly or indirectly to surface water bodies in the Wildcat Branch and Addison Branch watersheds. One study was conducted jointly by the Natural Resources and Conservation Service (NRCS) and USDA FS personnel in 2000 and 2001. Sample locations were selected based on observable or potential AMD impact near dams, pipe conveyances, or mine adits. This study generated water quality data typical of that resulting from AMD and showed dramatic effects on quality as water passes through mine waste piles. These effects are primarily in the form of reduced pH and elevated metals, such as iron and manganese, and sulfate concentrations, often far greater than water quality criteria limits. Data from mine spoil waste pile seepage also confirm increased sulfate and heavy metals loading.

Similar water quality data from limited water quality sampling during a coal mine features inventory study of 18 seeps, portals, and pond outfalls conducted by the Tennessee Valley Authority (TVA) in the Wildcat Branch Mines area confirm these findings (TVA, 2004). These results confirm low pH values and elevated conductivity, acidity, hardness, aluminum, cadmium, iron, lead, and zinc concentrations. Complete analytical results are available in the SI (USDA 2008).

1.5.5 Surface Water Sampling – 2015 Expanded Site Inspection (ESI)

Additional sampling and analyses were performed for the completion of an Expanded Site Inspection (ESI) for the Wildcat Branch and Addison Branch Mines areas in 2008-2012 (USDA 2015). Historical and recent field data and laboratory analytical results evaluated in the ESI (ESI Figure 12) are captured in the following five data sets, chronologically:

- November 6 to December 19, 2002 -- a coal mine features inventory and associated water quality data (TVA 2002); this data set emphasized the location of coal mine features and evaluation of sources; note that for these data, a number of heavy metals were not selected for analysis (18 samples), and some minimum detection levels (MDLs) for specific metals were not low enough to capture State and Federal criteria levels, thus providing results that could be considered false non-exceedances;
- June 2 – 6, 2008 -- measurement of surface water flows from various sources as well as the potentially impacted streams (several of the sources from the 2002 sampling were revisited without the further attempt to capture all of the associated, updated physical observations (17 samples));
- March 2 – 4, 2010 and March 29 – 31, 2011 – baseline data collected in support of a planned field treatment study for the cleanup of an underground mine by use of in-situ bioreactor technologies (20 samples);
- April 26 – 30, 2010 -- sample data from locations unrelated to the bioreactor study; for this data set

- a greater emphasis was placed on area streams (37 samples); and
- March 31, 2011 -- sample data from a previously unsampled surface-mined area in the western portion of area A (4 samples).

A record of the location of the various sample points by area is presented in Table 1-8. Complete sample results and analytical data are available within the ESI (USDA 2015).

Overall, almost all of the regular (non-background) samples collected from the Site showed evidence of AMD, i.e., low pH (< 6.0), elevated conductivity values, elevated sulfate, Al and Fe concentrations, and elevated heavy metal concentrations.

More importantly, for almost 87 percent of the regular samples, at least one heavy metal concentration exceeded the applicable criterion, indicating a hazardous substance release. Also, on this basis, each of the 4 areas showed some level of hazardous substance release. For the most heavily sampled areas, hazardous substance releases were observed for 100 percent of the 21 samples from Area A, and 81 percent for those (30 samples) from Area B. The elevated heavy metal concentrations indicating these hazardous substance releases were most commonly for Be and Ni, and to a lesser extent for Cd. Tabulations of the concentrations of the metals and other constituents in comparison with the applicable criteria are presented and discussed in greater detail in the ESI (USDA 2015).

1.6 STREAMLINED RISK EVALUATION

This chapter identifies the hazards that the contaminants from the Wildcat Branch/Addison Branch Mines Site present to the public health, welfare and the environment based on criteria established by federal regulations and USDA FS guidelines. A conceptual site model based on the potential contaminant migration pathways is also described.

1.6.1 Hazards of the Contamination

The USDA FS has determined that conditions at the Wildcat Branch/Addison Branch Mines Site represent a threat to public health, welfare or the environment as defined under both Section I of the Forest Service Guide to CERCLA (USDA 1996) and Section 300.415(b)(2) of the National Contingency Plan (NCP). The following criteria are the basis for this determination.

1. Actual or potential exposure to nearby human populations, animals, or the food chain from hazardous substances or pollutants or contaminants.

The resultant low pH and elevated metals concentrations have rendered the water seeping either directly or via streams into Wildcat Branch and Addison Branch unfit for drinking water usage, the sustainability of a viable fish and other aquatic species populations, and primary and secondary recreation. Recent fish and macroinvertebrate inventories have produced scientific evidence that supports this assessment. A 2014 aquatic insect survey identified a total of 4 aquatic insects, and the stream was given a “poor” rating for aquatic insect habitat. Ideal water quality habitat found in unaffected reaches in the vicinity (such as along Cane Creek to the northeast of the Site) sustains high populations of both fish and macroinvertebrates, such as mayflies, stoneflies, crayfish, caddis flies, and beetles, while Wildcat Branch and Addison Branch exhibit a marked and visible decline in such species. In many locations within the Site, aquatic species are non-existent.

2. Actual or potential contamination of drinking water supplies or sensitive ecosystems.

Because the Wildcat Branch/Addison Branch Mines Site lies within a rural, forested area of low-density population, the traditional source of drinking water for nearby residents has been from private

domestic groundwater wells. Currently, there are no known drinking water sources that rely on groundwater in the down gradient vicinity of the Site. However, AMD water that enters into the nearby karst terrain creates the potential for pollution of the underlying aquifer. Groundwater can travel rapidly through underground karst conduits (up to several miles a day) and contaminants can be transmitted quickly to wells and springs in the vicinity. However, there are no known wells within the vicinity of the Site.

The Nature Conservancy classifies Wildcat Branch as a "Critical Watershed" to conserve at-risk fish and mussel species. These aquatic species, and others, require a moderate pH range of 6.0 to 9.0 and can tolerate only a minimal amount of metals loading, a loading that is consistently exceeded by water in Wildcat Branch.

3. Weather conditions that may cause hazardous substances or pollutants or contaminants to migrate or be released.

The Wildcat Branch/Addison Branch Mines Site receives an annual rainfall of nearly 50 inches, 15 inches of which is snowfall. This high volume rainfall coupled with moderate to steep slope gradients produce increased underground and overland wet weather flow that can cause contaminants and pollutants to be transported and released offsite. Pyritic materials in exposed spoils and coal waste piles are also oxidized and mobilized as acidic runoff.

1.6.2 Contaminant Migration Pathways

The PA, SI, and ESI already completed for the Site (USDA 2004, USDA 2008, and USDA 2015) concluded that releases of hazardous substances, pollutants, and/or contaminants have occurred along the surface water and soil exposure pathways and that the potential of a release exists for the groundwater pathway. These releases are expected from both base-flow (dry-weather) and wet-weather flows of AMD from the sites within the watersheds. This section presents, in narrative form, a conceptual site model that identifies both human and biotic receptors and primary and secondary release mechanisms.

1.6.2.1 - Groundwater Pathway

There are no domestic groundwater wells located at the Wildcat Branch/Addison Branch Mines Site, and future use as a drinking water source is not anticipated; therefore, treatment of groundwater (beyond the mine pools) is outside the scope of these removal actions. If contamination of domestic groundwater is discovered in the future, additional sampling and analysis will need to be completed, and a separate removal/remedial process will be initiated.

There are approximately 24 known domestic wells within a four-mile radius of the center of the Wildcat Branch/Addison Branch Mines Site (USDA 2004). The only testing requirement for private groundwater systems in Kentucky is a bacteria test that must be completed when a well is initially installed (401 KAR 6:310). The Pulaski County Health Department also tests wells upon request. Where contaminants in private water systems are found to be in excess of safe drinking water standards, water treatment may be used to reduce contaminant levels.

The groundwater pathway should be considered potentially threatened by the source waste materials at the Wildcat Branch/Addison Branch Mines Site for the following reasons:

- The high annual precipitation, the highly permeable nature of the soils, and the unlined coal waste piles at the Site allow for a high degree of infiltration of precipitation into the waste piles carrying with it AMD contaminants and low pH water. Ultimately, if the acidic and heavy metal-laden water does not exit near the waste pile and become seepage (or surface) water, it can recharge the groundwater.

- Affected water in the underground mine tunnels enters as groundwater through cracks and fissures in the underlying and/or surrounding rock. AMD can be released either via the subsurface or as a seep/flow out of the mine, and if it exits to the ground surface, eventually it can flow into the surface streams.
- The pyritic nature of the coal waste promotes high acidity (low pH) and, consequently, high dissolution and mobility of metals in the resultant drainage.

1.6.2.2 - Surface Water Pathway

AMD enters local streams from seeps emanating from coal waste and spoil piles and flows from mine portals. In addition, contaminated groundwater can discharge into the streams at some distance from the AMD source.

Both Wildcat Branch and Addison Branch are perennial, swift-flowing mountain streams that collect water from timbered basins before discharging into the Cumberland River. These streams are 3rd-order streams that receive water from groundwater recharge during dry periods. The stream channels are, in large part, bedrock-controlled channels whose form is predominantly shaped by the local geology and only slightly by stream flow. Basin shape – typically rounded in this watershed – directly affects the storm hydrograph for this area and will have implications for the design of hydrologic structures. Under normal circumstances, the two streams (i.e., Wildcat Branch and Addison Branch) do not degrade very quickly and aggrade with sediment buildup only for short periods of time. The banks tend to be vertical with undercuts in some areas. The four specific source areas included in this study lie completely within the catchment areas of these two basins, except for a small strip of land in the western section of Area A that feeds directly to the Cumberland River.

The Wildcat Branch watershed drains an area of approximately 2.6 square miles of predominantly steep terrain with dense forests. The Addison Branch watershed is approximately 1.5 square miles of similar topography. Surface water flow in such steep terrain moves quickly to small rivulets or streams that feed into either stream's main channel. Therefore, drainage produced as leachate from coal waste and spoil piles from each source area is only minutes away from probable point of entry into the nearest 2nd- or 3rd-order stream channel. Although the 100-year floodplain is narrowed by steep gradients along the stream channels, most of the mine areas lie within or drain directly into the floodplain (USDA 2004). Such a hydrologic setting increases the likely transport of contaminants during a high-precipitation event.

The low pH and elevated concentrations of heavy metals have made the water reaching Wildcat and Addison Branches, either directly or via streams, unfit for drinking water usage and unsuitable for the sustainability of a viable fish and other aquatic species populations. Recent fish and macroinvertebrate inventories have produced evidence that supports this assessment (USDA 2004). Ideal water quality habitat that is found in unaffected reaches in the vicinity of the site (such as along Cane Creek to the northeast of this region) sustains high populations of both fish and macroinvertebrates, such as mayflies, stoneflies, crayfish, caddis flies, and beetles, while Wildcat Branch and Addison Branch support very few species and individuals. Some sections of stream within the Site are completely devoid of aquatic life.

Area streams have historically sustained viable and active sport fishery, which is an integral component of the region's tourist appeal. Pollution from AMD has resulted in significant losses to downstream fisheries, periodic fish kills, and lost recreational opportunity, all to the detriment of the local economy.

A total of approximately seven acres of delineated wetlands have been identified in the Wildcat Branch watershed, along with approximately 1.5 acres of delineated wetlands in the Addison Branch watershed. These wetlands are all primary ecological targets and are within a 15-mile downstream distance of the point of entry of contaminants from the Wildcat Branch/Addison Branch Mines Site. These wetlands are of the Palustrine system, with a forested subsystem and broad-leafed deciduous tree coverage and are typically diked or impounded by a man-made barrier and may be flooded temporarily or seasonally with

shallow water depths. The lower reaches of Wildcat Branch, Addison Branch, and the Cumberland River basin itself, have been classified as Lacustrine system wetlands with a limnetic (deep-water habitats) subsystem and permanently-flooded, unconsolidated bottoms.

The surface water pathway must be considered threatened and already severely impacted by the source waste materials at the Wildcat Branch/Addison Branch Mines Site for the following reasons:

- The high annual precipitation at the site allows for a high level of contaminant transport and associated groundwater recharge from precipitation directly through the unlined coal waste piles.
- The uncapped and unlined nature of the coal waste piles allows for hydraulic transmissivity through and across the waste and into adjacent streams and aquifers.
- Data resulting from several surface water studies in the proximity of coal waste areas have consistently shown very low pH and high concentrations of sulfate, metals, and total dissolved solids (TDS) commonly associated with AMD. All such levels represent exceedances of applicable surface water quality standards and/or warm water aquatic habitat criteria.
- A reduction in fish and macroinvertebrate populations in waterways receiving AMD demonstrates the negative effects on natural stream chemistry.

1.6.2.3 - Soil Exposure Pathway

Evaluation of risk from the soil pathway considers the likelihood of soil ingestion, dermal contact, and transport of contaminants via water flowing through the soils. Pyritic and metallic materials contained in loose coal refuse and waste piles must be considered as a potential source. The runoff and leachate from coal waste and spoil piles contribute to the risks associated with the surface water and groundwater pathways.

Soils in the Wildcat Branch/Addison Branch Mines area vary according to elevation because of their relationship to the various relatively horizontal geologic formations. The soils range from sandy to a clay loam, depending on the underlying geology. Soil depth ranges from 0-ft to 8-ft. Most stream-level soils are either Tate stony sandy loam or Tate-Trappist stony complex with a 30 to 50 percent slope. As hillsides rise from streams, the soils grade to Dekalb and Tate sandy loams, with the highest elevation soils being Muse-Trappist silt loam with clay.

The Tate series includes deep soils that are well-drained. It is the most extensive soil in the area and is formed on colluvium, which moved down slope from sandstone and shale bedrock. Tate soils have a high moisture capacity, naturally low pH, and moderate fertility. The Dekalb series soils occupy the steeply sloping areas. Formed in the residuum that weathered from acidic sandstone, these soils tend to be moderately deep and excessively drained.

Vegetation throughout the region is primarily of mixed deciduous and coniferous forests with a diversity of plant communities in the understory. The coal waste piles primarily support growths of Virginia and short leaf pine trees. Black locust trees were planted in years past, but their longevity was shortened to about 20 years, perhaps due to limited nutrient uptake from the coal waste piles.

Targeted populations for the soil pathway are primarily residents and workers within nearby areas. No onsite workers or residents are within 200 feet of the coal waste piles at the Wildcat Branch/Addison Branch Mines site, nor are there any schools or day care centers within the same radius. The only potential onsite populations are recreational users, such as hikers, hunters, and fishermen, who are typically of adult age and are not at high risk from the waste piles.

According to U.S. census data, there are approximately 637 persons living within four miles of the Wildcat Branch Mines site and no one living within 0.5 mile of the site (USDA 2004). One Endangered

Species, the Indiana myotis bat, has been identified in the area (USDA 2004), and several other threatened or endangered species could potentially be in the area, including the Northern Long-eared bat, the Gray Bat, and the Virginia Big-eared bat. Several small (less than five acres in size) wetlands have been delineated in the region impacted by drainage from the Wildcat Branch and Addison Branch Mines (USDA 2004).

The Wildcat Branch/Addison Branch Mines Site poses environmental hazards due to the soil pathway. Though the coal waste piles have been stabilized sufficiently due to age, geology, and vegetative cover that movement of soil itself and risk of dermal contact are minimal, the erosion of coal waste pile materials and water flowing through these piles can easily transport contaminants off site and contribute to the hazards posed by the surface water and groundwater pathways.

1.6.2.4 - Air Exposure Pathway

Evaluation of risk from the air pathway considers the likelihood of soil disturbance that might release fugitive air emissions.

The Wildcat Branch/Addison Branch Mines Site poses few environmental hazards due to the air pathway. The coal waste piles have been stabilized sufficiently due to age, geology, and vegetative cover and the dispersion of fugitive waste dust has not been a problem and is not anticipated to be one in the future.

Targeted populations for the air pathway are primarily residents and workers within nearby areas. There are no onsite workers or residents within 200 feet of the coal waste piles at the Wildcat Branch/Addison Branch Mines Site, nor are there any schools or day care centers within the same radius. The only potential onsite populations are recreational users, such as hikers, hunters, and fishermen, and off highway vehicle (OHV) riders.

The primary risk to air exposure may be from OHV use on the soils associated with coal mines. OHV use is becoming more frequent in these previously mined areas. The undergrowth and ground cover are rapidly being destroyed and removed by frequent trail use and dust then becomes a problem. These dust plumes can carry toxic metals through the air and inhalation of the dust by the OHV users especially during dry periods is most likely the result. These previously underground and surface mined areas at Wildcat/Addison Branches are highly used areas by OHV users; however OHV use is prohibited in many of these areas on the Forest.

2. REMOVAL ACTION OBJECTIVES

The principal objective of the removal action in the Wildcat Branch/Addison Branch Mines Site is:

- To reduce or mitigate the release of AMD, characterized by high acidity (low pH) and elevated concentrations of iron, aluminum, beryllium, cadmium, nickel, and sulfate to Wildcat Branch, Addison Branch, their unnamed tributaries, and groundwater, thereby reducing the potential threat to the public health and the environment from the exposure pathways associated with such releases.

Other objectives include:

- The protection of aquatic life and habitat in Wildcat Branch and Addison Branch; and
- The control of contaminant migration from coal waste piles and mine openings to the surface water, including the Cumberland River, and to the underlying groundwater aquifer.

As will be discussed in Section 3.0, all removal action alternatives being considered for the AMD control in

the Wildcat Branch/Addison Branch Mines Site would satisfy these objectives to varying degrees. However, due to the complex nature of the Site, no alternative will fully satisfy all of these objectives at each site area. Therefore, the final selection of the recommended removal action would balance the effectiveness of each alternative in satisfying these objectives against other decision factors judged to be of particular importance for the problem-specific and area-specific conditions.

2.1 REMOVAL ACTION JUSTIFICATION

According to 40 CFR 300.415(b), a removal action is justified if there is a threat to human health or the environment based on the eight factors listed below:

Factor	Site Condition	Removal Action Justified Based on this Factor?
(1) Actual or potential exposure to nearby human populations, animals, or the food chain from hazardous substances, pollutants, or contaminants.	Public access to gob, sediment, and surface water containing high concentrations of metals and exposure to food chain.	Yes
(2) Actual or potential contamination of drinking water supplies or sensitive ecosystems.	No public water supply but ponds are drinking source for wildlife and sensitive species may inhabit the site; emergent wetlands are present; high metals concentrations in surface water leaving the site and contributing to downstream degradation.	Yes
(3) Hazardous substances, pollutants, or contaminants in drums, barrels, tanks, or other bulk storage containers that may pose a threat of release.	No drums, barrels, tanks, or bulk storage containers on site.	No
(4) High levels of hazardous substances, pollutants, or contaminants in soils largely at, or near, the surface that may migrate.	High concentrations of metals in gob subject to erosion and migration.	Yes
(5) Weather conditions that may cause hazardous substances, pollutants, or contaminants to migrate or be released.	Gob in a stream channel and subject to erosion during high flows, rain events and snowmelt.	Yes
(6) Threat of fire or explosion.	Potential for long term fire from ignition of coal refuse.	Yes
(7) The availability of other appropriate federal or state response mechanisms to respond to the release.	None.	No
(8) Other situations or factors that may pose threats to public health or the environment.	None.	No

2.2 SCOPE AND PURPOSE

The scope of proposed removal actions can be broadly defined as reducing or eliminating the release of AMD and its contaminants of concern from the Wildcat Branch/Addison Branch Mines Site through source removal, treatment, and control. The Site includes four waste areas with a minimum affected area of approximately 104 identified acres and minimum waste area of approximately 22 identified acres, not including hollow fills. As discussed in Section 1.4, contaminants of concern are low pH; elevated concentrations of iron, manganese, and other metals; and elevated sulfate, a necessary component of resulting acidity. In addition, the removal action should decrease or eliminate the accumulation of iron hydroxide (“yellow boy”) on the stream bottoms. It is anticipated that multiple removal actions will be

completed in a phased approach over several years. Selected removal actions will have varying degrees (years to decades) of operation and maintenance, in addition to long-term monitoring for effectiveness.

2.3 REMOVAL ACTION SCHEDULE

The general schedule for removal activities, including both the start and completion time for the non-time-critical removal actions, should be part of the EE/CA (EPA 1993). Although EE/CAs are only required when a planning period of at least six (6) months is available, the nature of the threat may still dictate that action be initiated within 12 months or some other specific time period. The start dates may also be influenced by weather conditions, planning, survey, and design needs, availability of supplies and materials, and funding availability. In view of these uncertain variables, it is difficult to estimate a start date for the selected removal actions.

The completion time is also influenced by such factors as the nature of the threat, the time frame to ensure adequate protection of public health and the environment, the type of removal action, weather, and availability and statutory limits of funding. Again, it is difficult to estimate a completion time in view of the uncertain nature of these factors. For purposes of cost estimating, project duration is assumed to be five (5) years from the start date for each alternative selected, in addition to operation, maintenance, and costs, where applicable.

2.4 IDENTIFICATION OF APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARS)

Throughout any remedial or removal action undertaken pursuant to CERCLA at an abandoned mining and mineral-processing site, the project plan must consider compliance with CERCLA ARARs. ARARs are Federal, State, and local standards that are directly applicable or may be considered relevant and appropriate to the circumstances at the site. Although Section 121 of CERCLA does not require that removal actions attain all ARARs and TBCs, the U.S. EPA policy on removal actions is that ARARs and standards to be considered (TBCs) will be identified, considered, and attained to the extent practicable. USDA FS will comply with this policy.

The ARARs and TBCs for the proposed actions for the Wildcat Branch/Addison Branch Mines Site are listed in Appendix B. These potential ARARs and TBCs are categorized into the following U.S. EPA recommended classifications:

- Chemical-specific ARARs and TBCs;
- Location-specific ARARs and TBCs; and
- Action-specific ARARs and TBCs.

A discussion of each group and its relationship to the proposed action is given below.

2.4.1 Chemical-Specific ARARs and TBCs

Chemical-specific ARARs set health or environmental risk-based concentration or discharge limits in various environmental media for specific hazardous substances, pollutants, or contaminants. These requirements generally set protective cleanup levels for the chemicals of concern in the designated media or indicate a safe level of discharge that may be incorporated when considering a specific remedial activity. The chemical-specific ARARs and TBCs apply to all of the proposed removal actions since the contaminant concentration drives the action level for the implementation of the removal action. The chemical-specific ARARs and TBCs identified for the Wildcat Branch/Addison Branch Mines Site pertain

to acid (H⁺ IONS) and pH and are derived from the Clean Water Act (Water Quality Standards). The chemical-specific ARARs and TBCs, which provide protection from chemical constituents in surface water and groundwater, are used as the basis for the public health and environmental risk evaluation for each alternative.

2.4.2 Location-Specific ARARs and TBCs

Location-specific ARARs set restrictions on the concentration of hazardous substances or the conduct of activities solely because they are in special locations. For example, location-specific ARARs will take into consideration the existence of wetlands or floodplain areas, the presence of threatened and endangered species, and cultural and historical resources that may exist in or be a part of the project site. When an alternative is chosen for a particular mine area, the affected location will be surveyed to determine if any of the location-specific ARARs or TBCs will be applicable.

2.4.3 Action-Specific ARARs and TBCs

Action-specific ARARs specify particular performance standards or technologies, as well as environmental levels for discharged or residual chemicals. All alternatives for removal action involve on-site construction and/or excavation activities necessary to implement the action. Consideration is made regarding fugitive dust emissions, erosion potential from the operation of heavy equipment, and the effects of such activities on the quantity and quality of stormwater discharges. Implementation of good site planning and best management practices to control any stormwater discharges and sedimentation is required.

The table given in Appendix B lists all of the ARARs and TBCs that will be considered by the USDA FS for the various alternative actions proposed in this EE/CA.

3. REMOVAL ACTION TECHNOLOGIES AND DEVELOPMENT OF ALTERNATIVES

3.1 TECHNOLOGY IDENTIFICATION AND SCREENING

A set of potential removal action alternatives was initially screened using a predefined set of criteria consistent with U.S. EPA guidance on conducting an EE/CA. A smaller set of alternatives resulting from the initial screening were evaluated using professional engineering judgment based upon the criteria of effectiveness, implementability, cost, and compliance with site-specific ARARs to the extent practicable. The alternatives will be removal actions to remove, treat, or control either the contaminated water or the source material that produces the contaminated water.

3.1.1 Development of Initial List of Removal Action Technologies

The following types of response actions are generally considered removal actions under CERCLA (USDA 1996, Section I):

- Drainage controls where needed to reduce migration of hazardous substances, pollutants, or contaminants, or to prevent precipitation or runoff from other sources;
- Stabilization of berms, dikes, impoundments, and drainage or closing of lagoons where needed to maintain the integrity of the structures;
- Capping of contaminated soils or sludges where needed to reduce migration of hazardous substances into soil, groundwater or surface water, or air;
- Excavation, consolidation, or removal of highly contaminated soils from drainage or other areas

- where actions will reduce the spread of, or direct contact with, the contamination; and
- Containment, treatment, disposal, or incineration of hazardous materials to reduce the likelihood of human, animal, or food chain exposure.

Technologies that incorporated one or more of these actions and are applicable to coal mining related wastes were considered in developing the initial list of alternatives for evaluation for the Wildcat Branch/Addison Branch Mines Site. The technologies were divided into nine categories as follows:

1. Constructed wetlands
 - a. Aerobic wetlands
 - b. Anaerobic wetlands
 - c. Vertical-flow wetlands
 - d. Sulfate-reducing bioreactors (SRBs)
2. Limestone-based systems
 - a. Limestone-lined channels
 - b. Anoxic limestone-lined drains (ALDs)
 - c. Successive alkalinity-producing systems (SAPS)
 - d. Alkaline recharge/alkaline-producing systems (APS)
 - e. Limestone ponds/settling basins/leach beds
 - f. Diversion wells
 - g. Limestone sand treatment (dosing)
3. Source material removal to a repository or processing facility
 - a. Waste pile removal
 - b. Surface Remining and waste pile removal
 - c. AML Enhancement Rule removal
4. Hydraulic isolation using barriers and seals
 - a. Reactor barrier walls
 - b. Grouting/grout curtains
 - c. Fly ash slurry injection
 - d. Impermeable barriers/mine seals/plugging
 - e. Blasting/collapsing mine chambers
 - f. Plugging mine openings
 - g. Pyrite encapsulation / inactivation
5. Submergence
 - a. Mine chamber flooding
 - b. Area inundation
6. Injection / inoculation of chemicals into mine chambers and coal waste piles
 - a. Bactericides
 - b. Metal precipitating agents
 - c. Flocculating/coagulating agents
7. In-line active treatment of AMD flows
 - a. Pyrolusite[®] treatment system
 - b. Wood filters
 - c. In-situ bioremediation
 - d. In-line aeration and treatment
8. Conventional treatment plants
 - a. Reverse osmosis
 - b. Electrodialysis
 - c. Conventional treatment: neutralization/precipitation/etc.
9. Best management practices (BMPs) of on-site hydrology (typically required of mine closure and remining permits)
 - a. Re-grading of abandoned spoil piles

- b. Revegetation of mine waste piles
- c. Upstream planting to minimize runoff.

All of these technologies are described in Appendix A.

3.1.2 Screening Criteria

FS established five criteria to screen the initial group of candidate technologies in order to select the removal action alternatives that could most likely be applied successfully to the Site. The selected alternatives that passed this screening then received a more detailed evaluation as described in Chapter 4.0 of this EE/CA. The USDA FS criteria are:

1. Will be able to raise pH, reduce acidity, and abate metals contamination (i.e., the technology must be effective).
2. Has space requirements that can be accommodated in the area available at the Site. (i.e., the technology must be implementable).
3. Has proven to be effective in applications with similar AMD characteristics (i.e., the technology must be a proven technology).
4. Minimize annual and recurring maintenance and monitoring.
5. Implementation must be economically feasible, considering estimates of future budgets and other funding opportunities.

Table 3.1 presents an application of the five criteria to each of the listed technologies under initial consideration.

Three categories of treatment technologies were eliminated based on the first criterion because they all would require expenditure of effort and funds throughout their operating life. The categories eliminated were:

- Injection / inoculation of chemicals into mine chambers and coal waste piles (Category 6);
- In-line active treatment of AMD flows (Category 7); and
- Treatment plants (Category 8).

One of these technologies was retained – in-situ bioremediation (Category 7c) – as a pilot project has already been developed for and initiated at the Wildcat Branch/Addison Branch Mines Site.

Category 5, submergence (mine chamber flooding or area inundation), was eliminated due to the long term responsibility, risks, and liabilities associated with dams and reservoirs, in addition to cost estimates that were deemed infeasible for implementation.

Abandoned mines have often yielded AMD for well over a century; the length of treatment period needed is equally extensive (EPA 2000). Two other categories involve passive technologies that would require regular attention, action, and even rebuilding during the lifetime of treatment. These are:

- Constructed wetlands (Category 1); and
- Limestone-based systems (Category 2).

Though annual maintenance and periodic rebuilding are not preferred, these technologies, including periodic maintenance and reconstruction costs may be the most economically feasible and implementable alternatives at some locations. Innovative approaches and combinations of these technologies can reduce the maintenance requirements and provide significant improvements to water quality. Specifically, sulfate reducing bioreactors (SRBs) will be considered due to their applicability to site conditions and economic

feasibility. Additionally, the technologies under Categories 1 and 2 may have applications in a secondary, “polishing” role.

Best management practices (BMPs), such as regrading of spoil piles and planting vegetation upgradient or on the waste sites (Category 9), could be considered supplemental measures, not primary removal technologies. These actions are statutory requirements of most or all remining permits and were retained as closure actions.

The following categories of technologies remained under consideration after the initial screening:

- Category 1 – Constructed wetland systems;
- Category 3 - Source removal to a repository or processing facility;
- Category 4 - Hydraulic isolation using barriers and seals;

The USDA FS then evaluated the technologies in each of these four categories and selected several for more detailed analysis as potential removal actions at the Site. These are described in the next section. All of the above technologies are described and evaluated in Appendix A.

3.1.3 Results of Technology Screening

The USDA FS identified three potential technologies that could be applied to the encapsulation or removal of source materials from the surface-mined (“valley fill”) portions of the Wildcat Branch/Addison Branch Mines Site.

These are:

- Waste pile removal;
- Remining with waste pile removal; and
- Sulfate Reducing Bioreactors (SRBs).

The USDA FS selected five technologies for potential application to the deep mines at the Site:

- Remining with waste pile removal;
- Fly ash slurry injection;
- In situ bioremediation;
- Sulfate Reducing Bioreactors (SRBs); and
- AML Enhancement Rule removal.

The USDA FS also selected three technologies as potential supplemental “finishing” measures to the surface-mined areas and/or deep mines:

- Re-grading;
- Revegetation;
- Constructed wetlands;
- Limestone based systems.

Each of these alternative removal technologies is described in detail in Sections 3.2.1 and Section 3.2.2, below.

3.2 DEVELOPMENT OF ALTERNATIVES

The USDA FS and its contractors will systematically integrate safety into management and work practices at all levels so that the implementation of the removal action is accomplished while protecting the public, the worker, and the environment. This will be accomplished through effective integration of safety and environmental protection management into all facets of work planning and execution.

3.2.1 Description of No Action Alternatives

Typically, the EE/CA process examines a set of no action alternatives as possible decision options. This allows decision-makers and the public a chance to consider the risks of leaving the site in its present condition or providing minimal protective measures by instituting administrative controls.

3.2.1.1 - No Action

The No Action alternative would imply the following:

- The site would remain unchanged from its present condition.
- Natural degradation would occur over time, and the pyrite found in the mine spoils would slowly oxidize and release acid mine water as precipitation and atmospheric oxygen continue to react with the pyrite.
- Seeps would occur at the current rate and would continue to impact Wildcat Branch and Addison Branch, impairing their ability to establish and sustain a macroinvertebrate or fish population.
- Surface water and groundwater in the watersheds would be impaired for recreational usage and remain unusable as a drinking water source.
- No maintenance or other operational costs would be associated with this alternative.

3.2.1.2 - Administrative Controls

The Administrative Controls alternative would include all of the above consequences for the No Action alternative plus the following actions:

- Signage would be placed at stream crossings and other areas where human interaction might occur. Such signage would proclaim the stream unfit for swimming and/or wading.
- Cost associated with the Administrative Controls alternative would be minimal in comparison with removal action alternatives described below.

3.2.2 Description of Removal Action Alternatives for Surface-Mined and Deep-Mined Areas

The USDA FS has identified six technologies for detailed consideration in conducting the removal action related to the AMD source materials associated with the surface-mined and deep-mined spoil and mine areas at the Wildcat Branch/Addison Branch Mines Site. These alternative technologies are described below. At the end of each description, a set of one or more uncertainties associated with the alternative is described. This list of uncertainties is helpful in the overall assessment of effectiveness and/or implementability of the alternative.

3.2.2.1 - Alternative 1 – Waste Material Excavation and Placement in a Repository or Processing Facility (Surface-Mined Areas)

The overburden removed by surface mining was composed typically of net alkaline material. However, waste piles throughout the site are made up of overburden mixed with unrecovered coal and acid shale that can readily produce acid mine drainage when placed in valley fills or other areas where it is exposed to air

and water. This alternative involves excavation, segregation, and removal of potential acid-forming materials, and their placement in a designed “repository” in a suitable location, either adjacent to the existing spoil piles or elsewhere within the Site. This is a proven technology using excavation, isolation, and encapsulation techniques to minimize contact between acid-forming materials and groundwater and surface water runoff.

A limestone base of at least one foot is constructed. The mining waste is typically blended with agricultural lime at a rate that is dependent on waste acid-base accounting (Skousen, et al., 1987) prior to placing above the base. The repository is covered with a compacted sloping cap of clay or other low permeability material at a 2-foot minimum depth.

The installation of a liner or cap creates a “relatively impermeable” barrier overlying the acid-forming material pile to prevent water and oxygen from reaching the sulfide minerals present in the spoil piles. The relatively impermeable barrier is formed either of an earthen or synthetic material that is significantly less permeable than the surrounding overburden. It is only suitable for placement of spoil piles in a repository above the permanent groundwater table and not in or near perennial or intermittent streams.

Design geometry of the cap should reduce the volume of water passing through the cap. A dome shaped cap is used as it tends to “shed” water most effectively. Compaction machinery, such as rubber-tired equipment or sheepsfoot rollers, is required for adequate levels of compaction. Permeability of a cap is affected by grain particle size, mineralogy, and moisture content of the earthen material, the degree of compaction, and the thickness of the lifts. Research has found that a mix of particle sizes - a mixture of fly ash, sand, and clay - results in the highest packing bulk density and lowest permeability (Perry, 1998). Waste placed in the repository must be compacted throughout its construction in lifts no greater than 1 foot, especially during toxic material placement, to reduce voids between rock fragments. The repository must then be buried and covered with the chosen native soil or synthetic barrier as soon as possible.

Moisture-consuming vegetation, such as native grasses and legumes, would be seeded on the cap. A cover of topsoil or approved topsoil substitute, over a relatively impermeable barrier, on top of pyritic source materials, doesn’t completely prevent oxygen diffusion and oxidation processes. However, the thickness and degree of compaction or acquired bulk density of this surface material can effectively reduce the amount and rate of oxygen diffusion. Covering the waste repository with an oxygen-consuming layer (revegetated soil with active microorganisms) is a good oxygen control strategy. Synthetic or plastic liners are effective in eliminating oxygen diffusion, but the toxic material must be completely surrounded or encapsulated or oxygen will enter from the bottom and sides of the repository.

This alternative is applicable to those site areas in which waste piles have been left:

- in an unreclaimed state (i.e., exposed openly to precipitation and air), or
- left at a low elevation which can be affected by fluctuating groundwater and surface water levels or surface runoff from storms.

These potentially acid-forming materials would need to be rapidly excavated, segregated and covered to prevent prolonged exposure and subsequent weathering of the materials due to the presence of oxygen and water. At the Wildcat Branch/Addison Branch Mines Site, the siting of a repository will always be above the water table, i.e., “high and dry” as opposed to “dark and deep” (EPA 2000). There will be no attempt here to recover marketable coal/source material (aka “remining”). There are several locations within the Site in which valley fills were left at the conclusion of mining operations that will be considered for this alternative.

The major uncertainty associated with this alternative is its permanence as a source removal option with minimal maintenance. The drying of the earthen cap could result in shrinking and cracking, allowing precipitation to infiltrate and permeate the pile. The importance of the initial cap design and construction

cannot be overestimated. The design will need to consider the shrink-swell, freeze-thaw and moisture holding properties/attributes of the cover material as well. In addition, methods may be employed to minimize or eliminate the problem of separation of backfill embankment after construction (Chalfant, et al, 1984). The depth of freezing in the project area extends to two feet or more below surface elevation. In addition, even with thorough mixing of agricultural limestone (pulverized limestone) and the pyritic mine waste under ideal conditions, placement and handling, oxidation of pyrite will not completely stop since dissolved oxygen will continue to support oxidation reactions to a limited degree.

3.2.2.2 - Alternative 2 - Remining with Special Handling of Source Materials

This alternative involves the surface mining (mountain-top removal mining) of previously-mined and abandoned underground mines to remove the remaining coal that is the source of most of the pyrite. Remining is an accepted industry procedure, and standard best management practices have been carefully described by the EPA as an incentive for ongoing efforts (EPA, 2000).

Remining is carried out through a process known as “daylighting,” i.e., the removal of coal reserves left in abandoned underground mine workings by surface mining techniques. These coal reserves are usually left in the form of pillars (square blocks of coal that support the mine roof) in tunnels and passageways. The process necessarily involves the excavation of rock and soils above the underground tunnels (called the overburden), the backfilling of the excavated areas after removal of the coal and overburden, and surface-grading so as to establish favorable contours upon the disturbed area. All toxic and acid-forming materials encountered during the excavation will be handled with special requirements. This alternative is best applicable and economically feasible only for those underground mine sites with reserves situated within certain depths of the surface, e.g., 50-120 feet.

The remining alternative will normally require the daylighting of a substantial or complete area of abandoned underground mines. Although remining will yield some remaining marketable coal reserves from the abandoned underground mines, the primary objectives of remining under this alternative are to decrease or eliminate AMD discharges, to improve site drainage and aesthetics by backfilling and revegetation of remined areas according to current reclamation standards, and to reduce safety and environmental hazards by eliminating open portals. Abandoned facilities and equipment will also be removed. These objectives can be achieved by implementation of a well-prepared remining plan that describes reclamation, maintenance and monitoring strategies.

A primary advantage of remining is the removal of pyritic material from the site and, in the process, generating revenue (from the coal extracted) that will help defray the costs of the action. Therefore, successful remining operations provide income through coal production, create local jobs, and afford environmental enhancement through reclamation of previously-affected areas. Remining has been documented to improve water quality primarily due to short-term reductions in flow from the reclaimed site, which in turn reduces contaminant loadings. (Over time, remining has actually shown to increase water yield, changing the quantity and timing of previous flow patterns.) Water quality is also improved by removing or burying high sulfur coal wastes and shale, fragmenting and mixing overlying alkaline overburden with unreclaimed acid spoils, and regrading and revegetating the mine site.

The source removal through remining and reclamation initiatives must be carried out within the context of a rigorous permitting and enforcement program to ensure that the proposed remining and reclamation practices will essentially eliminate overall production of AMD. In the Commonwealth of Kentucky, this permitting enforcement program requires the collection of site-specific geological and water quality data, and unless waived, geochemical analysis of the overburden to be mined. However, there are uncertainties associated with coal remining at the Wildcat Branch/Addison Branch Mines Site areas:

- Reserve (remaining) coal estimates are often incorrect due to inaccurate or unavailable underground mine maps and unknown surface augering activities. Underground mine workings may have

collapsed and pillars crushed. Under these conditions, separating coal from the waste rock can be difficult (and, possibly, uneconomical) and less coal may be available for removal from the site than anticipated. Industry estimates range between 5 and 20 percent of the coal may still be left after daylighting.

- Overburden material can be highly acidic, and disturbing it could result in additional pyrite exposure and oxidation, release additional acidity, and, possibly, increase the pollution load. To prevent this, potential acid-producing and alkaline-yielding zones, as well as the net acidity or alkalinity of the overburden, should be determined prior to re-mining. In some cases, alkaline addition may be required. (Note: Historical overburden data from the Wash Ridge Coal Company can be used to draw some conclusions regarding potential acidity/alkalinity at the Wildcat Branch Site.) For overburden material to be determined not suitable or potentially toxic, it must have a net potential deficiency of 5.0 tons of calcium carbonate equivalent or more per 1,000 tons of material. (The 1,000 tons is based on the assumption that one acre at plow layer depth contains about 2 million lbs of soil). Likewise, pH values must be less than 4.0 as pulverized rock slurry in distilled water before being defined as being acid-toxic. Furthermore, it is projected that for each 0.1 percent sulfur, in pyrite form, the tested material yields an amount of sulfuric acid that requires 3.125 tons of calcium carbonate to neutralize 1,000 tons of material. The pyritic form of sulfur is responsible for the toxic acid production.
- The coal itself may be acidic (with total sulfur concentrations greater than 0.5 percent). Additional coal mixed in with the spoil and left in the backfill can be problematic for marginal sites.
- There is also the same uncertainty mentioned above regarding the building of the waste repository and its permanence as a source removal option with minimal maintenance. The drying out of the earthen cap could result in shrinking and cracking, allowing precipitation to infiltrate the pile. The same concern lies with freezing and thawing cycles in the winter as the freeze line extends below two feet from ground elevation. The importance of the initial cap design and construction cannot be overestimated.

3.2.2.3 - Alternative 3 - Fly Ash Slurry Injection (Deep-Mined Areas)

This alternative involves injection of fly ash slurry into void spaces in underground mines where coal has been removed. The purpose is to fill the mine voids completely or to create barriers inside the mine to block interconnected underground passages as a way to control groundwater flow and improve the quality of drainage. Fly ash is selected as filling material because it is readily available (e.g., waste generated from a coal-fired power plant), has acceptable levels of impurities and is strongly alkaline.

Fly ash slurry is normally injected down a series of boreholes into the underground mine works. In order to determine the locations of injection holes and to estimate the volumes of the mine void and mine pool, a detailed mining map, along with other relevant geological and hydrological information, is required.

The injection method to be used in the Wildcat Branch/Addison Branch Mines Site is often referred to as “blind flushing.” Blind flushing occurs when access within an underground mine has been obstructed by roof falls or gob generated from retreat mining. In this method of slurry injection, the underground cavity may be dry, partially filled with water, or completely filled with water. The volume of voids is estimated from old mine maps and any other available, relevant data source. Since it is nearly impossible to determine, with a high level of confidence, how much slurry an individual borehole will accept, a series of holes must be drilled. When one borehole becomes clogged or full, the injection equipment moves to the next hole, and so on. The slurry is pumped to the borehole and injected into the mine at a relatively high velocity. Once the slurry leaves the turbulent area at the bottom of the injection borehole, the coarser material will settle first with the ultra-fines being transported further away. Some of these ultra-fines will

exit the mine to be captured for re-injection or fill the abundant fine cracks, fractures or joints in the bedrock or coal outcrop barrier or via auger holes. There is some concern that these ultra-fine particles may also seep out of the mine over time via cracks, fractures or joints in the bedrock and the backfill on the mine bench or along the coal outcrop, potentially creating an environmental concern with respect to suspended solids and turbidity in receiving streams.

The fly ash to be used would likely come from a local source, e.g., John S. Cooper Power Station of East Kentucky Power Cooperative, Burnside, KY, which uses locally obtained (Kentucky) coal. Coal in this area is bituminous coal, with a fairly low-moisture and high-carbon (45% - 85%) content, and a high heating value of 22-23 million BTUs/short ton of coal. When pulverized coal is combusted in a dry-ash, dry-bottom boiler, about 80 percent of all the ash leaves the furnace as fly ash, entrained in the flue gas, and collected by means of electrostatic precipitators, baghouses, or mechanical collection devices such as cyclones. The principal components of bituminous fly ash are silica, alumina, iron oxide, and calcium with varying amounts of carbon. In a fly ash of this type, total calcium ranges from 1 to 12 percent, mostly in the form of calcium hydroxide, calcium sulfate, and glassy components in combination with silica and alumina. The slurry would be made into a low-strength flowable fill grout by mixing with a small percentage of Portland cement and enough water to make the mix flowable. The mix would be pumped downhole under pressure in order to force water out (i.e., displace the mine pool) of mine portals/adits and underground tunnels. Studies by Professor W. Lee Daniels of Virginia Tech and others found that coal ash significantly reduced the threat of acid mine drainage by both reducing the level of metals found in water run-off from mine sites and restricting water movement through coal waste material.

The primary uncertainty associated with fly ash injection is the volume needed to fill the underground voids. The extent of mine tunnels and caverns and their range of inner-connectedness may prove to limit the effectiveness of sealing the voids and/or be prohibitive regarding cost. A bench-scale study may be warranted in order to determine the correct fly ash mixture (ash/Portland cement/water) to use and estimate the volume needed for this mine location.

3.2.2.4 - Alternative 4 - In Situ Bioremediation (Deep-Mined Areas)

The objective of this technology is to return the underground mines to natural conditions where AMD and oxidation of pyrite or acid-forming materials will not occur. The initial steps to achieve these conditions include:

- Generation and maintenance of an anaerobic atmosphere in the underground mine by adding carbon dioxide to the mine void above the mine pool. This will create a dense, gas-phase atmosphere above the pool, slowing the rate of gas exchange with the surrounding environment and thus reducing or eliminating oxidation of pyrite or acid-forming materials.
- Stimulation of growth of sulfate-reducing microorganisms under anaerobic conditions by introducing a degradable organic carbon source into the mine pool. This will enhance the sulfate reduction reactions.

USDA FS contractors have been studying the site for over 5 years, and have developed, through a series of field tests, some understanding of the mine discharge chemistry and have made assessments regarding the apparent flow patterns and hydrology. The proposed in-situ approach is preferred for several reasons. The AMD on site has high enough metals loading and acidity that it would, at a minimum, require a semi-passive system for long term treatment outside the mine. Treating the water inside the mine would reduce long term operation and maintenance costs. Sludge handling costs would likely be delayed and could potentially be eliminated (sludge handling costs can be as high as 50% of the total cost for treatment). In addition, if the in-situ system is also successful at consuming oxygen and slowing the acid generation process, chemical costs will be reduced significantly and the requirement for base addition could be

eliminated. If the requirement for base addition is eliminated, power would no longer be required and the system would only require the periodic addition of a carbon source to maintain the biological processes within the mine. Although USDA FS contractors recommend using alcohol for the carbon source initially, alcohol could be replaced by a less costly waste product for the long term to reduce operations and maintenance costs further. Even if biological reduction in acid generation is not observed, this test will likely result in greater than 95% reduction in dissolved metals loading from the mine during treatment, assuming the pH can be adjusted appropriately. (Tsukamoto, 2015)

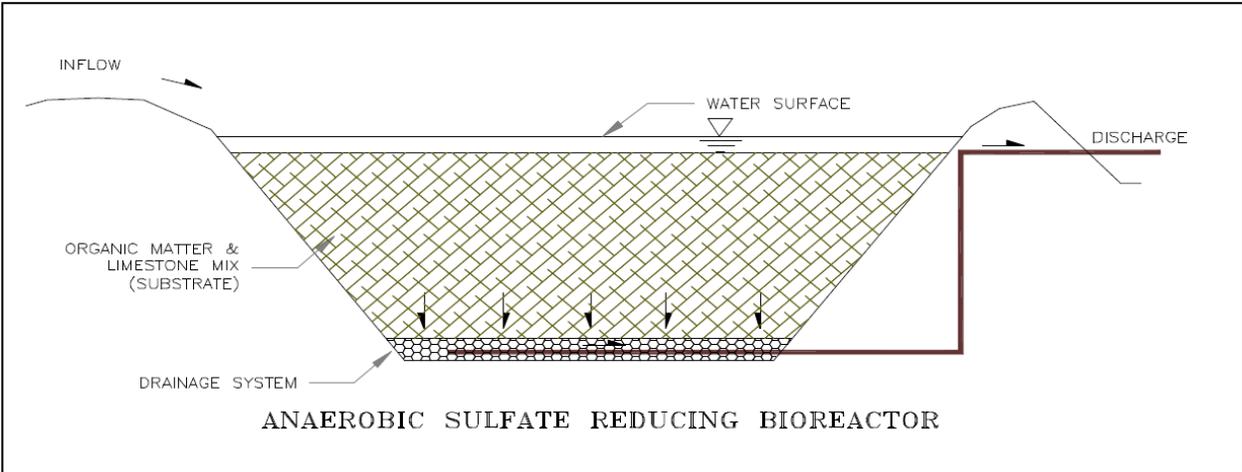
A feasibility study to demonstrate the implementability of this technology is currently being performed by USDA FS contractors at the Mt. Victory No. 3 Coal Mine, which is located in Area A of the Wildcat Branch/Addison Branch Mines Site. The purpose of the project was to assess the feasibility of the in-situ bioreactor approach and if promising, proceed with the design of a demonstration project to further assess the feasibility of this method of AMD treatment on site. The study is scheduled for completion in 2015.

In-Situ Bioremediation is an innovative technology and, as such, has some inherent uncertainty. Although this technology has been used in the western U.S. for treatment outside of the mines), it has only been applied at one mine location in the east (the Tide Mine in Pennsylvania), which was effective in the short term, however, long term data is unavailable. Therefore, the effectiveness of such a technique is not certain. In addition, as a “semi-passive” technology, there are uncertainties regarding the need for continued operation and maintenance (including continual substrate addition) required to keep anoxic conditions in the mines and to keep the communities of bacteria thriving. Temperature, pH, residence time and chemical parameters such as BOD and TOC must be carefully monitored to ensure optimal conditions for microbial activity.

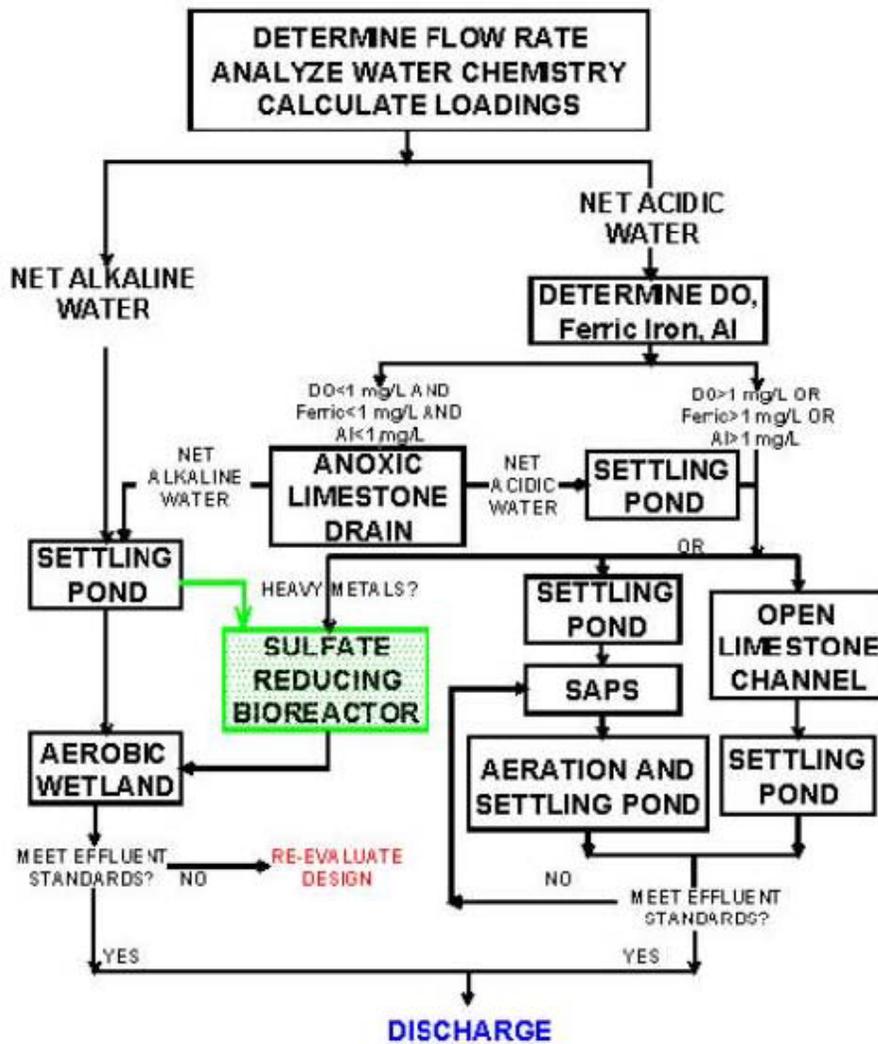
3.2.2.5 - Alternative 5 - Sulfate Reducing Bioreactors (SRBs)

Sulfate reducing bioreactors (SRBs) are anaerobic treatment cells that are typically applicable to AMD with high acidity and a wide range of metals, such as is present at the Wildcat Branch/Addison Branch Mines Site. Advantages to using SRBs include: the ability to work in cold, high altitude environments, handle high flow rates of mildly affected AMD in moderate acreage footprints, treat low pH acid drainage with a wide range of metals and anions, including uranium, selenium, and sulfate, and the acceptance AMD containing aluminum without clogging with hydroxide sludge (Gusek, 2002). SRBs can be constructed parallel or in series and be followed with aerobic wetlands for polishing and sediment deposition.

Sulfate reduction has been shown to effectively treat AMD containing dissolved heavy metals, including aluminum, in a variety of situations. The chemical reactions are facilitated by the bacteria *desulfovibrio* in SRBs, as shown in the following schematic (Gusek, 2002):



The following schematic adapts the commonly used passive treatment selection flow chart to illustrate where SRBs fit in to treat AMD with high DO, ferric iron, or aluminum concentrations (Gusek, 2002):



Design challenges for SRBs include determining an effective and available mixture of organic substrate and designing for the progressive degradation of the organic substrate and its effects on the hydraulics of the SRB cells (Gusek, 2004). Bench and pilot size study systems are typically implemented to increase the likelihood of a successful full scale design (Gusek, 2004).

Potential disadvantages to SRBs include vulnerability to high flows, seasonal variation in performance, the need for periodic maintenance or renovation, space requirements, and the relative lack of technical experience with these systems. Periodic maintenance may include site inspections, pipe cleaning, and sampling to determine performance. Organic substrate may need to be replaced every 15-30 years.

Space requirements are estimated to vary from 3 acres – 10 acres at potential Wildcat Branch Mines Site areas. Construction costs could vary from \$300,000 - \$800,000+ per site, depending on availability and types of substrate used, cell size, and various other design factors. Additional costs would be included for pilot/bench studies, design, maintenance, and monitoring.

3.2.2.6 - Alternative 6 - AML Enhancement Rule Removal

An AML Enhancement Rule project is a special type of reclamation project focusing on reclaiming abandoned mine lands that might not otherwise be reclaimed. The projects allow an AML contractor to remove coal refuse from an abandoned mine site and sell the coal to offset the cost of the project. Benefits of AML Enhancement Rule Projects include:

- offending problem completely removed;
- site reclaimed and restored to original appearance;
- trees planted on site;
- fossil fuel provides source of energy;
- government saves money and;
- contractor makes profit.

The AML Enhancement Rule guidelines were published in the Federal Register on February 12, 1999. The rule addresses projects that involve incidental coal removal, requiring a determination under the provision of 30 CFR Parts 707 and 874.16. In 1997, just prior to the Enhancement Rule guidelines, the Department of the Interior (DOI) Office of Surface Mining (OSM) authorized Kentucky Division of AML to enter into a reclamation agreement to remove a large refuse pile and several large slurry ponds in western Kentucky that saved the Kentucky AML Fund an estimated \$4.5 million. Since 1999, Kentucky has entered into reclamation agreements with contractors for the removal of refuse from seven AML project sites, resulting in an estimated savings to the AML Fund of \$1,438,692. These projects were all located in Eastern Kentucky and involved the removal of coal refuse from abandoned refuse piles, on about 34 acres, using loaders and coal trucks. The refuse was hauled on public roads to nearby permanent program permitted coal processing facilities, where any additional waste from the reprocessing was disposed of under permanent program permit requirements. No processing of the refuse is allowed on the AML project sites. All of the projects required the contractor to reclaim the areas to a near pre-mining configuration, establish a growth medium on the surface, and establish a general vegetative cover.

3.2.3 Description of Mine Reclamation Activities

Two mine reclamation activities are briefly described below as standard best management practices that will accompany most or all of the removal action alternatives described above. These two activities are statutory requirements for most or all remaining permits.

3.2.3.1 - Re-grading

Abandoned spoil piles commonly exhibit poor drainage. A significant amount of surface-water infiltration can be reduced by re-grading abandoned mine spoils. This may involve removal of closed contour depressions, elimination of spoil ridges and valleys, and creation of runoff inducing slopes within spoil piles.

Re-grading is also an integral part of most re-mining permits. In order to achieve a minimum reclamation standard as statutorily-mandated, abandoned spoil piles are regraded to return the site to the approximate original contour or to at least achieve a more natural-looking post-mining condition.

3.2.3.2 - Revegetation

Revegetation of mine spoil can dramatically reduce the amount of surface water that would otherwise eventually make its way to the underlying groundwater system. Vegetative cover also can decrease the amount of atmospheric oxygen that can enter the subsurface, because biological activity in soil, such as decay of organic matter, can create an oxygen sink. A well-developed soil with a dense cover of vegetation can retain a significant amount of water. Eventually, this water evaporates or is transpired by the plants and does not recharge the spoil aquifer.

Ideal plants for this application are metal-tolerant, drought-resistant, and fast-growing crops that can also grow in low-pH, nutrient-deficient soils. Currently, stands of *Sericea lespedeza*, or Chinese bush clover, are thriving on reclaimed surface mine lands and regraded mine spoils in the Wildcat Branch area. This grass will tolerate soils from very acidic to slightly alkaline quality, and has few insect and disease problems. It was first used in the U.S. as a protective cover for sites with poor soils. *Sericea* grows best where annual precipitation is 30 inches or more and has survived winter temperatures of -17 degrees Fahrenheit (Ohlenbusch 2001).

Revegetation is also a statutory requirement of all re-mining permits, and is one of the most frequently employed best management practices.

3.2.4 Description of Polishing Actions - SAPS, Wetlands, Ponds, Limestone Technologies

Certain proven technologies have found widespread use in treatment of AMD. Because of the extremely poor water quality at the Wildcat Branch/Addison Branch Mines Site, these technologies may not by themselves serve as effective removal actions. However, each might warrant consideration as a polishing or finishing action for water that has passed through an area on which a removal action has been completed to remove additional metals or to increase the alkalinity of the water leaving the site.

A system that could be described as a Successive Alkalinity Producing System (SAPS) has the following basic elements through which AMD passes sequentially: organic mulch layer, limestone layer, and a drainage system. The organic layer serves to remove dissolved oxygen from the water, while deeper in the system anaerobic conditions support the establishment of sulfate-reducing bacteria. The anaerobic environment is a reducing environment that changes ferric iron (Fe^{3+}) to ferrous iron (Fe^{2+}), thereby reducing the likelihood of iron hydroxide precipitation. Finally, the water enters the limestone region, essentially devoid of oxygen and preventing the armoring of limestone. Upon leaving the SAPS, the water is usually directed to an aerobic settling pond or wetland to allow metals, such as iron and manganese to oxidize, hydrolyze, and form precipitates and promote further water polishing.

A downstream aerobic wetlands cell (or group of cells) might be added to provide sufficient residence time to allow additional metal oxidation and hydrolysis, thereby causing precipitation and physical retention of Fe, Al, and Mn hydroxides. Wetland plants encourage more uniform flow, help stabilize the

substrate, help maintain microbial populations, and provide aesthetic qualities to the wetland. This technology is effective for treating water of average to poor quality, but not effective for water at very low pH and very high content of manganese and other metals.

Submergence was eliminated as a removal alternative as described in Section 3.1.2. However, small areas of inundation, or ponds, might be created as the finishing step of a treatment in order to allow additional sedimentation and dilution to take place. Such a technology would only be considered cost-effective in an area of suitable geology and topography.

Limestone treatment technologies include open (oxic) limestone drains, anoxic limestone drains, limestone diversion wells, et al., that could be used for polishing and in conjunction with other alternatives for treatment.

4. ANALYSIS OF ALTERNATIVES

4.1 INDIVIDUAL ANALYSIS OF ALTERNATIVES

Once a set of potential removal action alternatives is selected for each site, the attempt is made to quantitatively evaluate the alternatives to a set of criteria. The defined alternatives described in Section 3.2 are evaluated against the short- and long-term aspects of three broad criteria: effectiveness, implementability, and cost. These criteria are fully described below.

4.1.1 Effectiveness

To achieve consistency with the removal action objectives identified in Chapter 2.0, the effectiveness criterion will reflect the success in achieving the principal objectives of both long-term and short-term protection of public health and the environment.

Environmental protection will consider the degree to which resultant low pH and elevated toxic metals in AMD from the Wildcat Branch/Addison Branch Mines Site will be brought to acceptable ranges, thereby reducing the potential for exposure to environmental receptors, such as fish, macroinvertebrate species, and wildlife. Additionally, the evaluation will consider factors normally assessed under NEPA, including immediate environmental impacts that may result from implementing the removal action.

The alternative will be evaluated as to its effectiveness in reducing the toxicity, mobility, and/or volume of the contaminants of concern. Wildcat Branch has some of the poorest water quality in the nation among coal-mined areas; removal actions taken will need to be robust enough to mitigate this poor quality. This component also involves an assessment of the potential for future exposure from residual conditions at the site, as well as the potential for long-term failure of the alternative and any potential threats from such a failure.

The evaluation of this criterion will focus on the extent to which the completed action reduces or mitigates identified threats, as well as compliance with chemical-specific ARARs and TBCs. This evaluation will also consider the extent to which the actions meet the location-specific ARARs and TBCs, particularly those pertaining to environmentally-sensitive areas. In addition to these, consideration will also be given to short-term protection of workers during the initial construction and implementation.

4.1.2 Implementability

The implementability of an alternative is defined by its technical and administrative feasibilities.

4.1.2.1 - Technical Feasibility

The factors evaluated regarding an alternative's technical feasibility includes:

- The ability to construct and operate the alternative, considering unknowns that may lead to schedule delays;
- The ability to meet the required process efficiencies or performance goals;
- Compliance with action-specific ARARs and TBCs; and
- The previously demonstrated performance of a technology.

The technical feasibility evaluation also considers the availability of necessary equipment, materials, personnel, expertise, etc., including any measures that may be required at the completion of the action, such as monitoring, and availability of a responsible party to assume these activities.

4.1.2.2 - Administrative Feasibility

The evaluation of administrative feasibility of an alternative includes the likelihood of public acceptance, activities necessary for coordination with other agencies, and the ability to obtain necessary approvals or permits. Consideration will be given to the necessary acquisition of easements and right-of-ways where applicable, and to the potential impact on adjacent properties.

4.1.3 Cost

Evaluate each alternative to determine the projected costs. Consider the following costs:

- Capital costs;
- Operating and maintenance (O&M) costs (annual); and
- Periodic costs (replacement or abandonment).

The total cost of an alternative is the final criterion to be considered. This criterion includes direct capital costs, engineering and management costs (indirect capital costs), operation and maintenance costs, post-removal site control costs (if applicable), an allowance for contingencies, and present worth values in order to facilitate comparisons.

The cost estimates are based only on conceptual designs and are intended only for alternative comparison purposes. They are best utilized for their relative value rather than for actual value. The best estimates here will only provide a "ballpark" number with, at best, an accuracy of ± 25 percent. According to a Forest Service Region 10, "it is tough to get defensible cost estimates at this stage of the project" (Maas, undated). Actual costs will be more closely estimated during the bid and procurement process.

Cost estimates are given in Appendix C for those site areas/alternative combinations that seem reasonable to consider based on knowledge of the sites and professional engineering judgment.

4.1.3.1 - Direct Capital Costs

Direct capital costs include costs associated with implementation of the applied technology, including mobilization and demobilization of heavy equipment, construction labor costs, equipment and materials necessary for building, earth moving, road construction, and drilling.

Direct capital costs were obtained for each of the six alternatives by first developing line-item unit costs from published case studies, actual costs from representative projects, vendor information, etc. Total direct costs were then calculated using this unit cost and information known or estimated about each site area.

Unit costs for each alternative were derived from the following sources:

- EPA’s Best Management Practices guidance manual for remining (EPA 2000). This manual collected actual data from over 100 remining case studies employing various BMPs. It then employed the tools of statistical analysis to determine best-fit linear regression models to predict costs on a unit basis. These models were used in Appendix C spreadsheets to produce cost numbers for various alternatives. Because most of the case studies were conducted in earlier years, the manual projected the costs onto current dollars (the year 2000 at the time of its writing) by using a ratio of Cost Construction Index (CCI) values obtained from the U.S. Census Bureau website. This project extrapolates the dollar values still further into 2015 dollars using the same ratio technique.
- The Office of Surface Mining’s treatment cost manual (OSMRE 2000). This manual, prepared by Tetra Tech, Inc., includes unit costs for line item activities involved in a range of acid mine drainage treatment options. As above, these dollars were projected forward onto current dollars using a ratio of CCI values.
- Information obtained from current and past Forest Service projects and projects conducted or overseen by the Office of Surface Mining, state agencies of West Virginia, Ohio, and Pennsylvania, and universities, such as West Virginia University. Some alternatives, or activities within the alternatives, have already been implemented on USDA FS property in the Daniel Boone National Forest or other National Forests. Where actual costs were available, these dollar numbers were considered to be fairly accurate and applicable and were used as much as possible as part of the estimates.
- “AMDTREAT” cost estimation software from the OSMRE.
- Proposed and actual costs submitted for the In-Situ Bioremediation Pilot Project.
- Vendor information.
- Professional engineering judgment.

4.1.3.2 - Indirect Capital Costs

Indirect capital costs include those that are incurred for engineering and design, legal and licensing fees (if any), and other fees not directly related to actual installation, such as public and community relations. For purposes of this cost estimate, indirect costs are estimated at 16% of the direct capital costs (OSMRE 1999) for each alternative.

4.1.3.3 - Operation and Maintenance Costs

Operation and maintenance (O&M) costs may be a significant part of a project budget. Though removal action alternatives considered in this project include only those that entail minimal post-implementation O&M costs, most removal alternatives will require some form of maintenance, whether planned or unplanned. O&M costs will vary between the alternatives and are considered and estimated where applicable. Obtaining Forest Service funding for long term O&M is problematic, and the difficulty of identifying O&M funding has to be considered when evaluating alternatives. The Forest Service is looking for opportunities to identify and obtain funding for long term O&M.

4.1.3.4 - Annual Post-Removal Site Control (APRSC) Costs

The APRSC costs that are anticipated include monitoring / analytical costs and reporting costs. These costs are included in estimates here but are considered to be part of the annual operating budget for the USDA Forest Service. Similar to long term O&M, identifying Forest Service funding for APRSC costs has proved problematic, and the Forest Service is currently engaged in nationwide discussions on opportunities to identify APRSC funding.

4.1.3.5 - Contingency Allowance

Because of the inherent high level of uncertainty at this conceptual stage of design, an allowance for contingencies of 20% (OSMRE 2000) is introduced at this stage of the cost analysis and applied to the total project cost.

4.2 COMPARATIVE ANALYSIS OF ALTERNATIVES

The evaluation of the six removal action alternatives is presented in this chapter and is based on the criteria described in Section 4.1. The evaluations of the individual alternatives are presented in Section 4.2.1 through 4.2.6. A summary of the evaluations as applied to each site area will be presented in Section 5.0.

Each of the Wildcat Branch/Addison Branch Mines Site areas has locations with unique characteristics that make some removal actions more suitable than others. The removal action alternatives for each site must incorporate one or more of the technologies described in Section 3.2, above. Based on professional engineering judgment and preliminary assessment of site-specific conditions, the removal action alternatives were selected using one of the decision flowcharts given in Figures 4.1 and 4.2. Usage of these flowcharts results in the most reasonable removal action alternative based on a site's size, elevation, and type of mining used. For example, in Area A, In-Situ Bioremediation or fly ash slurry injection may be the most reasonable alternative for the deep mining area, depending on the results of the treatability study, whereas Sulfate Reducing Bioreactors would be appropriate alternatives for the surface mined areas. Accordingly, each of the remaining mine sites will be examined in the same way.

4.2.1 Alternative 1 - Waste Material Excavation and Placement in a Repository (Surface-Mined Areas)

4.2.1.1 - Effectiveness

This alternative is very effective regarding protection of human health and the environment because it reduces or eliminates the mobility of the contaminants within mining waste spoil piles. This is actually a source isolation technique, and its effectiveness depends on the ability to identify and extract the source material, and then to isolate this material hydrologically. The process must ensure that the excavation and removal action does not unintentionally recontaminate other areas of the site via fugitive dust emissions, erosion during removal phase, spillage, etc.

The effectiveness for each area will be limited by the accessibility of the source material. Clearing of trees and vegetation may be necessary even to locate and define the extent of the source material properly. The alternative is compliant with ARARs and results in a reduction of contaminant mobility, but not in contaminant volume or toxicity.

4.2.1.2 - Implementability

This alternative is implementable because it utilizes conventional heavy construction equipment and practices. Excavation, loading, casting, and compaction can be accomplished using backhoes, draglines, cranes, bulldozers, front-end loaders, and sheepsfoot rollers. Hauling can be done using dump trucks and rubber-tired haulers. A repository can be constructed and shaped using bulldozers and grading machines.

The alternative would be accepted by the State and local community because it would not involve hauling waste off-site. Alkalinity-producing materials for blending with acid toxic spoil are readily available, and the action could be completed in a timely fashion.

The Surface Mining Control and Reclamation Act (SMCRA) requires that the removal of contaminated soils use Best Available Technologies to minimize disturbance to wildlife, fish, and the environment, and include measures to prevent subsequent erosion or air pollution.

4.2.1.3 - Cost

Cost estimates are given for each applicable Site area in Appendix C. Assumptions are made using whatever information is available for each area. The cost estimate data that will vary with each area are:

- Volume of waste to be excavated;
- Area of waste repository required;
- Location of repository and distance required for haul;
- Amount and cost of material needed for cap construction, limestone base, and buffering materials.

For each site, it is assumed that excavation will be performed using conventional equipment, and the waste piles will need to be placed above permanent water table ("high and dry").

The site for waste repository will be prepared by first constructing an alkaline base of up to 1 foot of limestone material. The waste would be excavated and blended with an agricultural lime material using a front-end loader, Bobcat loader, or bulldozer. Lifts would be graded using a dozer and compacted after each lift. A cap with minimum thickness of 2 feet will be built and seeded or planted and graded appropriately.

O&M costs are not anticipated, provided the repository functions properly and the cap maintains effectiveness.

4.2.1.4 - Application to Wildcat Branch/Addison Branch Mines Site Areas

Alternative 1 is applicable to areas of hollow fill or ridge-top areas with aboveground volumes of waste that can be readily excavated, segregated (if needed) and re-placed in a repository. As such, it is applicable to portions of Site Areas A, B, C, and D.

4.2.2 Alternative 2 – Surface Remining with Special Handling of Source Materials

4.2.2.1 - Effectiveness

This alternative is very effective for both protection of human health and the environment as it actually reduces the volume of contaminants that are the source for AMD. It is compliant with ARARs as long as a remining permit is obtained and best management practices for remining are followed.

The effectiveness is limited by the ability of the remining contractor to access the coal seams and effectively mine the coal without leaving pyritic spoils in the process.

4.2.2.2 - Implementability

The administrative feasibility of this alternative depends on the ability to obtain necessary permits from both the Kentucky Office of Surface Mining and Reclamation (KY-OSMRE) and the Kentucky Division of Water (DOW). Kentucky requires separate SMCRA and NPDES permits to be obtained. If this alternative is chosen for a source, a remining permit application is submitted to the KY-OSMRE. This agency then contacts the DOW, which will send a representative to visit the site and identify monitoring points that will have to be sampled and how often. During the initial visit by DOW, a KY NPDES permit application is provided. This permit application (generally) has to be approved before OSMRE approves

the Title V (SMCRA) permit application. Both groups will work together and may comment on each other's permit and application. If there is a water quality problem, it is the SMCRA authority that takes charge, and this authority requires KY-OSMRE to handle such problems on any active mining site. Once operations begin, a mine operator must have a Best Management Plan on site (KY OSMRE 2006).

Additionally, surface mining on National Forest lands require special approvals and compatibility determinations due to SMCRA language that prohibits surface mining on National Forest lands unless certain criteria are met and approval is granted by the of the Secretary of Agriculture. Meeting the criteria and obtaining approval will likely be difficult and may be impossible in certain instances.

Remining is technically feasible and locally acceptable as it is a common practice in coal-producing states. It is not as timely as Alternative 1 because of the exploration process required to determine the size, location and extent of existing coal seams and pockets.

4.2.2.3 - Cost

The primary resource for developing this cost estimate is Section 7.0, “Best Management Practices – Cost”, of EPA’s BMP manual (EPA, 2000). The cost numbers were developed in 1999 dollars and then extrapolated to 2015 dollars.

Costs associated with this alternative are:

- Exploration / discovery costs to determine where the remaining coal is located;
- Application and acquisition of remining permit;
- Mobilization of the mining contractor;
- Sediment controls – temporary and permanent (i.e., more than 5 years post-project);
- Excavation, removal and transportation of the mined material; and
- Activities associated with mine closure - regrading, revegetation, etc.

Some of these costs may be offset by income produced by the sale of the reclaimed coal, the price of which fluctuates with the energy market. Coal recovery rates are usually in the range of 20 to 35 percent (EPA, 2000). For purposes of a cost estimate, this report will utilize a recovery rate of 30 percent. Cost estimates are provided in Appendix C.

O&M and monitoring costs are unknown and would be influenced by BMPs, such as settling ponds required by mining permits, and sampling costs associated with NPDES permits.

4.2.2.4 - Application to Wildcat Branch/Addison Branch Mines Site Areas

Alternative 2 is applicable to those areas that hold a substantial amount residual coal reserves (in the form of pillars) that is accessible from surface level without excessive amounts of overburden removal. Based on existing data underground mining voids within Area A are the only locations that can be described as such. Additional investigations could identify other applicable locations.

4.2.3 Alternative 3 - Fly Ash Slurry Injection (Deep-Mined Areas)

4.2.3.1- Effectiveness

This alternative is very effective for long-term protection of both human health and the environment as it permanently reduces the mobility of contaminants that are the source for AMD and reduces the toxicity of the contaminants by limiting the amount of oxygen and water that can reach the remaining pyritic material. It is easily compliant with ARARs, and there would appear to be no adverse residual effects.

The effectiveness is limited by the ability of the technology to completely fill the voids and openings within the mine cavities. Worker health and safety are concerns during implementation as workers handle the mixing and pumping of the fly ash / pozzolanic (siliceous) slurry.

Additional concerns exist regarding the effectiveness of this alternative. The filling of above-drainage mine workings with slurry may increase the hydraulic head on coal outcrop barriers to a degree sufficient to produce a blowout or to create seepage along the coal outcrop. This possibility necessitates the important work of evaluation of mine workings above a surrounding valley bottom or stream. However, once the mine pool has been displaced or confined to an area within the mine, or has been assimilated within the slurry itself – or, in other words, the slurry has achieved a hydrologic balance within the mine - seepage along the coal outcrop should diminish and then stop altogether. The accuracy of mine maps must be considered, and the underground coal outcrop barriers evaluated for adequacy to contain the slurry. Mines below natural drainage offer more secure disposal sites.

4.2.3.2 - Implementability

The injection of fly ash slurry is technically feasible as the technology has been used with success at other mine sites and is fully constructible. However, it is technically implementable only in those settings where drilling and pumping equipment can be employed safely. The technology is technically simple and straightforward, as competent personnel and suitable equipment will be readily available.

Administrative feasibility depends on the ability to obtain an injection permit from the U.S. EPA. Transportation of either the fly ash or the pozzolanic material will not require a permit as neither is considered a hazardous material for transportation. According to Kentucky Revised Statutes, “special wastes” are those wastes of “high volume and low hazard” which include, but are not limited to “utility wastes” (fly ash, bottom ash, and scrubber sludge) [KRS 224.50-760(1)(a)]. The alternative should be readily accepted by community and state agencies, and will not impact adjacent properties.

In flooded portions of an underground mine, the injected slurry will most likely displace the mine pool, which can result in a new or increased discharge elsewhere other than at the existing location. However, the slurry may confine or isolate pockets of the mine pool. Depending on the quality of the displaced water, treatment of acid/toxic effluent from the mine may be necessary to avoid adverse impacts to receiving streams. Some discharge points may also occur at undesired locations. These uncertainties affect the implementability of this alternative.

4.2.3.3 - Cost

The parameters of interest in estimating the cost of this alternative are:

- Total number of wells to be drilled;
- Average depth of wells;
- Approximate acreage of mine coverage;
- Truck mileage to site;
- Number of mine seals (over the portals) to be constructed; and
- Sediment controls.

Unit costs for each of the above parameters have been determined based on past projects or on current vendor cost data. These are then extrapolated to the various sites for which this alternative is being considered (Appendix C).

O&M costs would not be anticipated following successful implementation of this alternative.

4.2.3.4 - Application to Wildcat Branch/Addison Branch Site Areas

Fly ash slurry injection will be applicable to site areas that contain underground mine voids at a location where it would be possible to set up and operate a drilling rig for boring and injection. Thus, it will be evaluated for locations within Areas A, B, and D.

4.2.4 Alternative 4 - In-Situ Bioremediation (Deep-Mined Areas)

4.2.4.1 - Effectiveness

The long-term effectiveness of this alternative depends on the ability to sustain an indigenous microbial community to produce carbon dioxide and displace oxygen. The biological treatment strives to reduce the toxicity of the contaminated pool water by decreasing the oxidation of pyrite in the mine voids. A Class V injection permit will be required to comply with ARARs.

At this time, the long-term maintenance and operation requirements to maintain the initial effectiveness are not known. There are no adverse residual effects anticipated with this alternative.

4.2.4.2 - Implementability

The alternative has shown success in over 20 acid rock drainage sites in the western United States, but has only in the past few years been implemented in Appalachian coal regions. Only one project has been in place long enough to have produced results (see below). In this sense, the technology is the most innovative of the six under review.

The process does not produce waste, and appropriate equipment and personnel are available, but limited to the engineering contractor(s) who have experience with this technology.

It is technically feasible only in those settings where drilling and pumping equipment can be employed safely. The alternative is administratively feasible, should be easily accepted by state and community, and does not present potential impacts on adjacent properties.

4.2.4.3 - Cost

The unit cost estimate for this alternative is based on proposed numbers and actual costs submitted by USDA FS contractors for the remediation technology demonstration treatability study currently underway at the Mt. Victory Mine Site No. 3 between Snake Pond and Bear Wallow Ridges in the Wildcat Branch drainage area (Area A). Due to the uncertainty with this innovative technology, cost estimates for final implementation are unknown and will be estimated based on the treatability study.

4.2.4.4 - Application to Wildcat Branch/Addison Branch Mines Site Areas

This alternative is an innovative technology that is most applicable to underground mine sites with known internal pools and available drilling pad sites.

A treatability study of this technology is currently being performed in Area A. Implementation, as described in Section 3.2.2.4 will take place in phases with Phase 1 (site preparation, drilling, baseline sampling, dye tracer studies, and pumping tests) already complete. Additional phases will be implemented as funding and logistics allow.

Intensive monitoring of the quantity and quality of the mine effluent after treatment will determine treatment efficiency and whether project design parameters and conditions within the mine are meeting objectives, or whether modifications/adjustments are needed for achieving and sustaining desired results

over time.

Depending upon the results of the treatability study and potential implementation at Area A, the applicability of this alternative should be investigated for underground mine sites in Areas B, C, and D.

4.2.5 Alternative 5 – Sulfate Reducing Bioreactors (SRBs)

4.2.5.1 - Effectiveness

This alternative has proven effective for both protection of human health and the environment if properly designed, constructed, and maintained. SRBs have successfully treated AMD for a wide range of flows and water chemistries throughout the country, including the Appalachian coal regions, and would likely be effective over the short term at multiple sites within the Wildcat Branch/Addison Branch Mines Site. The long-term effectiveness of this alternative depends largely on the ability to provide annual maintenance and periodic substrate replacement, if needed. SRBs are low maintenance systems; however, failure to provide monitoring and maintenance will limit the system's effectiveness and potentially result in complete failure.

4.2.5.2 - Implementability

The alternative has shown success over a wide range of applications, including implementation in Appalachian coal regions. Materials should be available for organic substrates and required space is available at the AMD source locations.

In addition to monitoring, maintenance, and periodic substrate replacement, the SRB systems will require sludge removal at some point in the life of the system, including transportation of solids to an appropriate disposal facility (on-site or off-site). Sludge removal and substrate replacement activities are likely to be infrequent, and therefore the periodic nature of these maintenance activities can be a challenge to managing funding cycles.

4.2.5.3 - Cost

The cost estimates for this alternative are produced with OSMRE's AMDTreat software, using site specific flow and water quality parameters. Operation and maintenance costs were estimated base upon minimal annual maintenance and substrate replacement every 15 years. Cost estimates are available in Appendix C.

4.2.5.4 - Application to Wildcat Branch/Addison Branch Mines Site Areas

Each of the 4 site areas (A, B, C, D) have space and locations where this technology could be implemented.

4.2.6 Alternative 6 – AML Enhancement Rule Removal

4.2.6.1 - Effectiveness

Similar to the source removal and remining alternatives, this alternative is very effective for both protection of human health and the environment as it reduces the volume of contaminants that are the source for AMD. Removal of the coal refuse also may create an area to better locate other treatment technologies for other AMD sources.

The effectiveness will be limited by the accessibility of the source material in the coal refuse piles.

Clearing of trees and vegetation may be necessary to access the coal refuse. The alternative is compliant with ARARs as long as State and Federal regulations are followed and applicable BMPs are followed.

4.2.6.2 - Implementability

The Forest Service is working with contractors to find a destination for the coal refuse and anticipates conducting a pilot test in calendar year 2016, the results of which will guide the further use of the AML Enhancement Rule to remove coal refuse.

It is technically feasible where coal refuse is accessible by heavy equipment and the coal refuse has value to a contractor. The process does not produce waste, and appropriate equipment and personnel are available

4.2.6.3 - Cost

The cost for this alternative will be governed by the value of the coal refuse, which is yet to be determined. The current cost estimate is based upon the cost to excavate and transport the material to a contractor's facility, with a small estimate for coal refuse value. The yet to be determined value of the coal could be higher than estimated and would therefore further offset the cost and make this alternative more economical than currently estimated.

4.2.6.4 - Application to Wildcat Branch/Addison Branch Mines Site Areas

This alternative is applicable at areas where coal refuse piles are located and the coal refuse is accessible and has material of value to a contractor. It is highly likely to be applicable in Area C and should be explored at coal refuse piles in Areas B and D.

5. RECOMMENDED REMOVAL ACTION ALTERNATIVES

Using all available knowledge of the site-specific conditions for each Site area, one or more alternatives is applied to each site area. Then each of the alternatives is judged based on the criteria of effectiveness, implementability and cost.

The Forest Service proposes to use an adaptive management process to implement a variety of the recommended removal alternatives as site conditions, technology, available resources, and funding allow.

5.1 AREA A – ALTERNATIVE 1 - WASTE MATERIAL EXCAVATION AND PLACEMENT IN A REPOSITORY

5.1.1 Description

This alternative would essentially remove a core section of the hollow fill, from within the approximate location of the historical drainage-way, segregating, where feasible, that portion of the fill that has the more abundant amount of acid/toxic shale and waste coal. This material would then be placed in a protected repository and blended with agricultural lime at a rate supported by acid-base accounting to bring this material to near a neutral pH. The site will then be covered with topsoil, or an approved topsoil substitute, that will support good germination and growth of a selected mix of vegetative species to provide quality cover over the long-term. The width and depth of excavation will be determined on-site as conditions warrant. The excavated core area would be graded to a 2:1 or flatter slope and a stream channel restored

with some sinuosity and floodplain area established.

A variation on this alternative would couple waste removal (Alternative 1), with remining (Alternative 2) for Area A. A substantial portion of the overburden removed in remining the underground mines within the area would be utilized as cover material for burying and mixing material with higher neutralization potential with the acidic spoil in the selected repository locations. Furthermore, some of the overburden would be used to eliminate or reduce some of the existing highwalls from the adjacent contour stripping operation.

To implement this alternative, approximately 3 miles of an existing road on the ridge top would need reconstruction, including installation of culverts and gravel surfacing. Additionally, 2,000 feet of an old mine access road would need reconstruction to support mobilization of heavy equipment and supplies.

5.1.2 Evaluation

The ability of this alternative to immobilize and contain the AMD-producing materials once the repository is capped results in an effectiveness rating of “HIGH.” The necessity of moving trees and vegetation and the limited accessibility (due to grade of slope, difficulty in identifying waste, large extent of coverage) result in a rating of “MEDIUM” for implementability.

Cost for this alternative at Area A is estimated at \$3.3 million, and given a rating of “MEDIUM.”

This alternative is the only one being considered for the mine waste spoils (valley fill) in Area A.

5.2 AREA A – ALTERNATIVE 2 - SURFACE REMINING WITH SPECIAL HANDLING OF SOURCE MATERIALS

5.2.1 Description

The underground mine area in Area A would be eliminated by a remining operation, which would remove all overburden and the residual coal reserves left in blocks of coal (i.e. pillars) that provide support of the mine roof, and that coal left as an outcrop barrier. Remining here would be essentially a mountain top operation. The overburden would be utilized in reclamation of adjacent portions of Area A, blending alkaline overburden materials to provide a quality cover for revegetation. The marketable coal would be sold to offset project cost.

Once remining is complete, some of the overburden will be brought back to the remined area to reestablish designed landforms that function like natural systems, providing stability and erosion control, creating productive potential for the desired post mining land use (e.g. forestry, wildlife), and creating visually acceptable topographic features.

5.2.2 Evaluation

The effectiveness of this alternative is limited by the ability of the contractor to successfully locate and remove the underlying pillars of coal after daylighting. If coal is left in place, the problem of AMD remains, even if to a lesser degree, and is therefore given a rating of “MEDIUM.” The implementability is likewise hampered by the ability to obtain a remining permit from the Commonwealth of Kentucky and to find a willing and qualified contractor to undertake the task, and given a rating of “MEDIUM.”

Cost for this alternative at Area A is estimated at \$500,000, and is given a rating of “HIGH”. As coal prices fluctuate in an uncertain market, so would the cost for this alternative.

5.3 AREA A – ALTERNATIVE 3 - FLY ASH SLURRY INJECTION

5.3.1 Description

This alternative would be implemented at Area A as described in Section 3.2.2.3. Approximately 0.8 mile of temporary road will need to be constructed to facilitate drilling and injection. A track drill would work best for this work as it can access more difficult locations from which to set up and drill. It's projected that between 10 and 31 bore holes will be needed to fill the mine voids adequately to meet the objective of this alternative. However, it's also estimated that between 4 and 12 of these bore holes will not be positioned over the mine for the drill to enter the mine void, but will bore through a pillar or an unmined area. This is due to the inherent imprecision of correctly registering the surface/bore hole locations, with historical mine maps. Twenty holes are offered for planning purposes.

5.3.2 Evaluation

The major difficulty regarding the effectiveness of this alternative is its ability to completely fill the voids and openings within the mine cavities. This ability can only be estimated using accurate historical mine maps and is given an effectiveness rating of "MEDIUM." The technology has been widely used at abandoned mine sites and will be rating as "HIGH" for implementability at for this Area.

The cost associated with this alternative for Area A is \$3 million and so is rated as "MEDIUM" regarding cost.

5.4 AREA A – ALTERNATIVE 4 - IN-SITU BIOREMEDIATION

5.4.1 Description

This alternative would be implemented at Area A as described in Section 3.2.2.4. Intensive monitoring of the quantity and quality of the mine effluent after treatment will determine treatment efficiency and whether project design parameters and conditions within the mine are meeting objectives, or whether modifications/adjustments are needed for achieving and sustaining desired results over time.

5.4.2 Evaluation

The long-term effectiveness of this alternative still contains a great deal of uncertainty and is rated as "MEDIUM." It is, however, implementable in this Area as implementation has already been begun and thus given a rating of "HIGH."

The total cost anticipated for all phases of this project is approximately \$1.1 million; therefore, its rating based on cost is "MEDIUM". The results of the ongoing treatability study will provide additional information for estimating the total cost.

5.5 AREA A - ALTERNATIVE 5 – SULFATE REDUCING BIOREACTORS (SRBS)

5.5.1 Description

SRBs would be constructed at multiple locations within Area A, including below seeps and mine openings and/or along unnamed tributaries to Wildcat Branch, and would likely be combined with "polishing features," such as constructed wetlands or settling ponds to complete a passive treatment system. Space within Area A is abundant in which to locate, design, and construct the SRBs and associated features. An estimated 2-4 SRBs could be constructed within Area A, so for cost estimation, 3 will be considered. Minimal periodic O&M is anticipated and will be considered in the cost estimate, along with an assumption that the organic substrate and limestone will require replacement after 15 years. Also considered in the cost

estimate will be bench and pilot level studies to determine if the SRB will be effective and provide information for the design, along with costs for effectiveness monitoring.

5.5.2 Evaluation

Sulfate reduction has been shown to effectively treat AMD containing dissolved heavy metals, including aluminum, similar to the conditions at the Wildcat Branch Mines Site. Effectiveness will be dependent upon availability of suitable organic substrate and ability to maintain and periodically replenish the SRB. SRBs have been successful in conditions similar to those at the Site; however, due to the wide range of performance of passive systems such as SRBs, the effectiveness rating is “MEDIUM.” Area A has sufficient space available for construction of SRBs and polishing features, and access for construction is available, so implementability is rated as “HIGH.”

The estimated cost for 3 SRBs at Area A, including bench and pilot studies, polishing features, and periodic substrate replacement is \$2.5 million. Site locations could be prioritized, and the 3 SRBs could be constructed in phases, as funding and logistics allow for approximately \$850,000 each, and the alternative is given a rating of “HIGH.”

5.6 AREA B HEADWATERS – ALTERNATIVE 3 – FLY ASH SLURRY INJECTION

5.6.1 Description

The downstream mined area (location of the previous Forest Service Project #4) in the Area B headwaters is substantially higher in elevation above the receiving stream than the mined area in the upper reaches of Wildcat Branch. Remining would likely be prohibitively expensive as a large amount of overburden would need to be removed to “daylight” and remove the residual coal reserves and acidic shale’s that produce AMD. Also, due to the unknown mine conditions and the potential connectivity with other older mines, the risks and unit cost would likely be prohibitive. Alternative 4, Fly ash slurry injection, appears to be the preferred alternative at this higher elevation. The description is the same as described above in Section 3.2.2.3.

To support injection of fly ash, approximately 0.9 mile of road would need to be reconstructed and 1.5 miles of new temporary road construction would be needed to provide access with sufficient clearing to tram a drill rig to selected drilling locations, and support pumping of the ash slurry.

5.6.2 Evaluation

The major difficulty regarding the effectiveness of the fly ash grouting alternative is its ability to completely fill the voids and openings within the mine cavities. This ability can only be estimated using accurate historical mine maps and is given an effectiveness rating of “MEDIUM.” The technology has been widely used at abandoned mine sites and is rated as “HIGH” in Area B.

The cost associated with this alternative for the Area B headwaters is \$11 million and is rated as “LOW” regarding cost.

5.7 AREA B (DOWNSTREAM EAST) – ALTERNATIVE 3 - FLY ASH SLURRY INJECTION

5.7.1 Description

The description is the same as described above in Section 3.2.2.3.

To facilitate fly ash injection, approximately 0.9 mile of temporary road would need to be constructed, and an estimated 17 bore holes would have to be drilled.

5.7.2 Evaluation

The major difficulty regarding the effectiveness of the fly ash grouting alternative is its ability to completely fill the voids and openings within the mine cavities. This ability can only be estimated using accurate historical mine maps and is given an effectiveness rating of “MEDIUM.” The technology has been widely used at abandoned mine sites and is rated as “HIGH” for implementability in this portion of Area B.

The cost associated with this alternative for Area B eastern downstream location is \$5.5 million, and so is rated as “MEDIUM” regarding cost.

5.8 AREA B (DOWNSTREAM EAST) – ALTERNATIVE 1 - WASTE MATERIAL EXCAVATION AND PLACEMENT IN A REPOSITORY

5.8.1 Description

The description is the same as described above in Section 5.1.

5.8.2 Evaluation

The ability of this alternative to immobilize and contain the AMD-producing materials once the repository is capped results in an effectiveness rating of “HIGH.” Waste excavation in this Area would require re-building of the stream that is affected by residual piles. The necessity of moving trees and vegetation and the limited accessibility (due to grade of slope, difficulty in identifying waste, large extent of coverage) result in a rating of “MEDIUM” for implementability.

Cost for this alternative at Area B is estimated at \$600,000 and given a rating of “High”.

5.9 AREA B (DOWNSTREAM WEST) – ALTERNATIVE 3 - FLY ASH SLURRY INJECTION

5.9.1 Description

The description is the same as described above in Section 3.2.2.3.

To facilitate fly ash injection, approximately 0.9 mile of temporary road would need to be constructed, and an estimated 12 boreholes would need to be drilled.

5.9.2 Evaluation

The major difficulty regarding the effectiveness of the fly ash grouting alternative is its ability to completely fill the voids and openings within the mine cavities. This ability can only be estimated using accurate historical mine maps and is given an effectiveness rating of “MEDIUM.” The technology has been widely used at abandoned mine sites and is rated as “HIGH” for implementability in this portion of Area B.

The cost associated with the alternative for the western downstream portion of Area B is \$5.5 million, and so is rated as “MEDIUM” regarding cost.

5.10 AREA B – ALTERNATIVE 5 – SULFATE REDUCING BIOREACTORS (SRBS)

5.10.1 Description

SRBs would be constructed at multiple locations within Area B, including below seeps and mine openings

at the headwaters of Wildcat Branch and downstream in the southern portion of the area, and would likely be combined with “polishing features” such as constructed wetlands or settling ponds to complete a passive treatment system. Space within Area B is abundant in which to locate, design, and construct the SRBs and associated features. An estimated 1-2 SRBs could be constructed within Area B, so for cost estimation, 2 will be considered. Minimal periodic O&M and monitoring is anticipated and will be considered in the cost estimate, along with an assumption that the organic substrate and limestone will require replacement after 15 years. Also considered in the cost estimate will be bench and pilot level studies to determine if the SRB will be effective and provide information for the design.

5.10.2 Evaluation

Sulfate reduction has been shown to effectively treat AMD containing dissolved heavy metals, including aluminum, similar to the conditions at the Wildcat Branch Mines Site. Effectiveness will be dependent upon availability of suitable organic substrate and ability to maintain and periodically replenish the SRB. SRBs have been successful in conditions similar to those at the Site; however, due to the wide range of performance of passive systems such as SRBs, the effectiveness rating is “MEDIUM.” Area B has sufficient space available for construction of SRBs and polishing features, and access for construction is available, so implementability is rated as “HIGH.”

The estimated cost for 2 SRBs at Area B, including bench and pilot studies, polishing features, and periodic substrate replacement is \$1.7 million, Site locations could be prioritized, and the 2 SRBs could be constructed in phases, as funding and logistics allow for approximately \$850,000 each, and the alternative is given a rating of “High.”

5.11 AREA B – ALTERNATIVE 6 – AML ENHANCEMENT RULE REMOVAL

5.11.1 Description

Area B has approximately 3 acres of coal refuse that may be suitable for removal by the AML Enhancement Rule. The coal refuse will need to be sampled and tested to determine if it has sufficient value to transport to a processing facility. The existing road to the coal refuse location may need improvements prior to transporting the material.

5.11.2 Evaluation

Similar to waste removal to a repository, this alternative is considered highly effective due to the removal of acid forming coal refuse from the site and is given an effectiveness rating of “HIGH.” However, this alternative’s effectiveness is limited to the AMD associated with the coal refuse and will have to be combined with other alternatives to mitigate other AMD sources in the Area. The uncertain value of the coal refuse, along with the necessity of moving trees and vegetation and the limited accessibility (due to grade of slope, difficulty in identifying waste, large extent of coverage) result in a rating of “MEDIUM” for implementability.

The cost for this alternative could vary greatly depending upon the value of the coal refuse. If there is a market for the coal refuse but low value, the cost would include excavation, transport, and required road improvements. These costs are estimated at approximately \$700,000, a relatively low cost, and given a rating of “HIGH.” Any significant monetary value of the coal refuse would further offset this cost.

5.12 AREA C – ALTERNATIVE 1 – WASTE MATERIAL EXCAVATION AND PLACEMENT IN A REPOSITORY

5.12.1 Description

The description is the same as described above in Section 5.1.

5.12.2 Evaluation

The ability of this alternative to immobilize and contain the AMD-producing materials once the repository is capped results in an effectiveness rating of “HIGH.” Because of impacted stream below the fill area, waste excavation in this Area would require re-building about 500 feet of the stream below the site. The necessity of moving trees and vegetation and the limited accessibility (due to grade of slope, difficulty in identifying waste, large extent of coverage) result in a rating of “MEDIUM” for implementability.

Cost for this alternative at Area C is estimated at \$450,000– a relatively low cost - and given a rating of “HIGH”.

5.13 AREA C – ALTERNATIVE 5 – SULFATE REDUCING BIOREACTORS (SRBS)

5.13.1 Description

An SRB would be constructed at 1 location within Area C, including below seeps and mine openings and/or along unnamed tributaries to Wildcat Branch and would likely be combined with “polishing features” such as constructed wetlands or settling ponds to complete a passive treatment system. Space within Area C is abundant in which to locate, design, and construct the SRB and associated features. Minimal periodic O&M and monitoring is anticipated and will be considered in the cost estimate, along with an assumption that the organic substrate and limestone will require replacement after 15 years. Also considered in the cost estimate will be bench and pilot level studies to determine if the SRB will be effective and provide information for the design.

5.13.2 Evaluation

Sulfate reduction has been shown to effectively treat AMD containing dissolved heavy metals, including aluminum, similar to the conditions at the Wildcat Branch Mines Site. Effectiveness will be dependent upon availability of suitable organic substrate and ability to maintain and periodically replenish the SRB. SRBs have been successful in conditions similar to those at the Site; however, due to the wide range of performance of passive systems such as SRBs, the effectiveness rating is “MEDIUM.” Area C has sufficient space available for construction of SRBs and polishing features, and access for construction is available, so implementability is rated as “HIGH.”

The estimated cost for 1 SRB at Area C, including bench and pilot studies, polishing features, and periodic substrate replacement is \$900,000, which is relatively low and is given the rating of “HIGH.”

5.14 AREA C – ALTERNATIVE 6 – AML ENHANCEMENT RULE REMOVAL

5.14.1 Description

Area C has approximately 4 acres of coal refuse that may be suitable for removal by the AML Enhancement Rule. The process of testing the coal refuse in Area C to determine its value began in 2013 and results are anticipated in 2015. The existing road to the coal refuse location has already been improved so that it is suitable for transporting the material.

5.14.2 Evaluation

Similar in waste removal to a repository, this alternative is considered highly effective due to the removal of acid forming coal refuse from the site and is given an effectiveness rating of “HIGH.” The uncertain value of the coal refuse, along with the necessity of moving trees and vegetation and the limited accessibility (due

to grade of slope, difficulty in identifying waste, large extent of coverage) result in a rating of “MEDIUM” for implementability.

The cost for this alternative could vary greatly depending upon the value of the coal refuse. If there is a market for the coal refuse but low value, the cost would include excavation, transport, and required road improvements. These costs are estimated at approximately \$900,000, a relatively low cost, and given a rating of “HIGH.” Any significant monetary value of the coal refuse would offset this cost.

5.15 AREA D (SOUTH) - ALTERNATIVE 3 - FLY ASH SLURRY INJECTION

5.15.1 Description

Access needs to the abandoned mine entries would remain as expressed above for this alternative, but to a lesser degree. The basic needs for access to the bottom would be to mobilize equipment and supplies needed to construct a seal at the “fan house” opening as to contain any fly ash slurry that would flow to, and possibly exit the mine. Access roads for drilling bore holes for injection or monitoring purposes must be constructed on top of the mine. The gently rolling ridge top and gentle to moderate side slopes would pose few limitations to the drilling and pumping phase of this operation. The ridge top above the mine has locations that would serve well as a staging area to mobilize equipment, fly ash, and other supplies.

Approximately 0.75 mile of existing road would need reconstruction, 2,000 feet of new construction, and 0.75 mile of temporary road would need to be constructed, and an estimated 23 boreholes would need to be drilled.

5.15.2 Evaluation

The major difficulty regarding the effectiveness of the fly ash grouting alternative is its ability to completely fill the voids and openings within the mine cavities. This ability can only be estimated using accurate historical mine maps and is given an effectiveness rating of “MEDIUM.” The technology has been widely used at abandoned mine sites and is rated as “HIGH” for implementability in this portion of Area D.

The cost associated with this alternative for the southern portion of Area D is \$1.7 million, and so is rated as “MEDIUM” regarding cost.

5.16 AREA D (SOUTH) - ALTERNATIVE 1 - WASTE MATERIAL EXCAVATION AND PLACEMENT IN A REPOSITORY

5.16.1 Description

The same comments given above regarding access for Area D with respect to removing mine spoils and abandoned mining equipment (i.e. coal haulage shuttle cars) apply to this alternative. All coal mine spoils and abandoned mining equipment would need to be taken out by truck on an improved road to the ridge where a stable, protected waste repository could be constructed to store the mine waste. The old mine cars may potentially have historical value and could be donated to mining museum or other non-profit organizations. As with Alternative 4 for Area D, the ridge top above the mine has locations that would serve well as a staging area to mobilize equipment, and other supplies and for construction of a repository for coal waste recovered from the mine site below.

Approximately 4,000 feet of existing road needs reconstruction, in addition to 2,000 feet of new road construction.

5.16.2 Evaluation

The ability of this alternative to immobilize and contain the AMD-producing materials once the repository is capped results in an effectiveness rating of “HIGH.” The necessity of moving trees and vegetation and the limited accessibility (due to grade of slope, difficulty in identifying waste, large extent of coverage) result in a rating of “MEDIUM” for implementability.

Cost for this alternative at Area D is estimated at \$240,000 and given a rating of “HIGH,” due to the relatively low cost.

5.17 AREA D – ALTERNATIVE 5 – SULFATE REDUCING BIOREACTORS (SRBS)

5.17.1 Description

SRBs would be constructed at multiple locations within Area D, including below seeps and mine openings and/or along unnamed tributaries to Addison Branch and would likely be combined with “polishing features” such as constructed wetlands or settling ponds to complete a passive treatment system. Space within Area D is abundant in which to locate, design, and construct the SRBs and associated features. An estimated 1-2 SRBs could be constructed within Area D, so for cost estimation, 2 will be considered. Minimal periodic O&M and monitoring is anticipated and will be considered in the cost estimate, along with an assumption that the organic substrate and limestone will require replacement after 15 years. Also considered in the cost estimate will be bench and pilot level studies to determine if the SRB will be effective and provide information for the design.

5.17.2 Evaluation

Sulfate reduction has been shown to effectively treat AMD containing dissolved heavy metals, including aluminum, similar to the conditions at the Wildcat Branch Mines Site. Effectiveness will be dependent upon availability of suitable organic substrate and ability to maintain and periodically replenish the SRB. SRBs have been successful in conditions similar to those at the Site; however, due to the wide range of performance of passive systems such as SRBs, the effectiveness rating is “MEDIUM.” Area D has sufficient space available for construction of SRBs and polishing features, and access for construction is available, so implementability is rated as “HIGH.”

The estimated cost for 2 SRBs at Area D, including bench and pilot studies, polishing features, and periodic substrate replacement is \$1.7 million. Site locations could be prioritized, and the 2 SRBs could be constructed in phases, as funding and logistics allow for approximately \$850,000 each, and the alternative is given a rating of “High.”

5.18 AREA D – ALTERNATIVE 6 – AML ENHANCEMENT RULE REMOVAL

5.18.1 Description

Area D has approximately 2 acres of coal refuse that may be suitable for removal by the AML Enhancement Rule. The coal refuse will need to be sampled and tested to determine if it has sufficient value to transport to a processing facility. The existing road to the coal refuse location will need significant improvements prior to transporting the material.

5.18.2 Evaluation

Similar to waste removal to a repository, this alternative is considered highly effective due to the removal of acid forming coal refuse from the site and is given an effectiveness rating of “HIGH.” However, this alternative’s effectiveness is limited to the AMD associated with the coal refuse and will have to be combined with other alternatives to mitigate other AMD sources in the Area. The uncertain value of the

coal refuse, along with the necessity of moving trees and vegetation and the limited accessibility (due to grade of slope, difficulty in identifying waste, large extent of coverage) result in a rating of “MEDIUM” for implementability.

The cost for this alternative could vary greatly depending upon the value of the coal refuse. If there is a market for the coal refuse, the cost would include excavation, transport, and required road improvements. These costs are estimated at approximately \$525,000, a relatively low cost, and given a rating of “HIGH.” Any monetary value of the coal refuse would offset this cost.

5.19 SUMMARY TABLE

Table 5.1 gives a visual qualitative summary of whether each alternative rates "HIGH", "MEDIUM" or "LOW" for each of the evaluation factors. The purpose of the comparative analysis is to identify the advantages and disadvantages of each alternative relative to one another so that key tradeoffs that would affect the remedy selection can be identified. In this case of an Area with multiple sites, such a comparison is, of necessity, site-specific.

DRAFT

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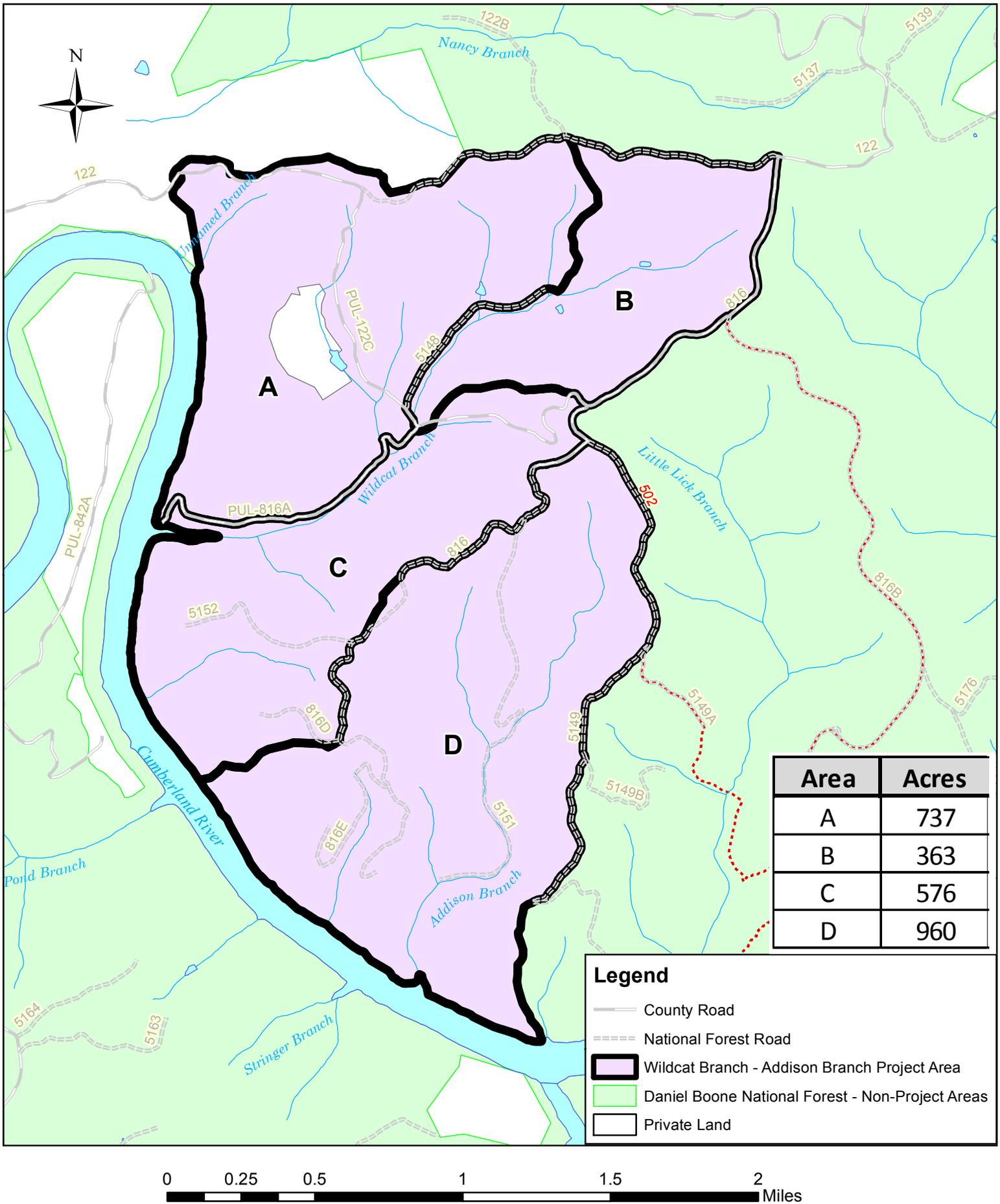


Figure 1-1. Wildcat Branch-Addison Branch Project Areas

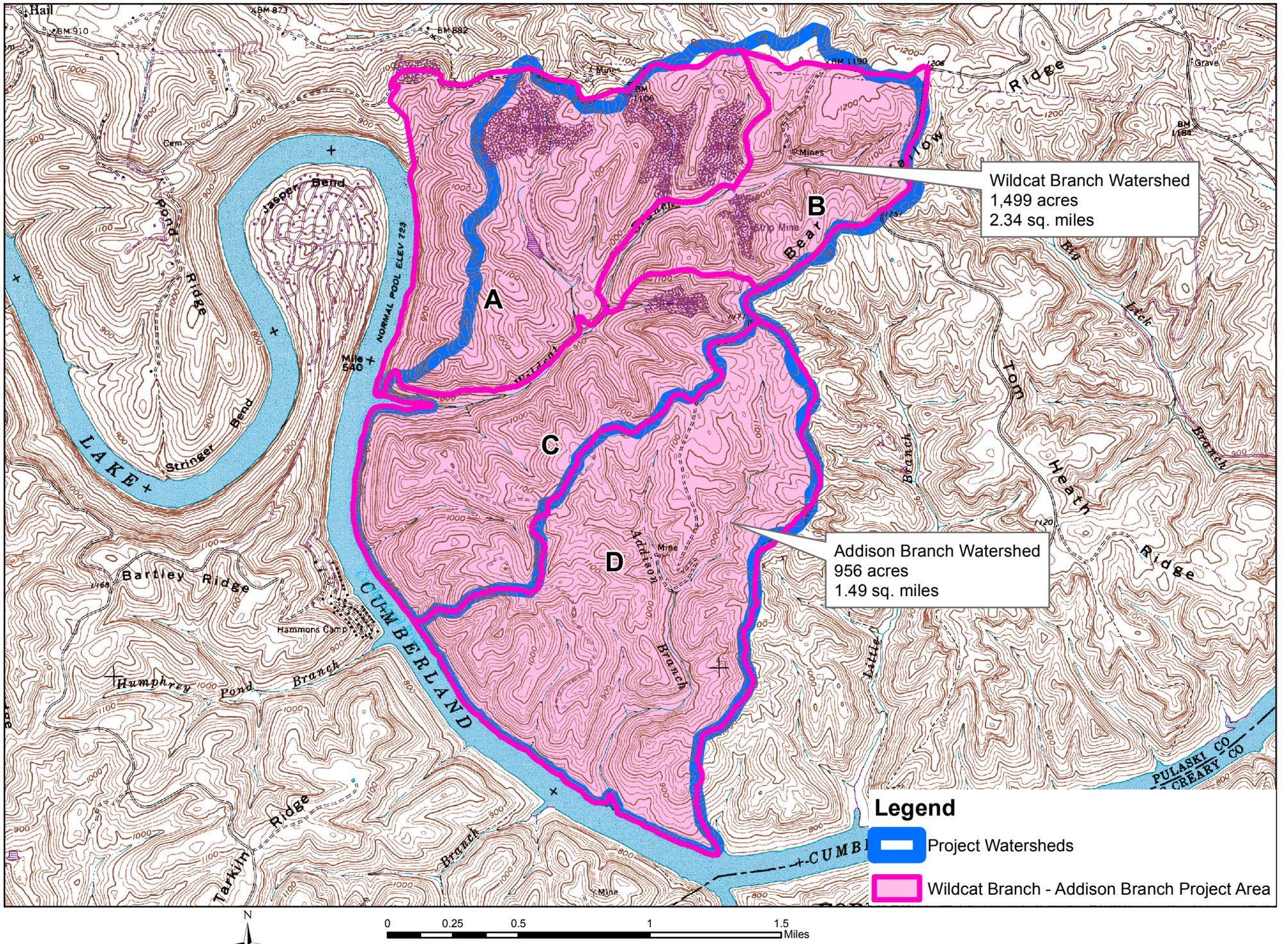


Figure 1-2. Wildcat Branch and Addison Branch Watersheds

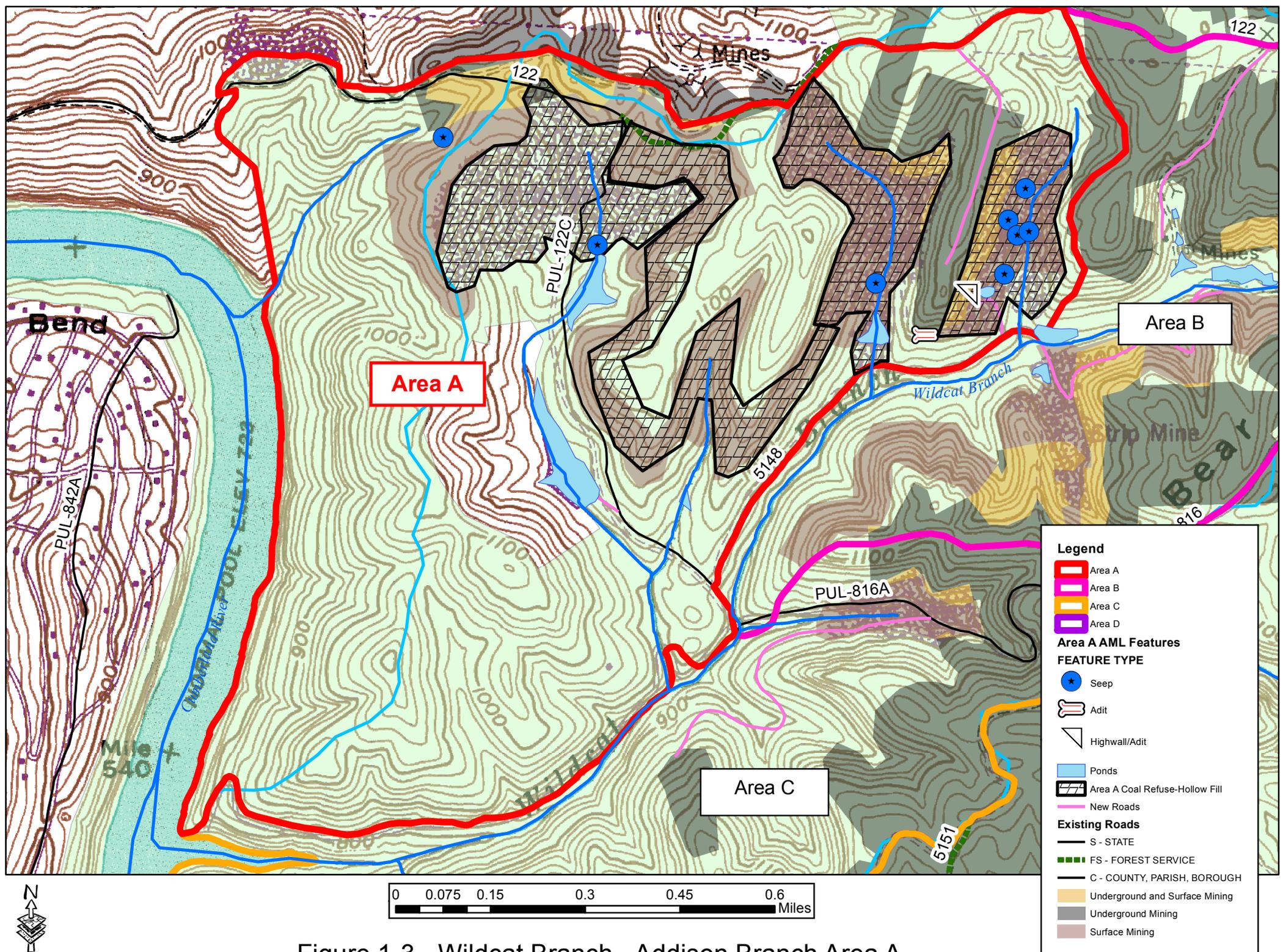


Figure 1-3 - Wildcat Branch - Addison Branch Area A

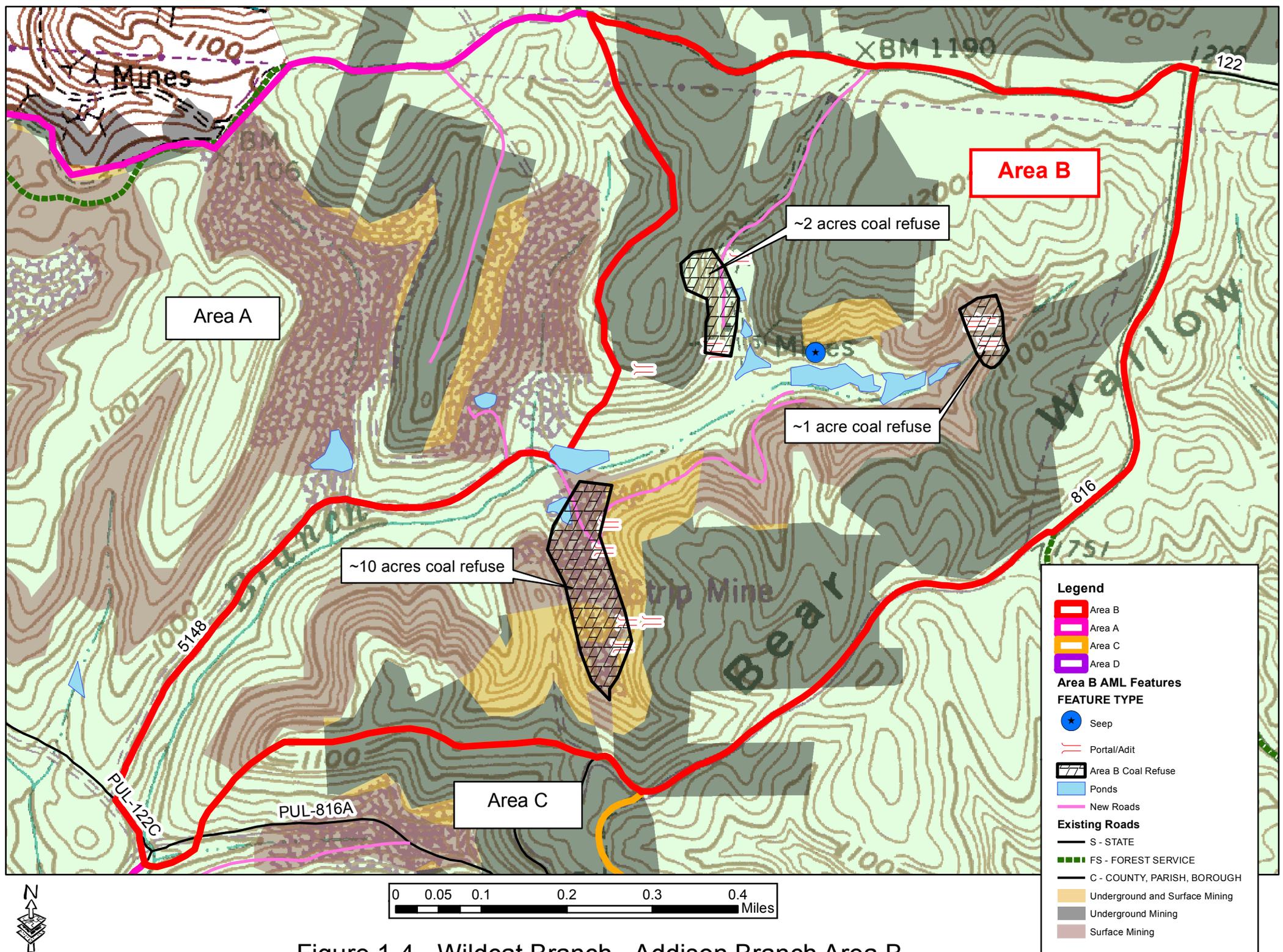


Figure 1-4 - Wildcat Branch - Addison Branch Area B

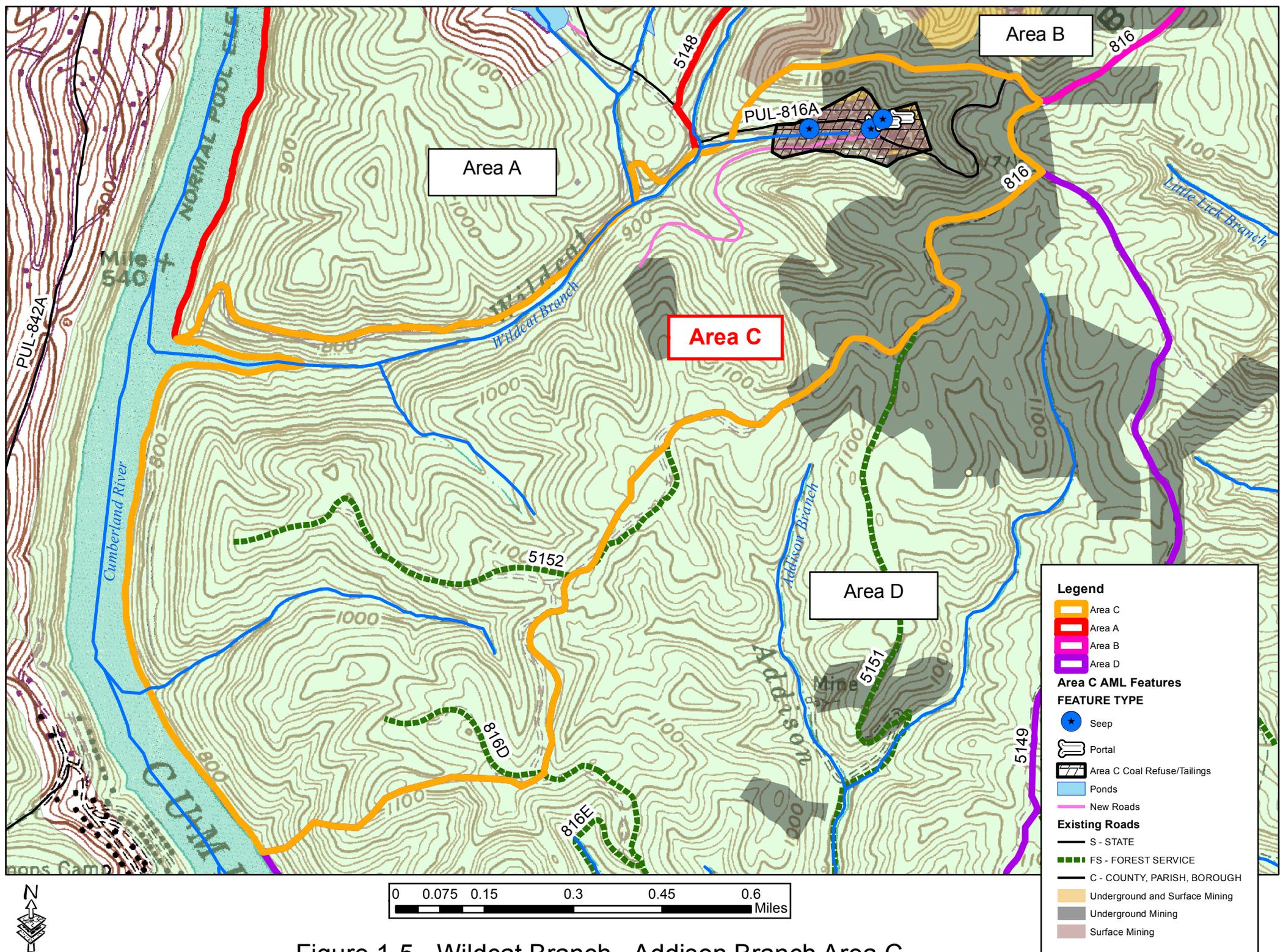


Figure 1-5 - Wildcat Branch - Addison Branch Area C

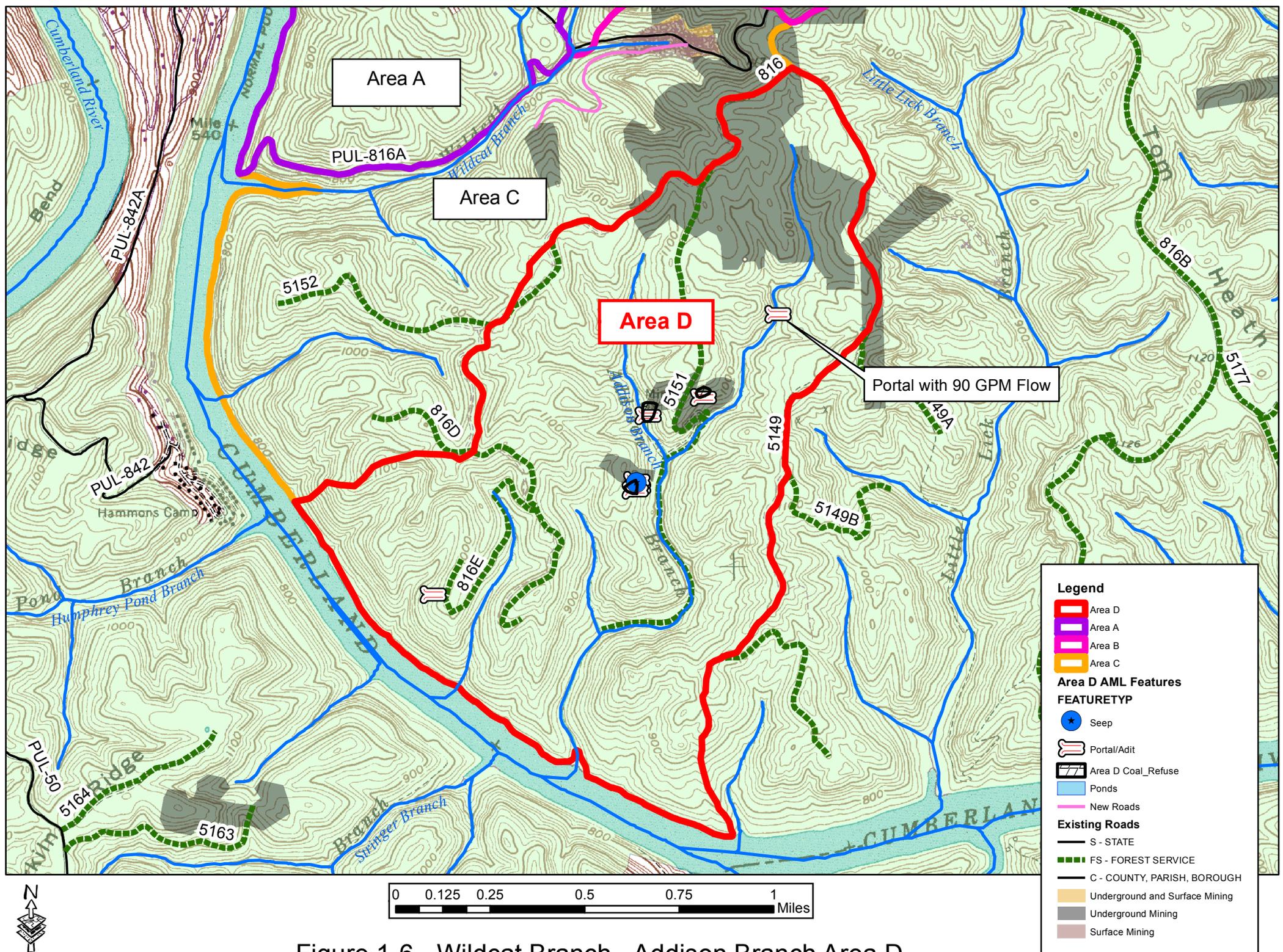


Figure 1-6 - Wildcat Branch - Addison Branch Area D

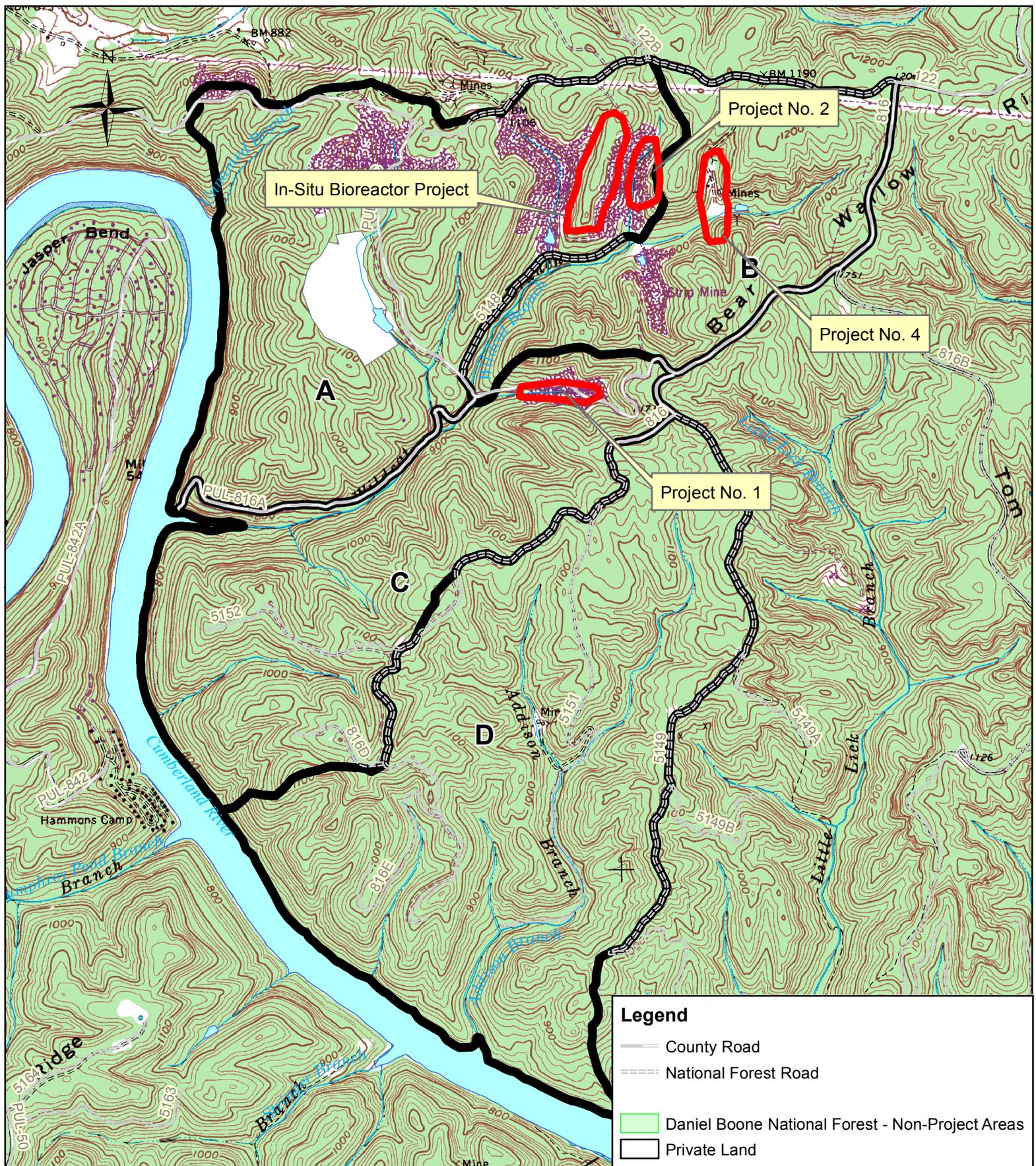
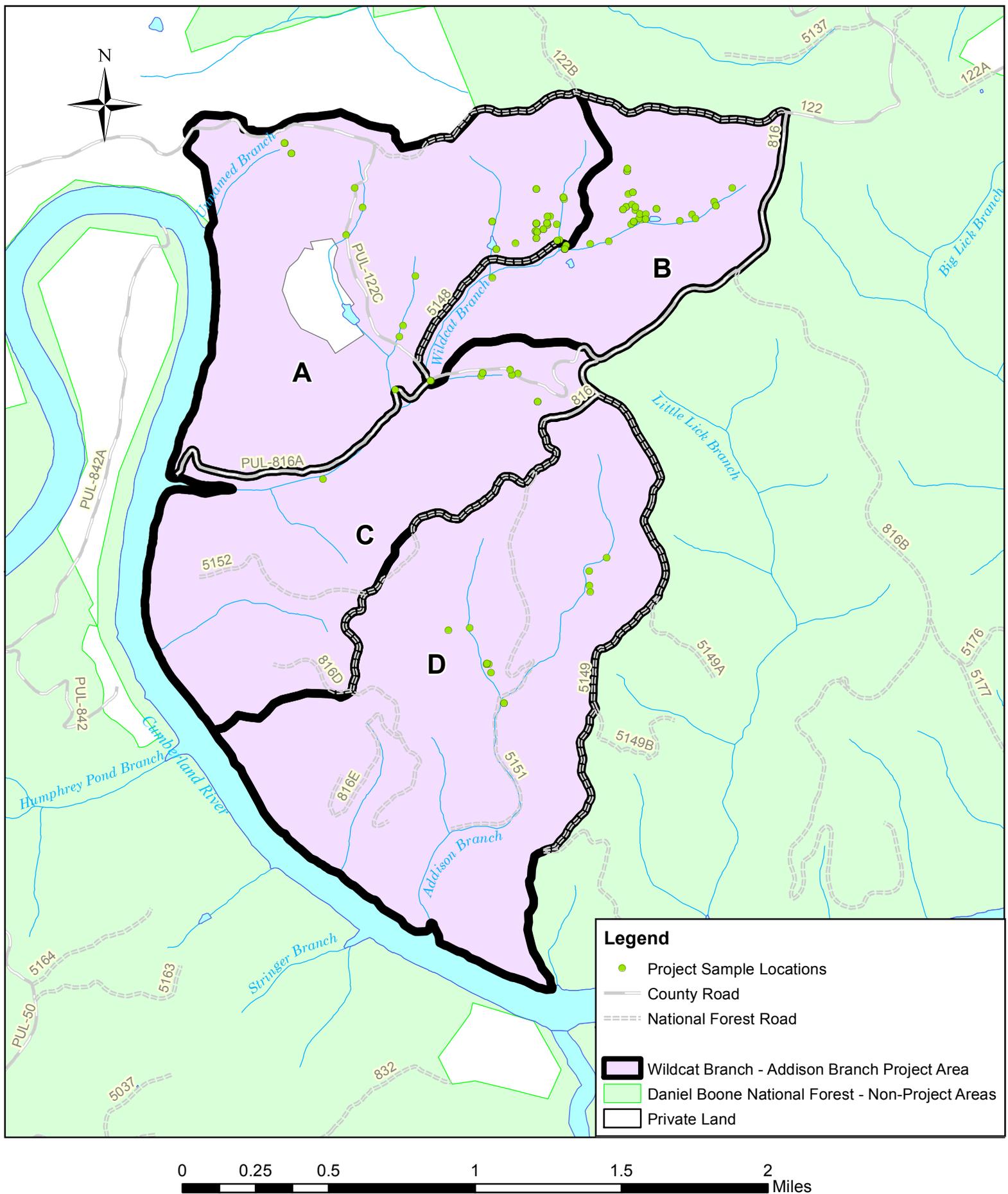


Figure 1-7. Wildcat Branch – Addison Branch Project Areas Previous Removal and Pilot Projects



**Figure 1-8. Wildcat Branch – Addison Branch Project Areas
Project Sample Locations**

Table 1-1. Four Source Areas Included in the Wildcat Branch Mines Complex

Site	Location	Area	Area Occupied by Waste (est)
Area A	Northwest portion of the Wildcat Branch watershed	737 acres	150 acres
Area B	Northeastern portion of the Wildcat Branch watershed, including the headwaters	363 acres	80 acres
Area C	Southeast portion of the Wildcat Branch watershed, to the confluence with the Cumberland River	576 acres	12 acres
Area D	Addison Branch Watershed	960 acres	7.7 acres

Table 1-2. Coal Refuse Sampling - Total Potential Acidity and Neutralization Potential

Sample	Description	Total Potential Acidity (Tons / kiloton)	Total Neutralization Potential (Tons / kiloton)	Net Acidity (Tons / kiloton)
1	Composite of black shale above Beaver Creek coal seam	186.6	< 0.5	186.1
2	Composite of coal refuse	20.9	< 0.5	20.4
3	Composite of coal refuse	44.7	< 0.5	44.2
4	Composite of mixed soil and coal refuse	6.9	< 0.5	6.4

Table 1-3. Coal Refuse Sampling – Other Parameters

Parameter	0 to 15 cm Depth	> 15 cm Depth
pH	2.4	2.4
Potential Acidity	46 meg/100g	6.4 meg/100g
Aluminum (mg/L)	86	212
Iron (mg/L)	50	688
Manganese (mg/L)	27	107
SO ₄ (mg/L)	524	1,257
Calcium (mg/L)	236	417

Table 1-4. Summary of Wildcat Branch Sediment Analytical Results

Analyte	Area B WB-S-01-01	Area B WB-S-02-01	Area A WB-S-03-01	Area C WB-S-04-01	Area D WB-S-05-01
Metals:					
Aluminum	2120.0	7310.0	6100.0	3930.0	6490.0
Antimony	ND	ND	ND	ND	ND
Arsenic	ND	20.0	ND	1.41	5.46
Barium	16.2	6.33	12.3	42.7	30.8
Beryllium	ND	3.26	2.22	ND	ND
Cadmium	ND	3.65	2.02	ND	ND
Calcium	238.0	1740.0	57.8	6270.0	1180.0
Chromium	4.68	11.1	8.48	8.87	17.2
Cobalt	ND	6.91	2.02	15.5	10.3
Copper	5.07	5.76	7.88	6.45	10.5
Iron	40000.0	259000.0	174000.0	13500.0	20900.0
Lead	2.34	2.69	5.66	6.65	12.5
Magnesium	89.1	55.9	97.8	448.0	1040.0
Manganese	36.3	130	271.0	1000.0	212.0
Mercury	ND	ND	ND	ND	ND
Nickel	1.17	57.8	4.44	29.0	ND
Potassium	102.0	ND	309.0	722.0	26.7
Selenium	ND	ND	ND	ND	1450.0
Silver	ND	ND	ND	ND	ND
Sodium	ND	ND	ND	ND	ND
Thallium	ND	ND	ND	ND	ND
Vanadium	ND	42.2	ND	ND	ND
Zinc	ND	26.5	37.6	44.4	48.0
General Chemistry Parameters:					
pH	4.50	3.4	4.0	6.8	6.4
Fluoride	ND	4.9	ND	ND	1.1
Chloride, s	ND	ND	ND	ND	ND
Nitrate-N as N	ND	ND	ND	ND	ND
Sulfate, s	232.0	3400.0	365.0	81.3	49.0
Bromide	ND	ND	ND	ND	ND
Notes: ND = Not detected at the laboratory limits. All results reported in mg/L.					

Table 1-5. Summary of Wildcat Branch Spoil/Soil Analytical Results (Page 1 of 2)

Analyte	Area B WB-P-01-01	Area B WB-P-02-01	Area B WB-P-03-01	Area C WB-P-04-01	Area C WB-P-05-01	Area C WB-P-06-01	Area A WB-P-07-01	Area A WB-P-08-01	Area D WB-P-09-01	Area D WB-P-10-01
Metals:										
Aluminum	3780.0	756.0	561.0	789.0	2410.0	4470.0	1910.0	1320.0	1940.0	811.0
Antimony	ND									
Arsenic	1.2	ND	6.87	ND	1.59	8.67	9.04	9.72	ND	6.63
Barium	86.2	28.4	62.2	32.4	143.0	17.0	139.0	103.0	26.4	34.1
Beryllium	ND	1.15	ND	ND	ND	1.73	ND	ND	1.19	ND
Cadmium	ND									
Calcium	256.0	300.0	176.0	ND	170.0	101.0	238.0	312.0	726.0	102.0
Chromium	11.2	8.97	4.77	8.01	18.1	13.5	13.8	9.13	11.1	14.6
Cobalt	2.2	4.96	ND	ND	2.78	15.8	1.92	1.59	14.1	ND
Copper	9.2	7.44	7.25	11.3	24.7	17.3	8.27	6.75	23.4	5.26
Iron	9660.0	2120.0	9920.0	8160.0	5650.0	17300.0	20000.0	13100.0	6390.0	16600.0
Lead	9.6	11.8	14.1	13.9	14.9	9.83	20.4	19.2	20.8	17.0
Magnesium	220	50.4	ND	ND	114.0	800.0	126.0	81.2	321.0	79.1
Manganese	14.4	6.49	13.2	4.3	3.98	171.0	76.7	13.3	218.0	4.48
Mercury	0.192	0.331	0.495	ND	ND	ND	0.77	0.153	ND	0.118
Nickel	7.0	13.2	3.05	2.15	16.9	66.7	8.85	6.35	23.8	1.75
Potassium	844.0	190.0	323.0	1010.0	722	757.0	723.0	802.0	312.0	998.0
Selenium	2.0	2.86	1.91	ND	2.58	2.31	2.12	ND	2.78	3.12
Silver	ND									
Sodium	ND									
Thallium	ND									
Vanadium	13.8	11.5	ND	ND	25.2	12.3	16.0	16.3	14.5	16.6
Zinc	13.6	15.6	11.6	11.9	ND	77.3	14.2	10.5	57.4	16.2

Table 1-5. Summary of Wildcat Branch Spoil/Soil Analytical Results (Page 2 of 2)

Analyte	Area B WB-P-01-01	Area B WB-P-02-01	Area B WB-P-03-01	Area C WB-P-04-01	Area C WB-P-05-01	Area C WB-P-06-01	Area A WB-P-07-01	Area A WB-P-08-01	Area D WB-P-09-01	Area D WB-P-10-01
Miscellaneous Chemistry:										
pH	3.0	3.7	2.3	2.8	3.6	2.4	2.5	3.1	4.9	3.5
Fluoride	ND	ND	ND	ND	ND	41.8	1.5	ND	ND	ND
Chlorides	ND									
Nitrate-N as N	ND									
Sulfate, s	416.0	71.9	4310.0	1030.0	67.3	49200.0	2290.0	304.0	ND	62.8
Bromide	ND									
Notes: ND = Not detected at the laboratory limits. All results reported in mg/L.										

Table 1-6. Description of Historical Surface Water Sampling Site Locations

NRCS	FS	Sample Location
3A	3F/3R, 3H	Taken at the upper seep above the valley fill pipe.
3B	3.2F/3.2R, 3S	Taken at the riprap chute below the precast concrete AMD cells on Forest Project #2, above the earthen bench above the old sediment pond.
--	3.3F/3.3R	Taken at the road ford or chute where the drainage from Site 3 and Site 8 cross the road.
5	W5R/5FA	Taken immediately below chute crossing of road.
8A	--	Taken just upstream of the existing earthen embankment at the lower part of the site.
8B	8W	Taken just below the lower beaver dam.
8C	8R/8F	Taken just inside the lower adit.
8D	--	Taken just inside the middle adit.
8E	8E	Taken in the ditch below the small wetland pond in the NE corner of Site 8.
9A	9/P9F/P9R	Taken in the drain of the red seep before it enters the SE corner of Site 8.
--	P9R2/P9F2	Taken in the concrete invert of the pond outflow just above the entrance to the road culvert.
9B	--	Taken at inlet of principal spillway pipe of dam.
9C	--	Taken at the valley fill pipe outflow above the pond at the toe of the valley fill.
<p>NOTES: NRCS = Samples taken by Natural Resources and Conservation Service. FS = Forest Service Samples.</p> <p>The letter "F" as a part of a sample number indicates samples that were fixed or acidified for metal determination. The letter "R" represents raw water samples.</p>		

**Table 1-7. Summary of Historical Water Quality Parameters at
Wildcat Branch Mines Site, NRCS Sampling 2000-2001**

Parameter	Range	Mean	Water Quality Criteria⁽¹⁾
pH (units)	2.2 – 7.1	4.5	6.0 - 9.0
TDS (mg/L)	200 – 2500	1667	750 ⁽²⁾
Alkalinity (total CaCO ₃)	0 – 26	8.5	--
Hardness (mg/L as CaCO ₃)	100 – 1600	884	NA
Conductivity (umhos/cm)	440 – 5300	2360	--
Total Acidity (mg/L)	320 – 3300	728	--
SO ₄ (mg/L)	89 – 1600	1073	250 ⁽²⁾
Al (mg/L)	0.08 – 39	8.7	NA
Fe Total (mg/L)	0.22 – 100	25.6	NA
Fe (mg/L)	0 – 107	15.0	4.0
Mn (mg/L)	0.12 – 42.0	15.5	0.05 ⁽²⁾
⁽¹⁾ Cold water aquatic habitat criteria for the Commonwealth of Kentucky, unless otherwise noted. ⁽²⁾ Domestic water supply use for the Commonwealth of Kentucky.			

Table 1-8. Sample Locations by Source Area¹ – 2015 Expanded Site Inspection (ESI)²⁻³

Source Area	Acreage	Total Samples	2002 Sample ID's	2008 Sample ID's	2010 Sample ID's	2011 Sample ID's
A	737	33	116, 120, 400, 402, 404, 407	5, 18	MW#3, A#1, P#1, S#1, SP#1, 16, 17, 18, 19, 20, 21, 22, 23, 23B	MW#3, MW#4, A#1, P#1, P#2, S#1, SP#1, SWS1, SWS1A, SWS2, SWS4
B	363	35	200, 29, 301, 302, 303, 304, 305, 92	1, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 24	-
C	576	5	220, 410	15,16,19	-	-
D	960	11	12	-	25, 26, 27, 28, 29, 30, 21, 32, 33, 34	-

1 - Sample numbers/designations represent different sample locations in different years, except for the bioreactor sample points.

2 – Sample locations are shown on Figures 4-10 of the 2015 ESI (USDA 2015).

3 – Complete analytical results are located in the 2015 ESI (USDA 2015).

Table 3-1: Results of Screening Technologies against the Five USDA FS Criteria

Technology	- 1 - No long-term outlay of labor/cost	- 2 - able to remove both metals and acid contamination (effective)	- 3 - Implementable at Wildcat/Addison Branch Mines Site	- 4 - proven effective in AMD applications	- 5 - Economically Feasible
Aerobic wetlands*	No	Partial	Yes	Yes	Yes
Anaerobic wetlands*	No	Yes	Yes	Yes	Yes
Vertical-flow wetlands	No	Yes	Yes	Yes	Yes
Sulfate-reducing bioreactor	No	Yes	Yes	Yes	Yes
Limestone-lined channels*	No	Partial	Yes	Yes	Yes
Anoxic limestone drains (ALDs)*	No	Partial	Yes	Yes	Yes
Successive alkalinity-producing systems (SAPS)* / Alkaline recharge/alkaline-producing systems (APS)*	No	Partial	Yes	Yes	Yes
Limestone ponds/Settling basins/Leach beds*	No	Yes	Partial	Yes	Yes
Diversion wells*	No	Partial	Yes	Partial	?
Limestone sand treatment (dosing)*	No	Partial	Yes	Partial	?
Burial of waste in repository*	Yes	Yes	Yes	Yes	Yes
Re-mining with source removal to repository*	Yes	Yes	Yes	Partial	Yes
Reactor barrier walls	Yes	Partial	Yes	Partial	Yes
Grouting / grout curtains	Yes	Partial	Yes	Partial	?
Slurry injection	Yes	Yes	Yes	Partial	Yes
Impermeable barriers / mine seals	Yes	Partial	Yes	Partial	?
Blasting / collapsing mine chambers	Yes	Partial	Yes	Partial	?
Plugging mine openings	Yes	Partial	Yes	Partial	Yes
Pyrite micro-encapsulation / inactivation	Yes	Partial	Yes	Partial	?
Mine chamber flooding	No	Yes	Yes	Partial	No
Area inundation (submergence)	No	Yes	Yes	Partial	No
Bactericides	No	Partial	Yes	Partial	?
Aeration / Oxidation / Metal precipitation agents	No	Yes	Yes	Partial	?
Flocculant/Coagulant agents	No	Partial	Yes	Partial	?
In-situ bioremediation	No	Yes	Yes	Partial	Yes
Pyrolusite treatment system	No	Partial	Partial	Partial	?
Wood filters	No	Yes	Partial	Partial	?
In-line aeration and treatment	No	Partial	Yes	Partial	?
Reverse osmosis	No	Yes	Partial	Yes	?
Electrodialysis	No	Yes	Yes	Yes	?
Neutralization / precipitation	No	Yes	Partial	Yes	?
Wastewater treatment plant	No	Yes	Partial	Yes	?
Re-grading of spoil piles	Yes	Partial	Yes	Yes	Yes
Re-vegetation of spoil piles	Yes	Partial	Yes	Yes	Yes
Upstream planting to divert runoff	Yes	Partial	Yes	Yes	Yes

Notes:

* indicates the technology has been installed at location(s) in the Daniel Boone National Forest

Yes = meets the criterion

No = does not meet the criterion

Partial = meets some aspect of the criterion

? = unknown whether it will meet the criterion

Table 5.1: Qualitative Comparison of Alternatives Using Evaluation Criteria

ALTERNATIVE	LOCATION	EFFECTIVENESS FEASIBILITY RATING	IMPLEMENTABILITY FEASIBILITY RATING	COST FEASIBILITY RATING	COMMENTS
Alternative 1 - Waste Material Excavation and Placement in a Repository	Area A	High	Medium	Medium (\$3.3 Million)	Valley Fill
	Area B Downstream East	High	Medium	High (\$600,000)	Multiple areas
	Area C	High	Medium	High (\$450,000)	Waste area at southernmost region of Wildcat Branch Watershed.
	Area D	High	Medium	High (\$240,000)	Southernmost site on Addison Branch; gob present at portals.
Alternative 2 - Surface Re-Mining with Special Handling of Source Materials	Area A	Medium	Medium	High (\$500,000)	Ridge area deep mine; site of In-Situ Bioreactor treatability study.
Alternative 3 - Fly Ash Slurry Injection	Area A	Medium	High	Medium (\$3 Million)	Ridge area deep mine; site of In-Situ Bioreactor treatability study.
	Area B Headwaters	Medium	High	Low (\$11 Million)	Large area in headwaters of Wildcat Branch.
	Area B Downstream East	Medium	High	Medium (\$5.6 Million)	Site of Project #4, below Wash Ridge Pond.
	Area B Downstream West	Medium	High	Medium (\$5.6 Million)	Southwest portion of Area B, between two waste sites.
	Area D	Medium	High	Medium (\$1.7 Million)	Southern portion of Area D, Addison Branch watershed.
Alternative 4 - In-Situ Bioremediation	Area A	Medium	High	Medium (\$1.2 Million)	Ridge area deep mine. Costs and effectiveness to be better estimated following completion of ongoing treatability study.

Table 5.1 (Cont'd): Qualitative Comparison of Alternatives Using Evaluation Criteria

ALTERNATIVE	LOCATION	EFFECTIVENESS FEASIBILITY RATING	IMPLEMENTABILITY FEASIBILITY RATING	COST FEASIBILITY RATING	COMMENTS
Alternative 5 – Sulfate Reducing Bioreactors	Area A	Medium	High	High (\$2.6 Million)	Cost includes constructing multiple SRBs at different source areas (Valley Fill and Deep Mine) within Area A and includes O&M, monitoring, and substrate replacement.
	Area B	Medium	High	High (\$1.7 Million)	Cost includes constructing multiple SRBs at different source (Valley Fill and Deep Mine) areas within Area B and includes O&M, monitoring, and substrate replacement.
	Area C	Medium	High	High (\$900,000)	Cost includes O&M, monitoring, and substrate replacement.
	Area D	Medium	High	High (\$1.7 Million)	Cost includes constructing multiple SRBs at different source areas (Valley Fill and Deep Mine) within Area D and includes O&M, monitoring, and substrate replacement.
Alternative 6 – AML Enhancement Rule Removal	Area B	High	Medium	High (\$700,000)	Coal waste pile in Area B. Cost will vary depending on the unknown value of the coal refuse.
	Area C	High	Medium	High (\$900,000)	Coal waste pile in Area C. Cost will vary depending on the unknown value of the coal refuse.
	Area D	High	Medium	High (\$525,000)	Coal waste pile in Area D. Cost will vary depending on the unknown value of the coal refuse.
“Low” = High Cost; “High” = Low cost					

**WILDCAT BRANCH/ADDISON BRANCH MINES SITE
ENGINEERING EVALUATION/COST ANALYSIS**

APPENDIX A

**TECHNOLOGIES FOR TREATMENT
OF ACID MINE DRAINAGE**

APPENDIX A TECHNOLOGIES FOR TREATMENT OF ACID MINE DRAINAGE

I. **Passive Treatment Systems:**

- Take advantage of naturally-occurring chemical and biological processes;
- Generally treat water in-situ;
- Utilize only naturally-available energy sources - e.g., gravity, microbial metabolic energy, photosynthesis;
- Generally require only infrequent, but regular, maintenance over the entire design life;
- Disadvantages: large land area needed, high capital (construction) costs, precise control of treatment not feasible, technology relatively new and unproven.

1) **Constructed Wetlands Systems:**

a. Aerobic wetlands

Description: Designed to provide sufficient residence time to allow metal oxidation and hydrolysis, thereby causing precipitation and physical retention of Fe, Al, and Mn hydroxides. Wetland plants encourage more uniform flow, help stabilize the substrate, help maintain microbial populations, and provide aesthetic qualities to the wetland. Good for polishing water after an initial treatment.

Comments: Requires long-term care and maintenance to prevent failure. Potentially used in a polishing role.

b. Anaerobic wetlands

Description: Rely on organic-rich substrates to generate reducing conditions, and also contain limestone for acid neutralization. These systems are used when the water is net acidic; alkalinity is generated through sulfate reduction and limestone dissolution. In addition, metals are precipitated as sulfides, hydroxides and/or carbonates. Like aerobic wetlands, anaerobic wetlands must have substantial residence time for the water; therefore, they require large areas to treat large volumes of strongly acidic AMD.

Comments: Requires long-term care and maintenance to prevent failure. Potentially used in a polishing role.

c. Vertical flow wetlands (VFWs)

Description: Water flows first downward through a layer of organic matter, then through a bed of limestone before flowing out through a drainage system. The system is designed to reduce ferric to ferrous iron and to scavenge dissolved oxygen as the AMD passes through the organic matter. The anoxic water is then introduced to an anaerobic limestone bed underneath the organic layer. Vertical flow wetlands can be placed in series with oxidizing ponds to achieve desired water quality.

Comments: Requires long-term care and maintenance, including periodic flushing and replacement of organic matter and limestone. The oxidation and reduction of metals (especially Fe and Al) can lead to precipitates that can clog the cell. Potentially used in a polishing role.

d. Biochemical Reactors, including Sulfate Reducing Bioreactors (SRBs)

Description: Biochemical reactors (BCRs) treat AMD by using microorganisms to transform contaminants and to increase pH in the treated water. The most commonly used BCRs for treating AMD are operated anaerobically (no oxygen) and are also called “sulfate-reducing” bioreactors (SRBRs, SRBs). The microbial process of sulfate reduction produces sulfide and bicarbonate within the reactor, allowing the target metals such as cadmium, copper, nickel, lead, and zinc in MIW to precipitate as metal sulfides at pH values above 5.0. The bicarbonate promotes an increase in pH and will promote the removal of some metals as carbonates such as FeCO_3 and ZnCO_3 under the appropriate conditions. BCRs may be applicable to the removal of a broad range of metal and metalloids found in AMD. BCRs can be designed to address a wide range of flows, acidity, and metals loading and also can be designed to operate in gravity flow or available powered mode. In general, BCRs are broken into active systems, which require continuous energy and/or chemical input, and passive systems. The active systems may employ separate tanks or zones for the bioprocesses, chemical reactions, and solids separation. The potential exists for recovery of metals at active mining and mineral processing sites using a variation of the sulfate-reducing process. Most passive systems (SRBs) use designs that incorporate the bioprocesses, chemical reactions, and the bulk of solids separation within an organic substrate. These systems may also require pretreatment and polishing steps. Because the effluent of these anaerobic systems has low dissolved oxygen, the polishing step is an aerobic cell that increases the oxygen and also decreases the toxicity. The organic substrate is generally a mixture of locally available organic materials (e.g., wood chips, manure) and often contains limestone to provide additional neutralizing capacity and to increase substrate permeability.

Comments: Requires long-term care and maintenance, replacement of organic matter and limestone and potential flushing of the system. Passive system (SRB) is retained for further consideration due to the potential to treat the highly acidic, metal laden AMD at the Wildcat/Addison Branch Mines Site.

2) **Limestone-based Systems:**

a. Limestone-lined channels

Description: Open channels or ditches lined with limestone. Experiments show that limestone coated with metal hydroxides, known as armoring, continues to dissolve at about 20 to 50% of the rates of unarmored limestone. However, continued dissolution probably depends on pH, thickness of coating, and other variables. Optimal performance is attained on slopes exceeding 12%, where flow velocities keep precipitates in suspension and help clean precipitates from limestone surfaces. Residence time is critical to OLC performance, yet water velocity must remain high.

Comments: Requires constant replenishment or scraping of the limestone. Channels may not be effective in water with high levels of Mn and Fe.

b. Anoxic limestone drains (ALDs)

Description: Buried and sealed cells of limestone into which anoxic water is introduced. The limestone dissolves in AMD, and since CO_2 cannot escape, a building of bicarbonate occurs, thus adding alkalinity. It is important that metal hydroxide precipitation within an ALD not occur because such precipitation will retard water flow, leading to premature failure. Effluent water from an ALD will then flow into a wetland where the ferric iron (Fe^{3+}) and aluminum (Al^{3+}) oxidizes and precipitates.

Comments: Manganese is usually not effectively removed and precipitation within the system will cause failure.

c. Successive alkalinity producing systems (SAPS)

d. Alkaline recharge / alkalinity-producing systems (APS)

Description: Have the following basic elements: organic mulch layer, limestone layer, and a drainage system. Mine drainage flows into the tops of the cell creating a top layer of water which prevents the infiltration of oxygen into the bottom layers. The organic layer serves to remove dissolved oxygen from the water, farther down anaerobic conditions support the establishment of sulfate-reducing bacteria. The anaerobic environment is a reducing environment that changes Fe^{3+} to Fe^{2+} , thereby reducing the likelihood of iron hydroxide precipitation. Finally, the water enters the limestone region, essentially devoid of oxygen preventing the armoring of limestone. Upon leaving the SAPS the water is usually directed to an aerobic settling pond or wetland to allow metals to form precipitates and further water polishing.

Comments: The oxidation and reduction of metals (especially Fe and Al) can lead to precipitates that can clog the cell. SAPS require some maintenance, not only for periodic flushing, but also to prevent or correct the development of preferential flow paths.

e. Limestone ponds / settling basins / leach beds

Description: Consist of a pond constructed to receive water that has little or no alkalinity or dissolved metals. The pond is filled with limestone, and designed with a retention time of at least 12 hours. [Slag leach beds are similar, but use steel slag fines to generate alkalinity. These are used to treat water with no Fe, Mn or Al.]. Limestone or slag leach beds are attractive because they are easy to construct and replenish.

Comments: Requires constant replenishment or scraping of the limestone. Channels may not be effective in water with high levels of Mn and Fe.

f. Diversion wells

Description: A water pressure-driven, fluidized limestone bed. These wells are commonly large cylinders composed of reinforced concrete or other erosion resistant material. Water is piped into the center of the well with the end of the pipe just above the well bottom. The water is fed from a point upgradient, where the water is dammed to yield a consistent 8 feet of head above the well surface. Only a portion of stream flow is diverted, while the rest continues to flow normally downgradient. A flowrate of 112 to 224 gpm may sufficiently operate diversion wells. Crushed limestone, of an optimum size of $\frac{1}{2}$ to $\frac{3}{4}$ of an inch diameter, is dumped into the well. The rapid upward movement of the water through the well causes the limestone chips to roil, creating a fluidized bed.

These wells yield alkalinity from acidic water that reacts directly with the limestone and by the churning action of the fluidized bed grinding the limestone into fine particles. The constant churning and surface abrasion of the limestone prevents armoring by dissolved iron in the mine drainage. Observations show that pH can be raised by 2 to 3 units. Limited alkalinity production is due primarily to low (atmospheric) levels of CO_2 , which govern the rate of limestone dissolution. Supplemental CO_2 injection is not passive in nature and would dramatically increase the cost and labor of the operation. Other problems: waters with high acidity concentrations will not be completely treated by one pass through a single well. Plus, recharging of the limestone may need to be performed on a weekly basis.

Comments: Limited alkalinity production is due primarily to low atmospheric levels of CO_2 , which govern the rate of limestone dissolution. Supplemental CO_2 injection is not passive in nature and would dramatically increase the cost and labor of the operation. Other problems: waters with high acidity

concentrations will not be completely treated by one pass through a single well. Additionally, recharging of the limestone may need to be performed on a weekly basis.

g. Limestone sand treatment (dosing)

Description: Limestone dosing utilizes the chemical makeup of limestone (calcium carbonate) to add alkalinity to contaminated water, raise the pH, and precipitate metals downstream of the addition. This low-tech option is easy to enact and effective for the short-term. It is one of the more common activities employed at an affected site.

Comments: Useful for short-term benefits only and requires constant addition of material. There must be easy truck access to the stream.

3) Source Removal:

a. Source removal to repository

Description: This action involves excavation of the potential acid-forming materials and placement of excavated materials in a specially designed “repository” either adjacent to the existing spoil piles or at another appropriate location. This is an old technology using segregation, isolation, and encapsulation techniques to minimize contact between acid-forming materials and groundwater and surface runoff. The repositories are constructed with a compacted sloping cap of clay or other low permeability material, and are usually covered with and underlain by alkaline material. They are constructed so that the spoil material is placed above the surface groundwater table.

The alternative is a source control technology best suitable for acid-forming materials that are in contact with groundwater. Potentially acid-forming materials need to be rapidly excavated and covered to prevent prolonged exposure of the materials to oxygen and water.

Comments: This technology is retained for further consideration.

b. Re-mining and source removal to repository

Description: The action involves the surface mining of previously-mined and abandoned underground mines (i.e., re-mining abandoned underground mines by surface mining methods) to remove the remaining coal that is the source of most of the pyrite. This will normally require daylighting of a substantial or complete area of abandoned underground mines. Although re-mining will yield some remaining coal reserves from the abandoned underground mines, the primary objectives of re-mining involved in this alternative are to decrease pre-existing polluted discharges, to improve aesthetics by backfilling and re-vegetating re-mined areas according to current reclamation standards, and to reduce safety and environmental hazards by sealing existing portals and removing abandoned facilities. These objectives can be achieved by implementation of a well prepared re-mining and reclamation plan.

The source removal through re-mining and reclamation initiatives must be done within the context of a rigorous permitting and enforcement program to ensure that the proposed re-mining and reclamation practices will reduce overall AMD. In the State of Kentucky, this permitting enforcement program requires the collection of site-specific geological and water quality data, and unless waived, geochemical analysis of the overburden to be mined.

Comments: This technology is retained for further consideration.

c. AML Enhancement Rule Removal

Description: An AML Enhancement Rule project is a special type of reclamation project focusing on reclaiming abandoned mine lands that might not otherwise be reclaimed. The projects allow an AML contractor to remove coal refuse from an abandoned mine site and sell the coal to offset the cost of the project. The AML Enhancement Rule guidelines were published in the Federal Register on February 12, 1999. The rule addresses projects that involve incidental coal removal, requiring a determination under the provision of 30 CFR Parts 707 and 874.16.

Comments: This technology is retained for further consideration.

4) Hydraulic Isolation using Barriers and Seals

a. Reactor barrier walls

Description: A wall or trench filled with concrete or a cement-based grout or slurry to prevent the flow of water into a spoils zone. The backfill behind the wall may be of high permeability in order to capture and channel the groundwater flow. The cost of such walls is high, especially in remote areas.

Comments: The cost of such walls is high, especially in remote areas. Additionally, the technical feasibility for success is low.

b. Grouting / grout curtains

Description: A wall or trench refilled with a material (e.g., bentonite slurry) that combines low permeability and high adsorption characteristics to impede the passage of groundwater into the spoils or abandoned mine zone. The effectiveness of the barrier wall is dependent on the ability of the wall to get a seal on the bottom (i.e., by contact with an impermeable soil or rock layer) to keep the groundwater from flowing under the barrier wall. Similarly, effectiveness is affected by construction of the wall with no gaps or other points for by-pass.

Comments: The cost of such curtains is high, especially in remote areas. Additionally, the technical feasibility for success is low.

c. Fly Ash Slurry injection

Description: This action involves injection of fly ash slurry into void spaces in underground mines where coal has been removed. The purpose is to fill the mine voids completely or creating barriers inside the mine to break up interconnected underground passages as a way to control flow and improve drainage quality. Waste fly ash is selected as filling material because it is cheap and readily available.

Fly ash slurry is normally injected down a series of holes into the underground mine works. In order to determine the locations of injection holes and to estimate the volumes of the mine void and mine pool, a detailed mining map along with other relevant geological and hydrological information is required.

Comments: This technology is retained for further consideration.

d. Impermeable barriers / mine seals

Description: This action involves installation of a liner or cap to create an “impermeable” barrier overlying an acid-forming material pile. The “impermeable” barrier is formed either of an earthen or synthetic material that is significantly less permeable than the surrounding materials. The objectives are

to restrict or prevent the infiltration of water into spoil material from above and to restrict diffusion of oxygen into the acid-forming materials. This alternative can be applied only to spoil material that lies above the surface groundwater table.

The term liner is usually used in the context of an underlying impermeable barrier formed either of an earthen or synthetic material that is significantly less permeable than the surrounding materials. However, materials used for liner construction can also be used as a cap over the specially handled pod. In this alternative, installation of liners, applies only for capping over spoil piles.

Installation of liners for capping is a source control technology to prevent or restrict acid-forming materials from contact with water and oxygen. It is best suitable for spoil piles located above the groundwater table. The cap is a placement of synthetic liners or impervious earthen materials (typically clay) to prevent precipitation from infiltrating waste materials or severely contaminated areas and leaching contaminants into the ground water.

Comments: Not applicable for the selected mine sites at Wildcat/Addison Branch

e. Blasting / collapsing mine chambers

Description: The intention of this action is to reduce the void spaces in which water and/or oxygen can infiltrate and produce low pH drainage by the oxidation of pyrite.

Comments: Such technology is extreme and risky, and there is little guarantee that all the voids would be eliminated.

f. Plugging mine openings

Description: In the case of augured mines, there is left an open shaft that may be open on both an upgradient end and a downgradient end. An installed plug (grout, concrete, foam, earthen) at both ends could ensure that atmospheric oxygen would not reach the pyrite and would not initiate the oxidation process.

Comment: Even though atmospheric oxygen could be prevented from entering the plugged shaft, water would still infiltrate during the wet seasons and create a hydraulic head capable of opening up the downgradient seal. Constant monitoring would be necessary to ensure rupture was not occurring.

g. Pyrite encapsulation / inactivation

Description: This would include any technique used to encapsulate or insulate the pyrite from coming into contact with water and/or atmospheric oxygen. Solidification refers to those processes that encapsulate waste in a monolithic solid of high-structural integrity. Contaminant migration is restricted by vastly decreasing the surface area exposed to leaching and/or by isolating the waste within an impervious capsule. In-situ vitrification is an expensive process in which heat is employed to melt and convert waste materials into glass or other crystalline products.

Comment: In-situ vitrification is an expensive process when undertaken on solid source material that is underground and difficult to retrieve in order to process. Furthermore, it is not known if the technology has been applied to acid mine source material.

5) Submergence

a. Mine chamber flooding

Description: This action involves the submergence of acid-forming materials via the sealing and flooding of underground mines to reduce acid generation. The purpose of the flooding is to prevent oxygen from coming into contact with pyrite, thus minimizing the oxidation of acid-forming materials. This alternative is focused on constructing impoundments to inundate selected mine chambers and isolate these underground areas from oxygen.

Comments: The cost and risk associated with this technology is deemed infeasible, and the technology is considered inapplicable to the Wildcat/Addison Branch Mines Site.

b. Area inundation

Description: This action involves the submergence of acid-forming materials below the surface of an impoundment reservoir or pond in order to prevent oxygen from coming in contact with pyrite, thus minimizing oxidation of acid-forming materials. This is similar in concept to sealing and flooding of underground mines to reduce acid generation. Inundation has limited application for surface mined lands or above-drainage deep mines in the mountainous Appalachian region. Complete inundation has been successful in some areas where acid-producing materials are submerged in lakes or other permanent impoundments.

This alternative focuses only on constructing impoundments to inundate selected areas of abandoned surface mines as a way to minimize or eliminate acid mine drainage (AMD), in particular, the creation of an impoundment in the final cut of an abandoned surface mine.

Comments: The cost and risk associated with this technology is deemed infeasible, and the technology is considered inapplicable to the Wildcat/Addison Branch Mines Site.

II. Active Treatment Systems:

- Intentional artificial treatment of or injection with chemicals to reduce acidity, remove metals or raise alkalinity;
- Require ongoing inputs of artificial energy, such as electric power for pumping, mixing, aerating, heat power to change reaction rates, or pressure to control gas-liquid exchange rates;
- Require ongoing inputs of (bio)chemical reagents, such as alkaline liquids or solids (CaOH, NaOH, etc.), organic polymers for coagulation / flocculation, or pressurized gases (less common);
- Patterned after traditional wastewater treatment plant - using elements such as oxidation, dosing with alkali, sedimentation;
- Waters are removed from their course, treated, and discharged;
- Important for the areas where flows are large and land is scarce.

6) Injection of Chemicals into Mine Chambers

a. Bactericides

Description: Bactericides attempt to block the catalytic effects of certain bacteria on the pyrite oxidation process. Although numerous bactericides have been tested against pyrite-oxidizing bacteria, the bactericides of choice for mine sites have been anionic surfactants. These bactericides occur in household cleansers and soap products. At near-neutral pH these surfactants generally are considered to be poor bactericides, but they are markedly more inhibitory at low pH. *Thiobacillus ferrooxidans* can exist in low pH conditions because of a coating that protects the cell from the externally low pH environment. Anionic surfactants dissolve the protective coating, thus subjecting the bacteria cell to low pH conditions, conditions under which it can not survive unprotected.

Comments: Bactericides have a limited effectiveness, and typically are only effective for up to four months. This limitation can be compensated for by repeated application or by application of time-release pellets.

b. Aeration / Oxidation / Addition of metal precipitating agents

Description: Iron and manganese may be removed in traditional water treatment by various means, the most common of which involves oxidation of the more soluble iron II (ferrous) and manganese II into the relatively insoluble iron III (ferric) and manganese III. The precipitates are then removed by filtration. Molecular oxygen, free available chlorine and potassium permanganate have all been used successfully as oxidizing agents. Oxygen can be added to the water simply by directing the water to a channel or site exposed to the atmosphere and increasing mixing by using a weir structure, natural or riprap ripples, aerating pumps, etc. In the case of acid mine drainage, the oxidation and precipitation is already taking place under natural conditions after a disturbance from mining. Thus, this treatment would involve intercepting the underground mine water that is already rich in ferrous iron (from the dissolution of FeS_2), and treat the water by adding the reagents, precipitating out the metals and re-releasing the water into the environment.

Comments: Such technology necessitates a long-term investment in personnel, equipment, and treatment chemicals.

c. Flocculating / coagulating agents

Description: Flocculation and coagulation describe a physical process for combining small particles into larger aggregates in order to aid removal by filtration or settling. The process is often used for removal

of humic organic substances, present in most natural waters. Iron II and manganese II are much more soluble than iron III and manganese III in natural waters. Thus, iron and manganese removal usually depends on oxidation to less soluble forms. This process occurs naturally in disturbed soils around mining sites. It may be mimicked in a treatment setting whereby the precipitation is aided by the addition of coagulating and flocculation agents. However, the process must occur in addition to oxidation of the metal-laden water.

Comments: Such technology necessitates a long-term investment in personnel, equipment, and treatment chemicals.

d. In-Situ Anaerobic Treatment (Bioreactor)

In situ treatment of mine pools is an emerging technology for treating AMD. The technology consists of the injection or placement of substances, including alkaline materials and organic carbon substrate, with nutrients directly into the mine pool lake to neutralize the AMD and to produce anaerobic conditions to precipitate metals in place. Injection of a carbon source such as molasses or alcohol with nutrients and sometimes an alkaline source, such as lime, can create conditions favorable to the precipitation of dissolved metals in place. The addition of a carbon source promotes the existing bacterial microbes to use in sequence oxygen, nitrate, ferric iron, manganese, and sulfate as electron acceptors for growth and results in the formation of a strongly anaerobic (sulfate-reducing) environment; i.e., a sulfate-reducing bioreactor is formed. Alkalinity is produced as the carbon substrate is metabolized, causing an increase buffering capacity of the AMD, which may also lead to an increase in the pH of the AMD. Carbon dioxide may also be produced and evolve from the mine pool into the unsaturated zones of the mine workings, displacing oxygen and reducing pyrite oxidation in the lower parts of the mine workings above the mine pool. Injection of alkaline materials, such as coal combustion by-products or lime, into a mine pool can raise the pH of the AMD. The rise in pH then promotes the equilibrium precipitation of dissolved metals as hydroxides and carbonates. However, some metals have higher solubility at high pH levels. In situ treatment of solid mining waste in the form of residual minerals in mine walls, tailings, or waste rock involves the application of amendments such as potassium permanganate, phosphate or biosolids, and carbon substrate to stabilize the metals in place and reduce the formation of leachate or inhibit the migration of metals. A successful In-Situ Bioreactor may be considered semi-passive.

Comments: A treatability study for this technology is in progress in Wildcat Branch Area A, the results of the treatability study (costs and effectiveness) will provide guidance on the technologies applicability to the Wildcat/Addison Branch Mines Site. If effective, as a semi-passive system, regular amendments of carbon substrate are anticipated, along with maintenance and monitoring.

7) In-line Active Treatment of AMD Flows

a. Pyrolusite® treatment system

Description: A biologically-driven patented process to remove iron and especially manganese from mine drainage, while raising the alkalinity of water. In this process, a bed of crushed limestone is inoculated with "cultured microorganisms" that oxidize iron and manganese in the water contacting the bed. These aerobic microorganisms produce relatively insoluble metal oxides while yielding alkalinity by "etching" the limestone hosting medium. The metal oxides formed during this process are believed to be manganese dioxide or pyrolusite (MnO_2) and hematite (Fe_2O_3). Both metal oxides are relatively stable and insoluble in alkaline water.

Restrictions on the use of Pyrolusite cells stem to some extent from the limited knowledge of these systems and details on precisely how they function. The mineral created may in fact be todorokite (i.e.,

delatorreite), which is a more complex manganese oxide. The microorganisms that oxidize the metals may be inherent in nature. Therefore, culturing and inoculation procedures may not be necessary. There are size considerations in the construction of these systems due to the relatively long residence times recommended (2.5 to 3.0 days). A large flow rate would require a fairly large system for successful treatment. It is also uncertain how highly acidic (pH < 4.0) metal-laden water would affect the treatment process.

Comments: Restrictions on the use of Pyrolusite cells stem to some extent for the limited knowledge of these systems and details on precisely how they function. There are size considerations in the construction of these systems due to the relatively long residence times recommended. A large flow rate would require a fairly large system for successful treatment.

b. Wood filters

Description: A project on the Wayne National Forest in 2002 has demonstrated that wood fiber filters can produce a rise in pH from 2.8 up to 5.0 and remove more than 90% of the heavy metals. The juniper fiber appears to be one of the most effective at removing contaminants. In a further interesting development, Forest Products Laboratory researchers found that filters removed from the AMD site contained highly acidic particles that can help capture phosphates at other sites, such as those impaired by agricultural runoff.

Comments: Wood fibers need to be replaced on a regular basis, supplemental chemicals need to be added for effectiveness, and a large quantity of product is needed to treat highly acidic water.

c. In-line aeration and treatment

Description: A simplified version of a dual phase lime treatment has treated flows with low levels of arsenic. Single-step addition of lime combined with vigorous aeration in a series of three 1000-gallon tanks neutralizes the AMD acidity and precipitates dissolved metals. A series of 15' x 15' bag filters captures large floc particles, and a 1.4-million gallon multi-cell settling lagoon allows extended contact of AMD with the lime and additional time for fine particles to settle. The effluent is discharged to the surface water. Waste streams from the process include hazardous, metal-rich sludge and floc particles captured by filter bags. A large flow rate (12-30 gpm) is required.

Comments: The technology is marked by high capital costs and continued operation and maintenance costs. Not applicable to low and seasonally intermittent flows found at Wildcat/Addison Branch.

8) Treatment Plants

a. Reverse osmosis

Description: The application of a pressure over a concentrated solution, forcing pure water to pass through a semi-permeable membrane to the dilute side. This system is often used in the purification of seawater, but also lends itself to the rejection of heavy metals.

Comments: Membranes clogged quickly with metal ions. Iron quickly fouls the membranes and causes problems for disposal.

b. Electrodialysis (ED)

Description: An electrochemical separation process in which ions are transferred through selective membranes from a less concentrated to a more concentrated solution as a result of the flow of direct electric current. ED is used in municipal water treatment for treating brackish water to produce demineralized water that meets drinking water standards. In industry, ED is used as a roughing demineralizer for the purification of foodstuffs and for wastewater recovery.

Comments: Membranes clogged quickly with metal ions. Iron quickly fouls the membranes and causes problems for disposal.

c. Conventional treatment: Neutralization / precipitation

Description: The conventional water treatment schema includes the following critical steps:

- 1 - Alkali dosing in order to raise the pH to appr. 8 units;
- 2 - Cascade aeration (large site) or mechanical or chemical oxidation (small site);
- 3 - Sedimentation pond (large site) or clarifier (small site).

Comments: The technology is marked by high capital costs and continued operation and maintenance costs. Not applicable to low and seasonally intermittent flows at Wildcat/Addison Branch.

9) Best Management Practices for On-Site Hydrology

a. Re-grading of abandoned spoil piles

Abandoned spoil piles commonly exhibit poor drainage. A significant amount of surface-water infiltration can be reduced by regrading abandoned mine spoils. This may involve removal of closed contour depressions, elimination of spoil ridges and valleys, and creation of runoff-inducing slopes within spoil piles.

Regrading is also an integral part of most re-mining permits. In order to achieve a minimum reclamation standard as statutorily mandated, abandoned spoil piles are regraded to return the site to the approximate original contour or to at least achieve a more natural looking post-mining condition.

Comments: This technology is retained as a recommended best management practice for usage with other removal technologies.

b. Re-vegetation of spoil / waste piles

Re-vegetation of mine spoil can dramatically reduce the amount of surface water that would otherwise eventually make it to the underlying groundwater system. Vegetative cover also can decrease the amount of atmospheric oxygen that can enter the subsurface, because biological activity in soil, such as decay of organic matter, can create an oxygen sink. A well developed soil with a dense cover of vegetation can retain a significant amount of water. Eventually, this water evaporates or is transpired by the plants and does not recharge the spoil aquifer. Re-vegetation is also a statutory requirement of all re-mining permits, it is one of the most frequently employed best management practices.

Comments: This technology is retained as a recommended best management practice for usage with other removal technologies.

c. Upgradient planting to divert runoff

Description: Revegetation of a slope or channel upstream of a mine spoils area can greatly reduce the amount of runoff reaching the affected site. A healthy stand of vegetation will slow runoff, increase infiltration into the soil and increase the uptake by plant stems and leaves. The type of vegetation used should be of a native variety and should be chosen consistent with the slope and the amount of water to be received and diverted. Vegetation should be maintained through cutting, fertilizing and reseeding if necessary, and established vegetation should be inspected periodically for scouring.

Comments: This technology is retained as a recommended best management practice for usage with other removal technologies.

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WILDCAT BRANCH/ADDISON BRANCH MINES SITE

ENGINEERING EVALUATION/COST ANALYSIS

APPENDIX B

TECHNOLOGIES FOR TREATMENT OF ACID MINE DRAINAGE

APPENDIX B
TABLE OF APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs) AND GUIDANCE TO BE CONSIDERED (TBCs) AT WILDCAT BRANCH MINES SITE

Requirement/Action	Citation	Description	ARAR Status	Comments
Chemical-specific				
Control of low-pH water Control of metals in water	Clean Water Act KY water quality standards	Regulates the discharge of any pollutant or combination of pollutants to water of the U.S. from any point source.	Applicable	Plan to achieve aquatic life standards.
	Safe Drinking Water Act KY state drinking water standards -	Establishes regulations to protect human health from contaminants in current and potential sources of drinking water. There are two sets of standards: Primary - MCLs, which are health-based goals, and Secondary - SMCLs, which affect the aesthetic qualities of drinking water	Relevant and Appropriate	Federal SMCLs: - pH (6.5-8.5 units) - Iron (0.3 mg/l) - Manganese (0.05 mg/l) - Sulfate (250 mg/l) - TDS (500 mg/l) No existing drinking water usage on Wildcat Branch site.
	KY TMDL levels [Section 303(d) of CWA] [40 CFR Part 130] [401 KAR 5:031]	Sets total maximum daily loads (TMDLs) for water bodies that are not meeting designated uses.	Applicable	Proposed Draft - Wildcat Branch of Cumberland River: for pollutants H+, sulfuric acid - pH must be in range of 6.0 to 9.0 - TMDLs in H+ lbs per day and corresponding load reductions for four sub-basins
Stormwater	Clean Water Act [40 CFR 122.26(b)(13)] -	Requires an NPDES permit for mining / construction activities that result in contaminated runoff.	Relevant and Appropriate	Stormwater requirements generally not applicable. However, they could be relevant and appropriate at mining sites where runoff water is contaminated.
Location-specific				
Protection of Wetlands	E.O. 11990, Protection of Wetlands [40 CFR 6.302(a), 40 CFR Part 6 Appendix A]	Requires federal agencies to avoid, to the extent possible, the adverse impacts associated with the destruction or loss of wetlands and alteration of an existing floodplain.	Applicable	If avoidance is not possible, mitigation should be considered for the loss of wetlands habitat.

Requirement/Action	Citation	Description	ARAR Status	Comments
Protection of T&E species	Endangered Species Act [50 CFR 402]	Prohibits Federal agencies from carrying out any action that would jeopardize a listed species or destroy or modify its "critical habitat".	Applicable	Check PA/SI for threatened and endangered species - both Federal and State-listed.
Protection of Migratory Birds	Migratory Bird Treaty Act [16 USC 703]	Protects almost all species of native birds in the United States from unregulated taking.	Applicable	Almost always an ARAR because a migratory species is almost always present.
Preservation of cultural and/or historical resources	National Historic Preservation Act [16 USC 470]	Designed to protect the Nation's historical heritage from extinction.	Applicable	Identify any historical or cultural sites in Wildcat Branch and Addison Branch watersheds.
Action-specific				
Health and Safety	Occupational Health and Safety Act; Hazardous Waste Operations and Emergency Response	Defines standards for employee protection during site activities.	Applicable	[29 USC 655] [29 CFR 1910.20]
Source material excavation / Re-mining	RCRA Subtitle D [40 CFR 258]	Provides standards for management of hazardous and non-hazardous waste.	Relevant and Appropriate	Excluded waste materials include: source material and materials not removed from the ground as part of the extraction process.
	SMCRA [30 CFR 816 and 817]	Includes standards for backfilling and grading, revegetation, post-mining land use, and guidance for activities associated with water control measures. Intended for active coal mines, thus are not applicable.	Relevant and Appropriate	Re-mining activities should be done in accordance with SMCRA guidelines and standards for mining and closure. A permit will need to be obtained from the Kentucky Division of Natural Resources.
Placement of source material in an on-site repository	[40 CFR Part 264 Subpart L] -	A waste pile is defined as "any non-containerized accumulation of solid, non-flowing <u>hazardous</u> waste that is used for treatment or storage."	Not Applicable	Source material here is not considered hazardous.
Installation of impermeable liner and/or cap			Relevant and Appropriate	If wastes are capped in place, then RCRA placement does not occur (not actively managed).

Requirement/Action	Citation	Description	ARAR Status	Comments
Fly ash slurry injection into mine cavities	EPA's Groundwater UIC Program – Class V Permit		Applicable	An EPA permit or authorization is needed to inject fly ash slurry. Contact U.S. EPA Region 4.
	KRS 224.50-760(1)(a)	Kentucky Revised Statutes define “special wastes” to include “those wastes of high volume and low hazard which include but are not limited to utility wastes (fly ash, bottom ash, scrubber sludge).”	Applicable	No permit required by the Commonwealth of Kentucky.
In-Situ Bioreactor Injection (carbon source/alkalinity source)	EPA's Groundwater UIC Program - Class V permit		Applicable	May be applicable depending on the scale and scope of the project. Have discussed with EPA on the treatability/feasibility study.
Construction of impoundments, Sulfate Reducing Bioreactors; AML Enhancement Rule Removal.	Fish and Wildlife Coordination Act – [E.O. 11990] [16 USC 661]	Designed to protect fish and wildlife when federal actions result in the control or structural modification of a natural stream or body of water.	Applicable	Because of impaired water quality, there are minimal populations of fish and wildlife currently utilizing the water resources that would be impounded.
	U.S. Army Corps of Engineers Sec. 404 of CWA –	Acts as regulatory agency for impoundments / fills and wetlands management. A 404 permit must be applied for in the case of an impoundment.	Applicable	A permit application must be submitted because of fill being placed in streambed. There will not be any natural wetlands affected by the impoundments.
	Ky Division of Water 401 KAR 4:030 –	Establishes minimum design criteria for earthen dams and associated structures.	Applicable	Mitigation of all stream loss.

WILDCAT BRANCH/ADDISON BRANCH MINES SITE

ENGINEERING EVALUATION/COST ANALYSIS

APPENDIX C

COST ESTIMATES

DRAFT

Alternative 1 - Waste Material Excavation and Placement in a Repository

*Notes

*CCI Increase where applicable: 1999 CCI = 6060; December 2014 CCI = 9937; Increase = 1.64

*EPA 2000 refers to EPA Coal Remining Best Management Practices Guidance Manual (EPA 821-R-00-007), March 2000.

*Skousen refers to "Remining in Pennsylvania and West Virginia: Costs and Water Quality Changes." West Virginia Universtiy, Published in Green Lands Magazine

Task #	Description	Unit	Unit Cost	Quantities				Cost				Basis for Cost
				Area A	Area B	Area C	Area D	Area A	Area B	Area C	Area D	
1	Preliminary Surveys	Lump Sum	\$10,000	1	1	1	1	\$10,000	\$10,000	\$10,000	\$10,000	Engineering Judgement
2	Road Construction	Mile	\$50,000	6	0.9	1	1.1	\$300,000	\$45,000	\$50,000	\$55,000	Engineering Judgement
3	Excavation of Waste Material	CY	\$2.05	367550	64486	38692	3224	\$753,478	\$132,196	\$79,319	\$6,609	Skousen - with CCI increase
4	Diversion Ditch	ft	\$16.48	4100	1000	600	50	\$67,576	\$16,482	\$9,889	\$824	EPA 2000 with CCI Increase
5	Pit Floor Drains	ft	\$98.91	2050	500	300	25	\$202,762	\$49,454	\$29,673	\$2,473	EPA 2000 with CCI Increase
6	Eliminate Highwall and Construct Repository	1000 CY	$C=0.136x^{1.217}$ $x = 1000 \text{ CY}$	322	64	39	3	\$251,445	\$35,197	\$19,262	\$849	EPA 2000 with CCI Increase
7	Revegetation	Acre	\$500.00	755	115	186	186	\$377,500	\$57,500	\$93,000	\$93,000	Engineering Judgement
8	Special Handling of Toxic and/or Acid Forming Materials	1000 CY	$C=0.309x^{1.129}$ $x = 1000 \text{ CY}$	322	64	39	3	\$343,694	\$55,460	\$31,704	\$1,752	EPA 2000 with CCI Increase
9	Direct Cost Totals							\$2,306,455	\$401,289	\$322,847	\$170,507	
10	Mobilization (5%)							\$115,323	\$20,064	\$16,142	\$8,525	
11	Engineering and PM (15%)							\$345,968	\$60,193	\$48,427	\$25,576	
12	Contingency (20%)							\$461,291	\$80,258	\$64,569	\$34,101	
13	Total Project Cost (2015)							\$3,229,037	\$561,805	\$451,985	\$238,710	

Alternative 2 - Surface Remining with Special Handling of Source Materials

*Notes

*CCI Increase where applicable: 1999 CCI = 6060; December 2014 CCI = 9937; Increase = 1.64

*EPA 2000 refers to EPA Coal Remining Best Management Practices Guidance Manual (EPA 821-R-00-007), March 2000.

Task #	Description	Unit	Unit Cost	Quantities				Cost				Basis for Cost
				Area A	Area B	Area C	Area D	Area A	Area B	Area C	Area D	
1	Preliminary Surveys	Lump Sum	\$10,000	1				\$10,000				Engineering Judgement
2	Permit Acquisition	Lump Sum	\$5,000	1				\$5,000				Engineering Judgement
3	Road Construction	Mile	\$50,000	1				\$50,000				Engineering Judgement
4	Daylighting	1000 Ton	$C=0.6x^{1.21}$ x = 1000 Tons Coal	38				\$80,266				EPA 2000 with CCI Increase
5.1	Construct Repository	1000 CY	$C=0.309x^{1.129}$ x = 1000 CY	100				\$91,791				EPA 2000 with CCI Increase
5.2	Diversion Ditch	ft	\$16.48	1000				\$16,482				EPA 2000 with CCI Increase
5.3	Pit Floor Drains	ft	\$98.91	100				\$9,891				EPA 2000 with CCI Increase
6	Regrading of Abandoned Mine Spoils/Highwall	1000 CY	$C=0.136x^{1.217}$ x = 1000 CY	100				\$60,587				EPA 2000 with CCI Increase
7	Revegetation	1000 CY	$C=0.772x^{0.961}$ x = 1000 CY	100				\$105,794				EPA 2000 with CCI Increase
9	Direct Cost Totals							\$324,018				
10	Mobilization (10%)							\$32,402				
11	Engineering and PM (15%)							\$48,603				
12	Contingency (30%)							\$97,205				
13	Total Project Cost (2015)							\$502,228				

Alternative 3 - Fly Ash Slurry Injection

*Notes

*CCI Increase where applicable: 2006 CCI = 7660 December 2014 CCI = 9937; Increase = 1.30

*CCI Increase where applicable: 1999 CCI = 6060; December 2014 CCI = 9937; Increase = 1.64

*EPA 2000 refers to EPA Coal Remining Best Management Practices Guidance Manual (EPA 821-R-00-007), March 2000.

Task #	Description	Unit	Unit Cost	Quantities					Cost					Basis for Cost
				Area A	Area B Headwaters	Area B DS East	Area B DS West	Area D	Area A	Area B Headwaters	Area B DS East	Area B DS West	Area D	
1	Preliminary Surveys	Lump Sum	\$10,000	1	1	1	1	1	\$10,000	\$10,000	\$10,000	\$10,000	\$10,000	Engineering Judgement
2	Road Construction	Mile	\$50,000	0.8	0.9	0.9	0.9	2	\$40,000	\$45,000	\$45,000	\$45,000	\$100,000	Engineering Judgement
3	Drilling of Injection Holes	ft	\$19.50	2125	4750	2125	1500	4750	\$41,438	\$92,625	\$41,438	\$29,250	\$92,625	Quote from Driller + CCI
4	Fly Ash (Haul)	Ton	\$20.00	1820	7000	3500	3500	700	\$36,400	\$140,000	\$70,000	\$70,000	\$14,000	Engineering Judgement
5	Portland Cement (furnish/haul)	Ton	\$205.00	78	300	150	150	30	\$15,990	\$61,500	\$30,750	\$30,750	\$6,150	Quote from Vendor
6	Water - pumping on-site, includes pumps and gas	Week	\$750	5	10	5	5	10	\$3,750	\$7,500	\$3,750	\$3,750	\$7,500	Engineering Judgement
7	Prep and Injection of Fly Ash	Acre	\$150,000.00	13	50	25	25	5	\$1,950,000	\$7,500,000	\$3,750,000	\$3,750,000	\$750,000	Correspondence 2006 Chalfant/Skousen
8	Mine Seals	Each	\$28,700	2	2	2	1	8	\$57,400	\$57,400	\$57,400	\$28,700	\$229,600	EPA 2000 with CCI Increase
9	Direct Cost Totals								\$2,154,978	\$7,914,025	\$4,008,338	\$3,967,450	\$1,209,875	
10	Mobilization (5%)								\$107,749	\$395,701	\$200,417	\$198,373	\$60,494	
11	Engineering and PM (15%)								\$323,247	\$1,187,104	\$601,251	\$595,118	\$181,481	
12	Contingency (20%)								\$430,996	\$1,582,805	\$801,668	\$793,490	\$241,975	
13	Total Project Cost (2015)								\$3,016,969	\$11,079,635	\$5,611,673	\$5,554,430	\$1,693,825	

Alternative 4 - In-Situ Bioremediation

*Notes

*Assume 15 year period for O&M, monitoring

Task #	Description	Unit	Unit Cost	Quantities				Cost				Basis for Cost	
				Area A	Area B	Area C	Area D	Area A	Area B	Area C	Area D		
1	Phase 1 Drilling/Investigation	Lump Sum						\$129,000					AE Contract
2	Phase 2 Treatability Study	Lump Sum						\$250,000					AE contract
3	Road Construction	Lump Sum						\$30,000					Actual Costs
4	Phase 3 Full Scale Implementation	Lump Sum						\$250,000					Engineering Judgement
5	O&M plus monitoring	Yearly	\$8,000.00	15				\$120,000					Engineering Judgement
9	Direct Cost Totals							\$779,000	\$0	\$0	\$0		
10	Mobilization (5%)							\$38,950	\$0	\$0	\$0		
11	Engineering and PM (15%)							\$116,850	\$0	\$0	\$0		
12	Contingency (20%)							\$155,800	\$0	\$0	\$0		
13	Total Project Cost (2015)							\$1,090,600	\$0	\$0	\$0		

Alternative 5 - Sulfate Reducing Bioreactors (SRBs)

*Notes

*Assume 15 year period for O&M, monitoring

*AMD Treat software used to estimate SRBs at various locations and average values were used.

*Assume substrate replacement 1 time in 15 years.

Task #	Description	Unit	Unit Cost	Quantities				Cost				Basis for Cost
				Area A	Area B	Area C	Area D	Area A	Area B	Area C	Area D	
1	Bench/Pilot Studies	Lump Sum	\$25,000	1	1	1	1	\$25,000	\$25,000	\$25,000	\$25,000	Engineering Judgement
2	Road Construction	Mile	\$50,000	0.5	0.5	0.5	0.5	\$25,000	\$25,000	\$25,000	\$25,000	Engineering Judgement
3	SRB Construction	Each	\$300,000.00	3	2	1	2	\$900,000	\$600,000	\$300,000	\$600,000	AMDTreat Software
4	Polishing Pond	Each	\$8,000.00	3	2	1	2	\$24,000	\$16,000	\$8,000	\$16,000	AMDTreat Software
5	O&M, Monitoring	Yearly	\$12,000.00	45	30	15	30	\$540,000	\$360,000	\$180,000	\$360,000	AMDTreat Software
6	Substrate Replacement	Each	\$100,000	3	2	1	2	\$300,000	\$200,000	\$100,000	\$200,000	
9	Direct Cost Totals							\$1,814,000	\$1,226,000	\$638,000	\$1,226,000	
10	Mobilization (5%)							\$90,700	\$61,300	\$31,900	\$61,300	
11	Engineering and PM (15%)							\$272,100	\$183,900	\$95,700	\$183,900	
12	Contingency (20%)							\$362,800	\$245,200	\$127,600	\$245,200	
13	Total Project Cost (2015)							\$2,539,600	\$1,716,400	\$893,200	\$1,716,400	

Alternative 6 - AML Enhancement Rule Removal

*Notes

*Assume 15 year period for O&M, monitoring

*Costs based on small scale "test burn" project.

*"Test Burn" project should provide greater information on value of coal refuse and improve cost estimate.

Task #	Description	Unit	Unit Cost	Quantities				Cost				Basis for Cost
				Area A	Area B	Area C	Area D	Area A	Area B	Area C	Area D	
1	Bench/Pilot Studies	1000Ton	\$70,000		1	1	1		\$70,000	\$70,000	\$70,000	Engineering Judgement
2	Road Construction	Mile	\$50,000		0.5	0.5	0.5		\$25,000	\$25,000	\$25,000	Engineering Judgement
3	Full Scale Removal	1000Ton	\$50,000.00		10	14	7		\$500,000	\$700,000	\$350,000	AMDTreat Software
4	Coal Refuse Value	Ton	-\$10.00		10000	14000	7000		-\$100,000	-\$140,000	-\$70,000	Conservative Ballpark Guess
9	Direct Cost Totals							\$0	\$495,000	\$655,000	\$375,000	
10	Mobilization (5%)							\$0	\$24,750	\$32,750	\$18,750	
11	Engineering and PM (15%)							\$0	\$74,250	\$98,250	\$56,250	
12	Contingency (5%)							\$0	\$99,000	\$131,000	\$75,000	
13	Total Project Cost (2015)							\$0	\$693,000	\$917,000	\$525,000	