# Homestead Refuse Reclamation: Fox Run & Pleasant Run Watersheds

## Homestead Refuse Clean Water Action Plan Project

## Final Report

January, 2003 – December 2005

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Grant No. C9994861-01
Memorandum of Agreement No. M-03032239
Workplan No. 01-18

March, 2008

The Kentucky Division of Water funded this project through the section 319(h) Nonpoint Source Implementation Program

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**Funding for this project, Homestead Refuse Clean Water Action Plan Project, was provided in part by a grant from the U.S. Environmental Protection Agency (USEPA) through the Kentucky Division of Water, Nonpoint Source Section, to the Kentucky Division of Abandoned Mine Lands as authorized by the Clean Water Act Amendments of 1987, §319(h) Nonpoint Source Implementation Grant # C9994861-01. The contents of this document do not necessarily reflect the views and policies of the USEPA, KDOW or the Kentucky Division of Abandoned Mine Lands nor does the mention of trade names or commercial products constitute endorsement. This document was printed on recycled paper.**

## ACKNOWLEDGEMENTS

The Kentucky Division of Abandoned Mine Lands would like to acknowledge the following state and federal agencies, conservation organizations, and individuals for their assistance with this project:

Kentucky Department for Natural Resources
Kentucky Division of Water
Kentucky Department of Fish and Wildlife Resources
United States Office of Surface Mining
Roy Jeffcoat
DAML- Madisonville Field Office
DAML- Frankfort Scientific Writing/Review Team

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# EXECUTIVE SUMMARY

The Homestead area of Hopkins County includes the headwaters of the Pleasant Run and Fox Run watersheds. The Homestead area is a small portion of the Bunt Sisk Hills, a region that has been severely disturbed by over 60 years of coal mining and processing activities. Acid mine drainage from barren, acidic refuse and slurry, underground mine seeps and portals, and mining pits with exposed highly acidic clays have rendered both Pleasant Run and Fox Run lifeless.

In the winter of 2003 a biological and water monitoring program began in the Pleasant Run and Fox Run watersheds. In the summer of 2003 construction began on a reclamation project targeting several refuse and slurry impoundments in both watersheds. Over 30 ha of severely eroded, barren refuse and slurry areas were graded and covered with an agricultural limestone barrier and onsite spoil materials. Grass and calcareous rock diversion ditches and open limestone channels were installed to control erosion and add alkalinity directly into the headwaters of both watersheds.

The work has resulted in a 65%+ reduction of acidic sediments that wash from the reclaimed areas into Pleasant Run and Fox Run. Despite the addition of alkalinity, both streams remain net acidic due to the numerous acidity sources outside the project area. Brief periods of high acidity loading still severely impact the aquatic communities. Future projects by conservation and reclamation organizations will continue to address the sediment and acidity loading into the watersheds improving the entire watersheds ability to support all levels of the aquatic communities.

# INTRODUCTION

The exposure and oxidation of certain sulfide minerals in rocks as a consequence of coal mining activities has resulted in acid mine drainage (AMD), a serious water pollution problem in portions of the Illinois Basin coal field region. Acid mine drainage is a low pH, sulfate rich water with high acidity that is formed under natural conditions when rocks containing pyrite, and/or other sulfide minerals, are exposed to the atmosphere or oxidizing environments. In the Eastern US coalfields, iron, manganese, and aluminum tend to be the primary metals associated with the sulfide minerals in the coal fields. Natural weathering processes only expose small amounts of pyrite to be oxidized, and acid generation is minimal. When large volumes of pyritic material are exposed to oxidizing conditions through disturbances such as mining, the pyrite reacts more quickly. Water then moves the reaction products (dissolved metals, sulfate, and acidity) into groundwater and surface water sources.

Acid mine drainage is formed by the oxidation of pyrite to release dissolved ferrous iron, sulfate, and free hydrogen ions. Further oxidation of the ferrous iron results in the formation of ferric iron and, at a pH greater than 3.5, the precipitation of iron as a hydroxide commonly referred to as “yellow boy”. The ferrous iron to ferric iron reaction results in an increase of free hydrogen ions and a lowering of pH. Acid mine drainage neutralized by limestone or other bases can form neutral mine drainage high in sulfate and possibly elevated concentrations of iron and manganese. These neutral solutions can become acidic on oxidation and precipitation of the metals.

Acidity is a measurement of the amount of base needed to neutralize a volume of water. Acidity in AMD is comprised of hydrogen ion concentration acidity (low pH) and mineral acidity which arises from the presence of dissolved metals in the water. In coal mine drainage the major contributors to acidity are ferrous and ferric iron, aluminum, and manganese as well as free hydrogen ions.

Many factors control the rate and extent of AMD formation. Acidity of the drainage tends to increase with an increase in the amount of pyrite in the overburden, coal, floor rock, or mine spoil and a decrease in the grain size of the pyrite. Iron oxidizing bacteria and low pH values speed up the acid forming reactions. Rates of acid formation tend to be slower in the presence of limestone or other neutralizing agents. Access to oxygen is commonly the limiting factor in rate of acid generation. Because of the complex interactions of these and other factors, prediction and remediation of AMD is site specific.

## Study Area Description

The Homestead Refuse Reclamation project area selected is located along a ridgeline that separates the Pleasant Run and Fox Run watersheds (Figure 1). The project sites were originally mined from the 1940's through 1958, prior to the advent of the Surface Mining Control and Reclamation Act of 1977 (SMCRA).

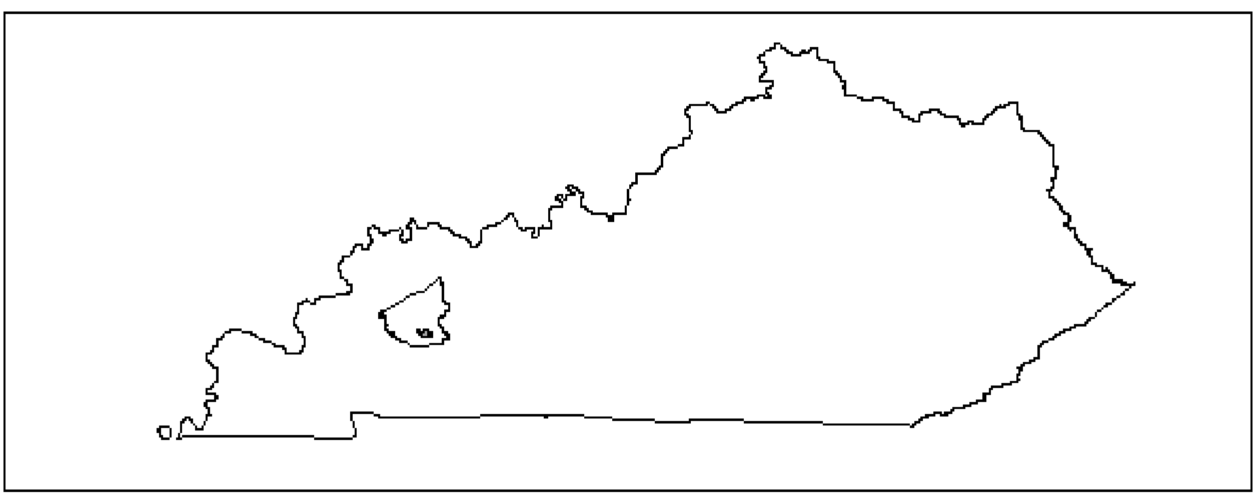


Figure 1: Location of Hopkins County, Kentucky.

**Hydrologic Regime**

*Pleasant Run*

Pleasant Run (HUC14 05110006040060), which is a first through third order stream within the study area, originates in south-central Hopkins County (Figure 2) and flows east to discharge into Drakes Creek 13.9 km (8.6 mi) upstream from its confluence with the Pond River (Figure 2). The Pond River discharges into the Green River, which flows northward into the Ohio River. Pleasant Run's main stem is approximately 12.7 km (7.9 mi) long and drains an area of 3,259.5 ha (8,054.5 acres (12.6 mi$^2$)). The average gradient is 6.8 m per km (35.5 ft per mi). Elevations for Pleasant Run range from 214 m (700 ft) above mean sea level (msl) in the headwaters to 122 m (400 ft) above msl at the mouth.

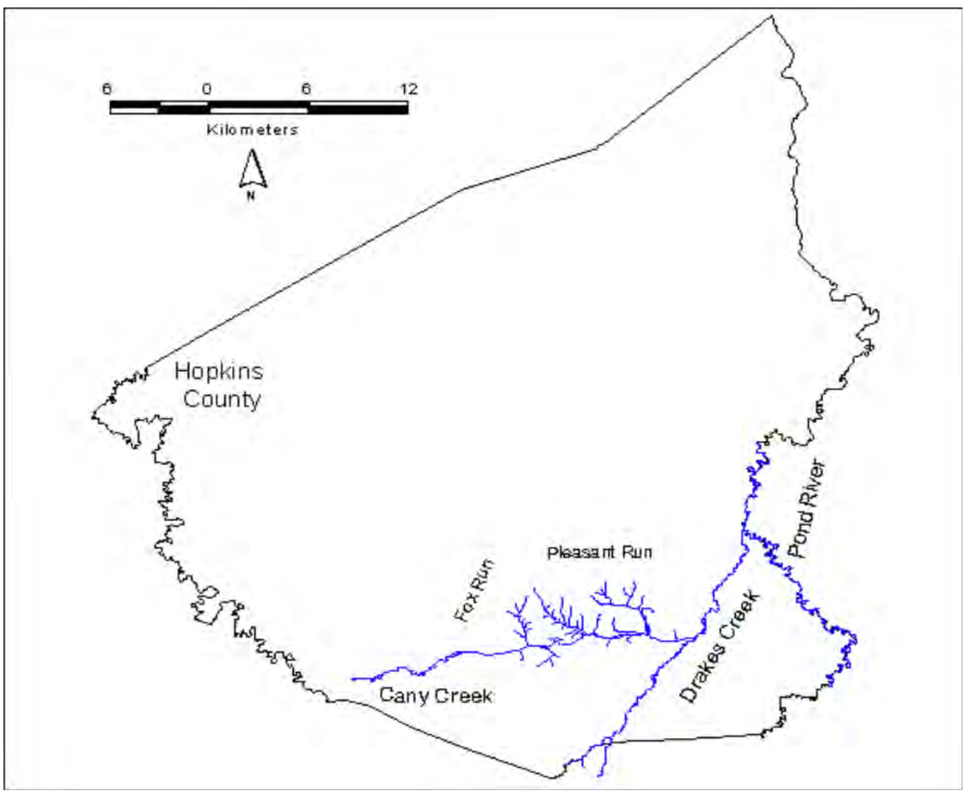


Figure 2: Location of Pleasant Run and Fox Run.

The 1998 303(d) list of waters for Kentucky (Wilson, 1998) indicates 12.7 km (7.9 mi) of Pleasant Run, from the headwaters to the confluence with the Pond River in Hopkins County, does not meet its designated use for contact recreation (swimming) and for aquatic life. The Pleasant Run watershed provides a classic example of impairment caused by AMD. Many sources of bituminous coal mine drainage, like that found in the Pleasant Run watershed, contain relatively high concentrations of sulfuric acid and may contain high concentrations of metals, especially iron, manganese, and aluminum.

*Fox Run*

Fox Run, which is a first and second order stream within the study area, drains into Cany Creek (HUC14 05140205030010), which in turn drains into the Tradewater River in Hopkins County. The Tradewater River is listed on Kentucky's 303(d) list. Fox Run is not listed as a pending or active TMDL nor is it on the 303(d) list (Wilson, 1998). However, Fox Run watershed receives AMD impacts from the Homestead Refuse site (Figure 2).

**Geologic Setting**

The Pleasant Run and Fox Run watersheds are in Kentucky's Western Coalfield physiographic region. The surface bedrock is of Pennsylvanian age. Formations of the Pennsylvanian age are mostly sandstone, siltstone, coal, and interbedded limestone and shale; alluvial deposits of siltstone and crossbedded sand or sandstone underlie the extensive lowland areas (USDA, 1977). The relief of the watersheds range from nearly level to steep. Gently sloping to steep soils are found in the uplands and nearly level soils are found on the floodplain (KYDOW, 2003).

**Land-use Activities**

The Pleasant Run and Fox Run watersheds contain two main landuses: resource extraction (mining and disturbed land area) and agriculture (KYDOW, 2003). Coal, oil, and natural gas are among the natural resources of Hopkins County.

## Soils Information

The Pleasant Run and Fox Run watersheds consist of acidic silt loam. The soils near the mouths of these streams are materials washed from loess, sandstone, and shale, formed into an acidic alluvium. At the headwaters, the subsurface consists of weathered acidic sandstone and shale covered by a thin layer of loess (KYDOW, 2003).

## Mining History

Mining activities have occurred in both the Fox Run and Pleasant Run watersheds during the pre-law, interim, and post-law eras. Mining permits in Kentucky are classified on the basis of whether the original permit was issued prior to August 3, 1977 (pre-law permit), after May 18, 1982 (post-Kentucky primacy) or in-between these dates (interim period). Only areas that were mined prior to May 18, 1982 were addressed under this project. A list of the various mining permits that have been issued for Pleasant Run is provided in the Total Maximum Daily Load (KYDOW, 2003).

**Monitoring History**

The waters of Pleasant Run were monitored as early as 1978 by the Division of Water (DOW) as reported in *The Effects of Coal Mining Activities on the Water Quality of Streams in the Western and Eastern Coalfields of Kentucky*, published in 1981 by the Kentucky Department for Natural Resources and Environmental Protection as part of an agreement with the Division of Abandoned Mine Lands (DAML). The DOW sampled the three unnamed tributaries to Pleasant Run on April 26, 1978. The three streams had pH values of 4.3, 3.5, and 3.2. The degradation of Pleasant Run is the consequence of acid mine drainage in the watershed as noted by the DOW. In 1997, the DOW conducted a survey of streams in the Western Kentucky Coal Fields, including Pleasant Run. The DOW reported a high level of pH impairment, citing acid mine drainage as the principal source. A pH of 2.9 was recorded on July 3, 1997. Based on these readings, the stream was listed as First Priority on the Kentucky 303(d) list of streams not meeting their designated uses. Pleasant Run does not support the designated uses of aquatic life and swimming (Wilson, 1998).

## Project Description

The project (37 ha (92 acres)) reclaimed an expanse of abandoned strip and deep mine disturbance in southern Hopkins County, approximately 1.6 km (1.0 mi) northeast of the community of Saint Charles. The project encompassed nine reclamation sites (Main site, sites A-H) intermingled with two borrow areas. The nine sites (30.7 ha (76 acres)) contained pit and ridge formations of severely eroded acidic mine spoil piles mixed with coal refuse. The Main, C, and E sites contained wet-weather/seasonal water-holding areas.

Sediment and erosion from all sites caused infertile deposition, channel filling, and increased swamping of the floodplain. Consequential water quality degradation has rendered much of the water within the Fox Run, Cany Creek, and Pleasant Run watershed basins unable to meet designated aquatic life uses, as well as, public, industrial, and domestic use.

Reclamation at the Main site, a ridge-top coal-refuse fill, and site A, a hillside coal-refuse fill, included heavy gradework to eliminate large and small gullies and to redirect drainage patterns. Reclamation at sites B, C, D, and E (coal refuse fills within abandoned sediment structures), and sites F, G, and H (eroding hillsides of coal refuse and soil), included light gradework to eliminate gullies and to provide a smooth surface for positive drainage. Prior to grading the Main, C, and E sites, water from wet-weather/seasonal water-holding areas was treated and released.

To minimize acid mine drainage and to present a medium capable of supporting vegetation, the graded coal refuse was capped with an agricultural limestone barrier covered by a minimum of two feet of suitable cover material. A maximum of 12.1 ha (30 acres) was used within the 35.6 ha (88 acres) designated as borrow area. This minimized surface disturbance and ensured vegetation establishment by allowing the best and most abundant cover material to be located. The cover material consisted of ridges of mine spoil vegetated with volunteer trees and scrub. Sufficient cover material remained within the borrow areas to provide adequate cover once cover material excavation was complete.

Rock, temporarily placed in one location of Pleasant Run and one location of Fox Run, was used to substitute for bridges to allow heavy equipment to access the project site. Since these streams are severely impacted by acid mine drainage and sedimentation, the limestone stream crossings provided additional alkalinity and helped improve water quality within the immediate area of the rock.

Ditches were lined with class II/III stone or erosion control blanket to control drainage. Hay-bale silt checks and silt traps were used to minimize sedimentation. All areas disturbed by construction were covered with suitable cover material and were vegetated as soon as it was practical, using agricultural limestone, fertilizer, seed, mulch, crimping, and, on steep slopes, netting.

## DATA COLLECTION AND METHODOLOGY

Data collection and methodology included a water monitoring program conducted by DAML personnel, a biological monitoring program conducted by DAML, and KDFWR personnel, and soil and refuse analysis including computer modeling utilizing the US Department of Agriculture's (USDA) Revised Universal Soil Loss Equation (RUSLE) conducted by DAML.  Best management practices were chosen after analysis of water chemistry, soil and refuse testing, and site specific conditions.

**Water Monitoring**

## Monitoring Objectives

The water monitoring objectives were to collect acid and metal concentrations and loading data for Pleasant Run and Fox Run watersheds where the water leaves the Homestead property near the WKY Parkway and US 62.

Pleasant Run and Fox Run are being degraded by pyritic coal mine refuse and by seeps discharging acid mine drainage.  Monitoring before and after the reclamation indicates the efficacy of the acid mine drainage abatement techniques used in the reclamation of the watersheds.

## Monitoring Program

Existing water quality data within the study area indicated severe degradation of the water quality, but did not take into account all of the acid drainage sources or any natural buffering which may occur within the watershed.  To address this, the main tributaries, including a tributary outside of the work area, were monitored (Figure. 3).  The sites were monitored monthly, for a period of seven months before construction activities began, to collect background data.  The sites were monitored monthly during construction of the project and then monthly thereafter to demonstrate project success.

The following sites are part of a larger monthly monitoring program but are specific to this project:

| Station Name | Site Number | Lat/Long |
|---|---|---|
| Upper Pleasant Run | PR – 1 | 37° 13’ 16” / 87° 31’ 12” |
| Lower Pleasant Run | PR – 2 | 37° 12’ 16” / 87° 31’ 28” |
| Lower Fox Run | FR – 1 | 37° 11’ 02” / 87° 32’ 03” |

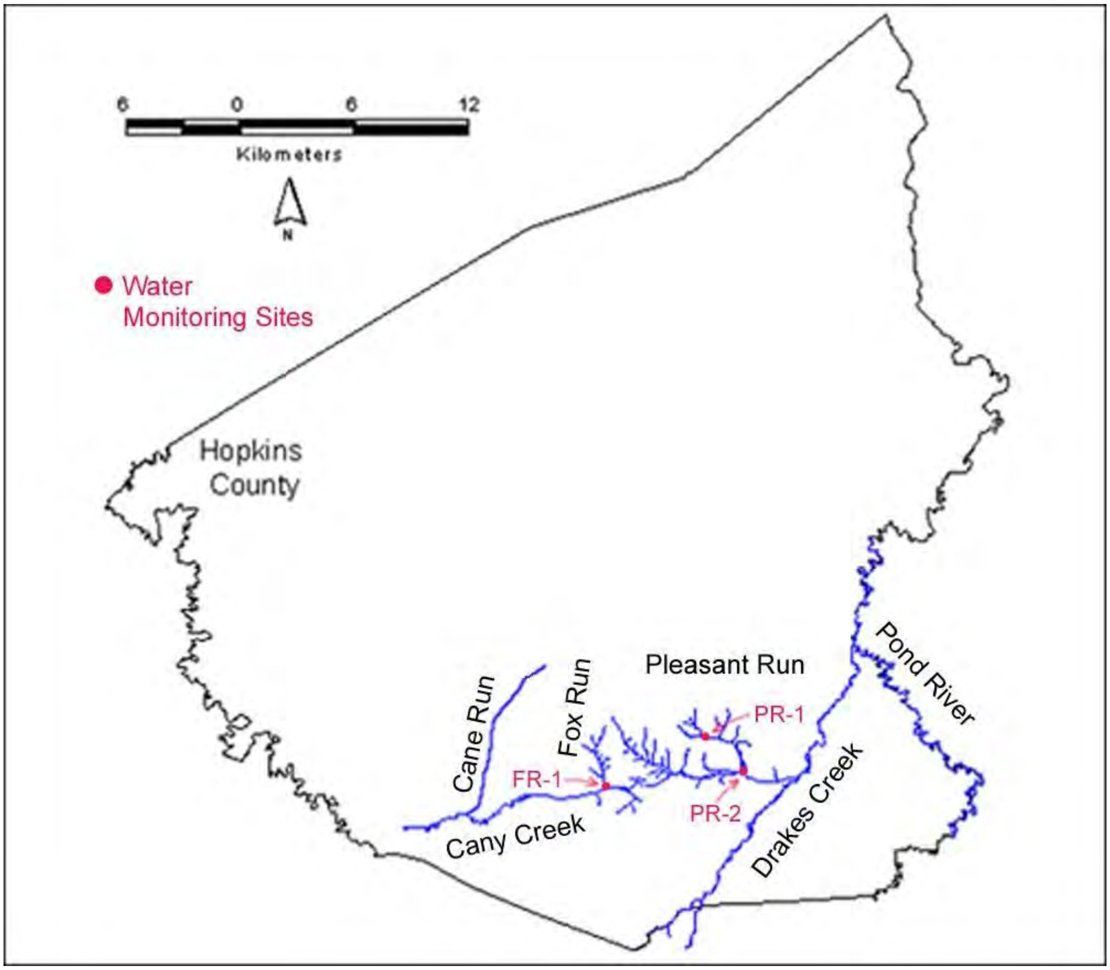


Figure 3:  Water quality sites.

The following parameters were tested monthly:

| **Parameter** | **Analyzed By** |
|---|---|
| Flow | Field |
| pH | Field/Lab |
| Conductivity | Field/Lab |
| Alkalinity | Lab |
| Acidity | Lab |
| Total Dissolved Solids | Lab |
| Calcium (total) | Lab |
| Aluminum (total) | Lab |
| Aluminum (Dissolved) | Lab |
| Iron (total) | Lab |
| Iron (dissolved) | Lab |
| Manganese (total) | Lab |
| Manganese (dissolved) | Lab |

| | |
|---|---|
| Sulfate | Lab |

The following parameters were tested twice for background levels:

| **Parameter** | **Analyzed By** |
|---|---|
| Chloride | Lab |
| Sodium | Lab |
| Potassium | Lab |
| Magnesium | Lab |

All sample collection, preservation, and analysis were conducted in accordance with Standard Methods for the Examination of Water and Wastewater (APHA, 1992). Discharge was measured by current velocity meter or by the “bucket and stopwatch” method where possible. The bucket and stopwatch method involves measuring how much time it takes a given source to fill a container of known volume. This time is then interpolated to volume per minute. Three measurements were taken and the results averaged. Conductivity and pH were measured using calibrated pH and conductivity meters.

## Chain of Custody Procedures

Division of Abandoned Mine Lands personnel conducted sampling for this project. Water monitoring samples were collected, labeled, preserved with a 1:1 nitric acid solution, placed on ice in a cooler and delivered to the laboratory within 24 hours with the following information:

- Date the sample was taken.
- Station at which the sample was taken.
- Name of the person conducting the sampling.
- Gear and/or method used to obtain the sample.
- General stream conditions at the time of sampling (high or low flow, turbid or clear, etc).
- pH.
- Conductivity.
- Stream Flow.

### Quality Control Procedures

Quality control procedures for parameters analyzed by McCoy and McCoy followed the procedures outlined in *Quality Assurance Program Plan* – McCoy and McCoy Laboratories Inc., Madisonville, KY.

## Biological Monitoring

While the adults forms of most species of aquatic insects are winged and highly mobile, their immature stages and other types of aquatic macroinvertebrates (crustaceans, mollusks, annelids, etcetera) have a relatively low degree of mobility. Thus, aquatic macroinvertebrates are continuously exposed to the full range of water quality conditions and are unable to flee poor conditions. If pollutants, such as acidity, dissolved metals, and sediments in the case of this study, are of sufficient concentration, many or all of the pollution-sensitive organisms may be eliminated, allowing the habitat to be overtaken by a few resistant species. These changes would be detectable even if the toxic levels of pollution occurred in short bursts at irregular intervals, and were not detected through water sampling. Recovery of macroinvertebrate populations following elimination of the pollution source would not be immediate. New generations of winged adult insects, from nearby unaffected waters, would be needed to lay eggs in the affected waters. Other macroinvertebrates would need to be transported by current from upstream, crawl from downstream areas, or rely upon other organisms for transport. As an example, many bivalve mollusks are dependent upon fish for transport of larvae (glochidia), which attach to the gills of host fish. As many bivalves appear to depend upon a limited number of fish species, their recovery must first await the return of those fishes from areas where the bivalves still exist. Therefore, recovery of the macroinvertebrate community following the elimination of a pollution source may take a significant amount of time.

Physical alteration of stream habitat, such as channelization, the clogging of interstitial spaces and the gills of organisms through sedimentation, and the alteration of temperature and flow as a result of the elimination of forest cover in headwater areas tend to result in a homogenization of habitats. These conditions eliminate specialized niche habitats, favoring a few generalist species over many specialist species.

Fish are more mobile than aquatic macroinvertebrates, and are capable of avoiding rising levels of pollution by taking refuge in unaffected tributaries or downstream reaches where the pollutant is diluted. They may then recolonize affected habitats from these refuges. So, given a sufficient food source, the diversity of a fish community may recover relatively quickly. However, the major portion of the base level of the fish community is composed of insectivores (chiefly of the family Cyprinidae – true minnows), which feed on macroinvertebrates. Thus, if the macroinvertebrate community is severely affected by a pollutant or stream alteration, the structure of the fish community will be affected. Also, while not a focus of this study, organic toxins tend to become more concentrated in fish, possibly causing fish communities to show the effects of low concentrations of those toxins through mutations and abnormalities. In very low concentrations, organic pollutants may cause these effects to occur before the toxins affect the macroinvertebrates. And, like the macroinvertebrates, alterations of the in-stream habitat can have significant impacts upon the makeup of the fish community, promoting hybridization of species and generalists such as green sunfish over other species, such as darters, that fill specialized niches.

## Monitoring Objectives

The objective of biological monitoring for this project was to determine the overall effectiveness of the acid mine drainage mitigation project on water quality. As noted above, while regular monthly water sampling and testing can provide a series of discrete “snapshots” of the water quality within a system, the biological community will react to intermittent surges of pollution and/or transient changes in water chemistry.  Also, the biological community will react to physical changes in the stream (sedimentation, altered flow and temperature regimes, and other habitat changes) that may not be detected through water sampling alone.

## Monitoring Program

The four biological monitoring stations utilized for this project were at the following sites, as shown by Figure 4:

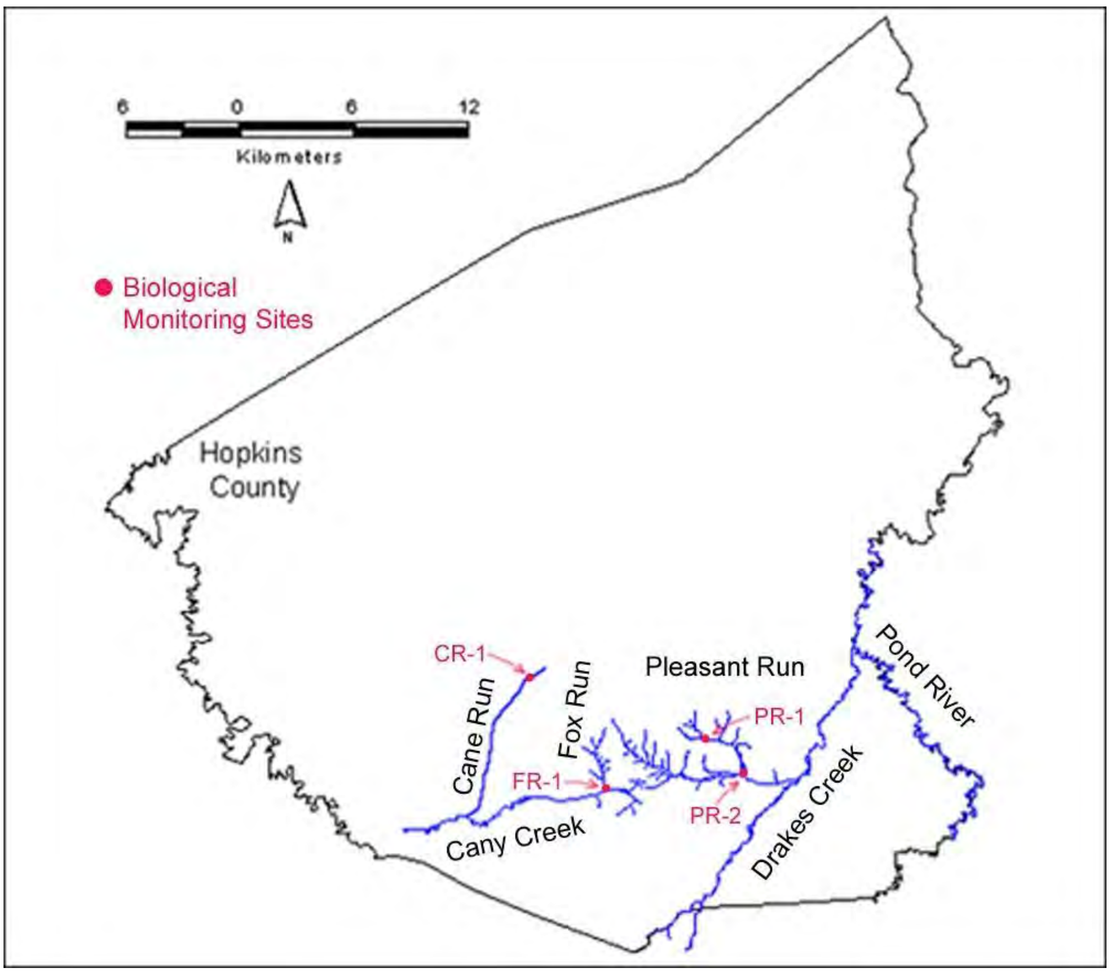



Figure 4:  Biological monitoring sites.

| Station Name | Site Number | Lat/Long |
|---|---|---|
| Upper Pleasant Run | PR – 1 | 37° 13' 16" / 87° 31' 12" |
| Lower Pleasant Run | PR – 2 | 37° 12' 16" / 87° 31' 28" |
| Lower Fox Run | FR – 1 | 37° 11' 02" / 87° 32' 03" |
| Cane Run | CR – 1 | 37° 12' 42" / 87° 34' 36" |

**The test sites PR – 1, PR – 2, and FR – 1 were selected primarily due to their relevance to project related construction activities, in order that sampling would be able to detect the effects of AMD treatments within the project area on the main stems of Pleasant Run and Fox Run. Therefore, each of these sites is located downstream from an area directly impacted by project related construction activities. The site on Cane Run (CR – 1) was selected as a control site due to its origin being in the same vicinity and geology as the project site. Therefore, the effects of any localized meteorological event upon the test sites should also occur at the control site, as should any effects produced by natural landform and geology. The control site, of course, was not impacted by project related construction activities.**

In addition to the low pH and high mineralization of these streams caused by the sources of acid mine drainage to be addressed by this project, the physical properties of these streams present severe challenges to the establishment of healthy macroinvertebrate or fish communities.

Pleasant Run at station PR – 2 exhibits characteristics of channelization, which may be a result of railroad construction adjacent to the stream corridor. During normal levels of flow, the stream is relatively wide and shallow. The channel substrate is predominantly composed of gravel and pebbles with some smaller cobbles. The substrate is heavily embedded with sediments that result from both disturbance of the erosive soils in the watershed and the presence of iron and aluminum oxide flocculants precipitating from the acidic drainage (Figure 5). These flocculants became more prevalent as pH levels rose following reclamation. Bars of accumulated sand and silt are also present (Figure 6).

Figure 5: View of stream conditions at Biological monitoring station PR – 2, showing wide, shallow flow and embedded substrate.

Figure 6: View of stream conditions at Biological monitoring station PR – 2, demonstrating sediment bar formation.

During the study period, the physical characteristics of stations PR – 1 and CR – 1 were similar. The substrates of both streams consisted of small cobbles, which were heavily embedded with sediment, as shown by Figure 7.

Figure 7: A view of stream substrate conditions at Biological Monitoring station CR – 1, showing heavily embedded conditions. This station was similar to station PR – 1 during the period of study.

A subsequent reclamation effort in the headwater section of Pleasant Run has altered the character of the stream at the site of station PR – 1 from its condition during the course of this study. As a result of that effort, the stream channel was lined with heavy limestone to treat acid mine drainage from the reclamation area (Figure 8).

Figure 8: A view of current conditions at the site of station PR – 1

The sampling station on Fox Run (FR – 1) is situated at the downstream end of a channelized section of stream that runs alongside an old roadbed. The stream exhibits many of the same characteristics at this site as those found on Pleasant Run at station PR – 02. The stream is wide and shallow, with a substrate largely composed of small cobbles, gravel and pebbles. This material is heavily embedded with sediments, though iron and aluminum flocculants are not as clearly evident (Figure 9) and sediment bar formation was only present in direct association with the twin box culverts beneath US 62. This sediment bar has likely formed due to that structure impeding flow when the stream is at normal and low levels. Immediately upstream from the station is an underground mine borehole that is flowing a significant quantity of water (Figure 10). A light coating of aluminum precipitate has been observed on the streambed immediately downstream from the inflow from the mine borehole. However, the water from the borehole has been found to not be acidic. Therefore, this precipitate must be the result of oxidation by dissolved oxygen present in Fox Run. The flow of water from the mine borehole remained steady throughout the period of study.

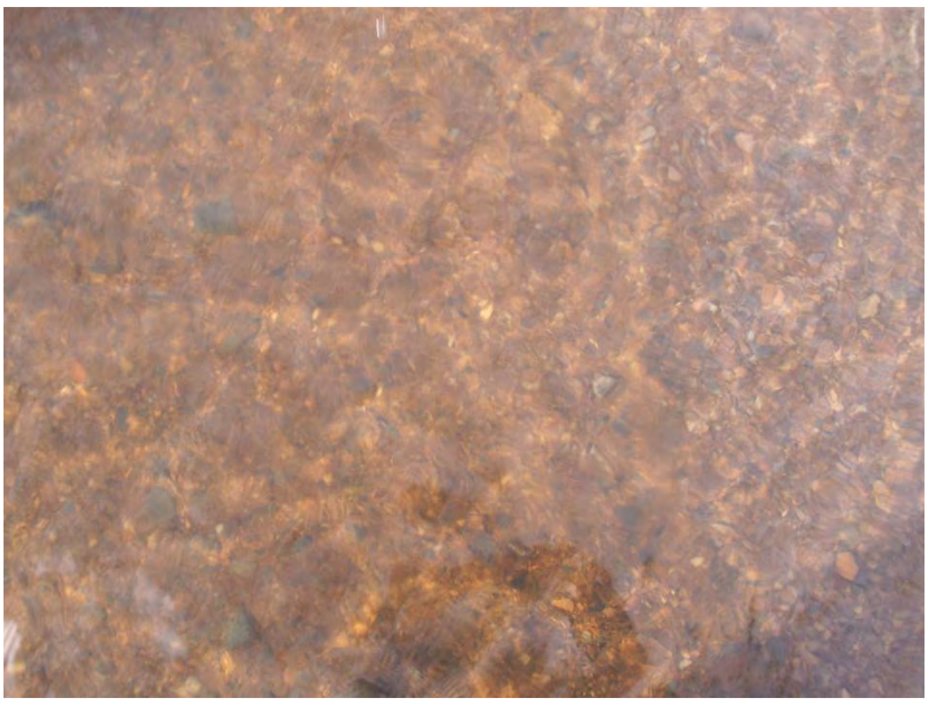


Figure 9: A view of stream substrate conditions at Biological monitoring station FR – 1. The substrate is composed of heavily embedded small cobbles, gravel and pebbles.

Figure 10: Water flowing out of a borehole from an underground mine enters Fox Run just above the sampling station FR – 1.

Macroinvertebrate sampling was conducted during the spring sampling period through both qualitative and quantitative sampling methods. Qualitative sampling was accomplished through the 15 minute composite kick-net method, using D-frame kick-nets. All habitat types available within a sampling station were sampled as they are encountered during the 15 minute effort. Cobbles and leaves were screened from the sample, then washed and examined for macroinvertebrates prior to being returned to the stream. The samples were then picked in the field, and all macroinvertebrates encountered were preserved in 70% ethanol for subsequent identification. Crayfish were counted in the field and returned to the stream. All macroinvertebrates in the preserved samples were identified to the lowest possible taxon by a qualified biologist, utilizing accepted dichotomous keys.

Quantitative sampling was accomplished using ¼ square meter kick-net samples. A 1-meter square kick-net was utilized, with a ¼ square meter area of stream substrate being thoroughly disturbed immediately upstream from the net. At each station, three samples were taken in a transect across a riffle. At the headwater stations where the streams are too narrow to permit a transect across a riffle, samples were taken from downstream to upstream along riffles. Of the four sample stations, only PR – 2 was sufficiently wide to permit sampling on a transect across the width of a riffle. Cobbles and leaves were screened from the sample, then thoroughly washed and examined for macroinvertebrates prior to being returned to the stream. The samples were then picked in the field, and all macroinvertebrates encountered were preserved in 70% ethanol for subsequent identification. Each sample was preserved separately. Crayfish were counted in the field and returned to the stream. All macroinvertebrates in the preserved samples were identified to the lowest possible taxon by a qualified biologist, utilizing accepted dichotomous keys.

After sorting and identification, the data was evaluated using the modified Hilsenhoff Biotic Index (mHBI) (Hilsenhoff, 1987; Lenat, 1993), which has been further customized for use in Kentucky by the Kentucky Division of Water Ecological Support Section (2002), to determine the overall pollution tolerance of the macroinvertebrate community and the degree to which the habitat is impaired. Other metrics used include the Total Number of Individuals, Ephemeroptera/Plecoptera/Trichoptera Richness (EPT), and Percent Dominant Taxon.

Fish sampling efforts were conducted in early summer by the use of a Smith-Root backpack electrofishing device. Both battery powered and generator powered models were utilized, depending upon availability of equipment. Regardless of the power source, the electrofishing gear utilized pulsed DC current. Such equipment is capable of maximizing capture potential while minimizing the potential for injury to any fish encountered. In order to minimize such injury, voltage and amperage of the unit were both set to the lowest settings which created an acceptable level of current that would provide for efficient sampling. During the early summer, the potential for interfering with nesting and/or spawning activities is low and flows should be stable and high enough to present stable populations, while still presenting optimal conditions for capturing fish. Any fish captured would be placed in a water-filled bucket while recovering from being stunned by the electrical field produced by the electrofishing unit. When possible, all fish would be identified in the field. If a species could not be identified in the field, a voucher specimen would be kept, preserved in a 10% formalin solution, and identified at a later time by a qualified biologist, utilizing accepted dichotomous keys. However, neither the pre-construction nor the post-construction sampling effort resulted in the capture of any fish. Also, no fish were noted as being present at any of the four biological monitoring stations utilized under this project. Following collection and positive identification, the data were to have been evaluated utilizing the Index of Biotic Integrity (IBI) (Karr, 1981). Also, Catch per Unit of Effort (CPUE) was to have been utilized.

**Chain of Custody Procedures**

Samples taken in the field were labeled with the following information:

- Date the sample was taken.
- Station at which the sample was taken.
- Name of the person conducting the sampling.
- Gear and/or method used to obtain the sample.

**As noted above, macroinvertebrate samples were collected, picked in the field, and preserved for later identification. This identification was accomplished by qualified biologists – both AML staff and a hired consultant. The resulting data was analyzed by the AML staff biologist. Fish samples were to have been collected by a**

**combination of personnel from the Kentucky Department of Fish and Wildlife Resources (KDFWR), DOW, and AML. However, as noted above, both sampling efforts resulted in the capture of no fish. Volunteers from AML staff, directed and supervised by qualified biologists, assisted in the collection of macroinvertebrates and the fish sampling efforts.**

**Quality Control Procedures**

**Equipment used in macroinvertebrate sampling was thoroughly rinsed in clear water between samples and inspected in order to prevent macroinvertebrates from one sample being transferred to another sample or site. Following the completion of sampling, all sampling equipment was thoroughly rinsed in clean water and dried. Organisms collected from each sample were preserved in a new, clean, empty container. Quality control for biological samples was provided by replicate samples at each station, and by ensuring that all habitat types at each station were sampled. Also, the preserved organisms from each sample are**

**maintained in separate containers with labels identifying the date of sample and equipment used.**

**Soil and Refuse Analysis**

## Monitoring Objectives

The soil and refuse analysis objectives were to collect site specific data to populate the Revised Universal Soil Loss Equation (RUSLE) and to collect acidity data from representative samples of the pyritic coal processing refuse that was reclaimed by this project. RUSLE was used to calculate soil loss from the project area, both before and after the Best Management Practices (BMPs) were completed. This provided a means of estimating the reduction in sediment leaving the project area

## Monitoring Program

McCoy and McCoy Laboratories in Madisonville, Kentucky analyzed the soil/refuse samples. The AML agronomist conducted all soil/refuse sampling for this project. The results were forwarded to the AML agronomist for interpretation. All holding times for laboratory analysis are greater than 24 hours. The methods of analysis are:

| Parameter | Analyzed By |
|---|---|
| pH, Buffer | Lab |
| pH, Soil | Lab |
| Potential Acidity | Lab |
| Phosphorus, Available | Lab |
| Potassium, Available | Lab |

**The RUSLE Model**

The Revised Universal Soil Loss Equation (RUSLE, Renard et al., 1997) is a set of mathematical equations for estimating average annual soil loss and sediment yield due to overland flow from undisturbed lands, lands undergoing disturbance, and from newly or established reclaimed lands. RUSLE estimates soil loss from a slope caused by raindrop impact and overland flow, plus rill erosion. It does not estimate gully or stream-channel erosion. Soil loss is defined here as that material actually removed from a particular slope or slope segment. The sediment yield from a surface is the sum of the soil losses minus deposition in macro-topographic depressions, at the toe of the slope, along field boundaries, or in terraces and channels sculpted into the slope.

RUSLE is derived from the theory of erosion processes, more than 10,000 plot years of data from natural rainfall plots, and from numerous rainfall simulation plots. RUSLE was developed by a group of nationally recognized scientists and soil conservationists who had considerable experience with erosion processes (SCS, 1993).

RUSLE retains the structure of its predecessor, the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978), namely:

$$A = R\ K\ LS\ C\ P$$

Where: A = Average annual soil loss in tons per acre per year
R = Rainfall/runoff erositivity
K = Soil erodibility
LS = Slope length and steepness
C = Cover management
P = Support practice

The R factor is an expression of the erosivity of rainfall and runoff at a particular location. The value of “R” increases as the amount and intensity of rainfall increases. The data for “R” for the project site was obtained from published maps (Renard et. al., 1997).

The K factor is an expression of the inherent erodibility of the soil surface material at a particular site under standard experimental conditions. The value of “K” is a function of the particle size distribution, organic matter content, structure, and permeability of the soil or surface material. For disturbed soils such as those encountered at the project site the nomograph equations embedded within the RUSLE program are used to compute appropriate erodibility values.

The LS factor is an expression of the effect of topography, specifically slope length and steepness, on rates of soil loss at a particular site. The value of “LS” increases as slope length and steepness increase, under the assumption that runoff accumulates and accelerates in the downslope direction. This assumption is usually valid for lands experiencing overland flow, as is found in our project area, but may not be valid for forest and other densely vegetated areas. The LS factor for our project site was determined by actual before and after reclamation surveys of the project area.

The C factor is an expression of the effects of surface covers and roughness, soil biomass, and soil disturbing activities on rates of soil loss at a particular site. The value of “C” decreases as surface cover and soil biomass increase, thus protecting the soil from rainsplash and runoff. The RUSLE program uses a sub-factor method to compute the value of “C”. The sub-factors that influence “C” change through time, resulting in concomitant changes in soil protection. A vegetation database is contained within the computer program that characterizes numerous plant types. RUSLE also contains an operations database file that characterizes the effects of various soil disturbing activities on soil loss rates. These operations alter the roughness, infiltration, distribution of biomass, and runoff properties of the surface. The operations include common tillage activities that may be used in the development of a seedbed at reclaimed sites. The “C” values were calculated using the RUSLE equations that consider local conditions.

The P factor is an expression of the effects of supporting conservation practices, such as contouring, buffer strips of close growing vegetation, and terracing, on soil loss at a particular site. The value of “P” decreases with the installation of these practices because they reduce runoff volume and velocity and encourage the deposition of sediment on the slope surface. The effectiveness of certain erosion control practices varies due to local conditions; therefore “P” values were calculated through the RUSLE equations based on site specific conditions.

### Soil / Refuse Sampling

The coal processing refuse was sampled by the project agronomist at various locations in the project area. Any areas that had noticeably different soil properties were sampled and analyzed as separate samples.

#### Chain of Custody Procedures

KY DAML personnel conducted sampling for this project. Soil/refuse samples taken in the field were labeled with the following information:

- Date the sample was taken.
- Station at which the sample was taken.
- Name of the person conducting the sampling.
- Gear and/or method used to obtain the sample.

### Quality Control Procedures

Quality control procedures for parameters analyzed by McCoy and McCoy followed the procedures outlined in *Quality Assurance Program Plan* – McCoy and McCoy Laboratories Inc., Madisonville, KY.

## Best Management Practice Technologies Installed

## Refuse Grading, Treatment, and Revegetation

**The Homestead Clean Water Action Plan project involved the reclamation of 14.8 ha (36.7 acres) within the Pleasant Run watershed and 15.9 ha (39.3 acres) with the Fox Run watershed**

**containing acidic mine refuse with sparse vegetation (Figures 11 and 12). The refuse was significant source of sedimentation and acid mine drainage (AMD) within the Fox Run and Pleasant Run watersheds.**

Figure 11: Main site looking east across both watersheds. Fox Run is left to right along bottom of the photo, Pleasant Run is left to right along far side of ridge.

Figure 12: Main site looking northeast across both watersheds. Fox Run is to the left side of the ridge, Pleasant Run on the right side of the ridge.

**Acidic impoundments and wet weather/seasonal water holding areas were treated, drained, graded to provide positive drainage and vegetated. The areas containing acidic mine refuse with sparse vegetation were graded to eliminate gullies and providing positive drainage. The graded coal refuse was capped with an agricultural limestone barrier (Figure 13) and covered with a minimum of two feet of suitable cover material (Figure 14).**

Revegetation efforts improved the vegetation of the site, reducing the sediment load to the stream. The refuse areas with sparse vegetation were seeded with a mix of acid tolerant warm and cool season grasses and legumes. Trees were planted on the borrow and riparian areas. Approximately 9,100 bare root stock trees were planted on the upland borrow areas and 1,200 live cuttings/live stakes were planted along the riparian areas. While the use of native grasses and trees is preferred, it has been the experience of the DAML agronomist that a combination of native and non-native species is required for successful vegetation of acidic coal mine refuse (Figure 15).

Figure 13: Agriculture Limestone barrier application

Figure 14: Main site after agriculture limestone barrier and earthen cover application.


Figure 15: Vegetation at one of the reclaimed slurry ponds.

Ditches

### *Grass Diversion Ditches*

**Grass diversion ditches were installed along the benches. The grass diversion ditches were lined with erosion control blanket. The erosion control blanket protects the diversion ditch from erosion while the grass is being established in the channel.**

### *Open Limestone Channels*

**Over 4 km (2.5 miles) of varying sized open limestone channels (OLCs) were constructed with limestone rock and limestone sand (Figure 16). In addition to providing erosion control, they treat acid mine drainage before entering the streams. The OLCs intercept acidic water from the upper slopes of the refuse fill areas and from seeps providing treatment by increasing alkalinity to the water before discharging into the main tributaries. OLCs were also installed as side drains and terrace diversion channels on the graded refuse slopes.**

**Figure 16: Typical open limestone channel.**

**OLCs introduce alkalinity to acid water in open channels or ditches lined with limestone rock (Ziemkiewicz et al., 1994). Acid water is introduced to the channel and the acid mine drainage is treated by limestone dissolution. Past assumptions have held that armored limestone (limestone coated with Fe and/or Al hydroxides) ceased to dissolve, but experiments show that coated limestone continues to dissolve at about 20% the rates of unarmored limestone (Pearson and McDonnell, 1975). Another problem is that hydroxides tend to settle into and plug the voids in limestone beds**

**forcing water to move around rather than through the limestone. While both armoring and plugging are caused by the precipitation of metal hydroxides they are two different problems. Maintaining a high flushing rate through the limestone bed can minimize plugging of the voids in limestone beds. Armoring, however, occurs regardless of the water velocity. Research by Ziemkiewicz and others (1997) has demonstrated that the rate of dissolution for armored limestone may be even higher than previous laboratory studies. Field experiments show considerable treatment by armored OLCs (Ziemkiewicz et al., 1994). The length of channel and the channel gradient are design factors that can be varied for optimum performance. Optimum performance is attained on slopes exceeding 20%, where flow velocities keep precipitates in suspension, and clean precipitates from limestone surfaces. Dissolved metals sorb onto the surfaces of the precipitates in suspension further reducing the amount of dissolved metals in the water.**

Alternative Treatment Options

## Active Treatment Technologies

**Active treatment systems involve treating mine drainage with alkaline chemicals to neutralize acidity, raise water pH, and precipitate metals. Active treatment technologies are effective. However, when the cost of equipment, chemicals, and manpower are considered active treatment is expensive (Skousen et al., 1990). Chemical treatment is a long term never ending process. A variety of active treatment methods can be employed. Most active chemical treatment systems consist of an inflow pipe or ditch, a storage tank or bin to hold the chemical, a means of controlling the chemical application, a settling pond to capture precipitated metal oxyhydroxides, and a discharge point. Chemical compounds used in AMD treatment include:**

**Crushed limestone – rotating drum**
**Hydrated lime**
**Sodium carbonate (soda ash)**
**Sodium hydroxide (solid and liquid forms)**
**Ammonia**
**Pebble Quicklime (Calcium oxide).**

**The above treatment options could possibly have been used on the refuse sites. The flow at the toe of the refuse areas would have to be intercepted and directed to a central application site. The treated water would then flow into a settling pond before being discharged into the stream. The costs for construction of an active treatment site and the continuous operation and maintenance of an active treatment site are prohibitive at current funding levels. In addition, many of the active treatment options use chemicals that are harmful to biota in their concentrated state. The risk of release of these chemicals in concentrated form by vandalism or accident must be considered before deciding to use them.**

Passive Treatment Options

***Aerobic Wetland***

**An aerobic wetland consists of a large surface area pond with horizontal surface flow. The pond may be planted with cattails and other wetland species. Aerobic wetlands can only effectively treat water that is net alkaline. In aerobic wetland systems, metals are**

**precipitated through oxidation reactions to form oxides and hydroxides.**

**Aerobic wetlands are not suitable for the refuse sites. The water discharging from the sites is net acidic.**

***Compost / Anaerobic Wetland***

**Compost wetlands, sometimes called anaerobic wetlands, consist of a large pond with a lower layer of organic substrate. The flow is horizontal through the substrate layer of the pond. The compost layer usually contains calcium carbonate either naturally as in spent mushroom compost, or added during construction of the wetland. A typical compost wetland will have 12 to 24 inches of organic substrate and be planted with cattails or other wetland vegetation. The vegetation helps stabilize the substrate and provides additional organic matter to perpetuate the sulfate-reduction reactions. Compost wetlands can treat discharges that contain dissolved oxygen, ferric iron, aluminum, or acidity in the 500 ppm range.**

**The compost wetland acts as a reducing environment. The compost removes oxygen from the system. Microbial organisms within the organic substrate reduce sulfates to water and hydrogen sulfide and increase the partial pressure of carbon dioxide. The elevated carbon dioxide levels increase the dissolution rates of limestone. Chemical and microbial processes generate alkalinity and increase the pH.**

**The refuse sites may be suitable for compost wetlands. The flow from the refuse would need to be intercepted and directed to the wetlands at the toe of the slopes. Compost wetlands are relatively expensive to construct and this project concentrated on grading and vegetating barren areas of refuse. Revegetation of the refuse slopes was necessary before the installation of compost wetlands could be considered. Budget constraints do not allow the installation of compost wetlands on the project area at this time.**

*Anoxic Limestone Drains*

**An anoxic limestone drain (ALD) is a buried bed of limestone constructed to intercept subsurface mine water and prevent contact with atmospheric oxygen. Keeping the water anoxic prevents oxidation of metals and prevents armoring of the limestone. The closed environment traps carbon dioxide, increasing the partial pressure and resulting in a greater dissolution rate than a system open to the atmosphere. The purpose of an ALD is to provide alkalinity thereby changing net acidic water to net alkaline water. ALDs are limited to the amount of alkalinity they can generate based on solubility equilibrium reactions. An ALD is a pretreatment step to increase alkalinity and raise pH before the water is oxidized and the metals precipitated in an aerobic wetland. The water leaving the site has already been oxidized so the use of an ALD on the refuse sites was not possible.**

*Vertical Flow Reactors*

**Vertical flow reactors were conceived as a way to overcome the alkalinity generation limitations of an anoxic limestone drain and**

**the large area requirements for compost wetlands. The vertical flow reactor consists of a treatment cell with a limestone underdrain topped with an organic substrate and standing water. The water flows vertically through the organic substrate that strips the oxygen from the water making it anoxic. The water then passes through the limestone, which dissolves increasing alkalinity. The water is discharged through a pipe with an air trap to prevent oxygen from entering the treatment cell. Highly acidic water can be treated by passing the water through a series of treatment cells. A settling pond and an aerobic wetland where metals are oxidized and precipitated typically precede and follow the treatment cells.**

**Problems associated with vertical flow reactors include plugging of the pipes and precipitation of metals on the organic substrate surface, preventing flow into the limestone underdrain.**

**The refuse sites may be suitable for vertical flow reactors. However, it would be difficult to intercept all of the acidic water flowing through the refuse and direct it to the treatment cells.**

Other Options

**Other options included removal of the pyrite-rich refuse, mixing the refuse with agricultural limestone and placing it in a compacted fill. This option is expensive and current funding levels are not adequate for consideration of this option. The estimated cost for this option is in excess of ten million dollars for the refuse sites.**

**Other options also include doing nothing. The acid mine drainage and silt will continue to erode unabated into the streams impacting fish and other aquatic life downstream from the site.**

**Maintenance Agreement**

**The Division of Abandoned Mine Lands continues to monitor all project sites annually for a period of 5 years after the final inspection of the project. All project sites are inspected annually by DAML's staff agronomist or his representative. In addition, DAML responds to any complaints received for maintenance on its project sites. Any maintenance required will be performed under a separate maintenance contract. The DAML, as part of its annual grants from the Office of Surface Mining (OSM), budgets a portion**

**of the annual grant for maintenance of reclamation projects completed by AML. Funds for any maintenance work required will be made available through DAML's annual grant from OSM. This is standard operating procedure for all DAML projects. After the 5 year monitoring period by DAML maintenance of the project sites will be performed by mutual agreement with the landowner.**

## RESULTS

### Pleasant Run Above and Below the Reclamation Area

**The field pH values for the headwaters of Pleasant Run above the reclamation ranged from 3.2 to 7.7 with an average of 4.1 (Figure 17). The field pH values of the lower Pleasant Run site leaving the Homestead property ranged from 3.1 to 5.8 prior to reclamation and ranged from 2.9 to 7.1 after reclamation began (Figure 18). The largest decline in pH occurred on June 30, 2004 with a reduction from 6.8 above the reclamation to 2.9 at the lower sampling point of Pleasant Run.**

Total calcium concentrations below the reclamation increased slightly from an average of 321 mg/l to 343 mg/l after grading and agricultural limestone applications and construction of the open limestone channels. Overall, total calcium concentrations above the reclamation averaged 400 mg/l and were attributed to residual limestone fragments within the spoil ridges.

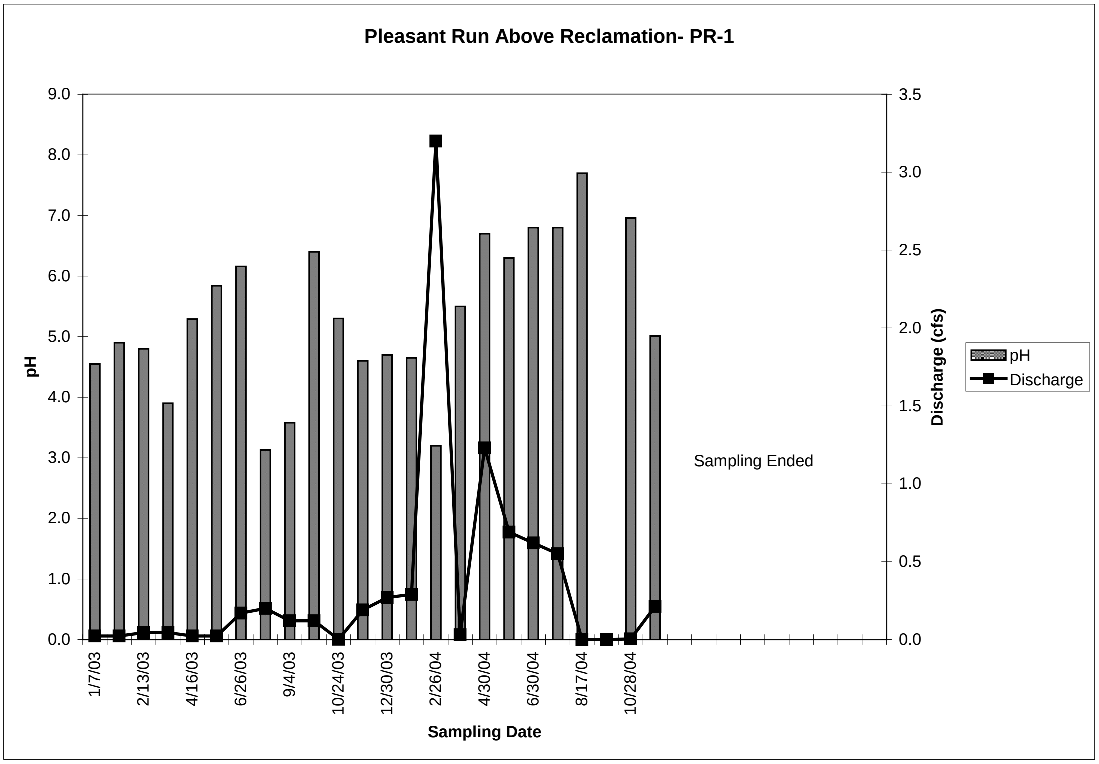



**Figure 17: Discharge and pH values above the reclamation work in the Pleasant Run watershed.**

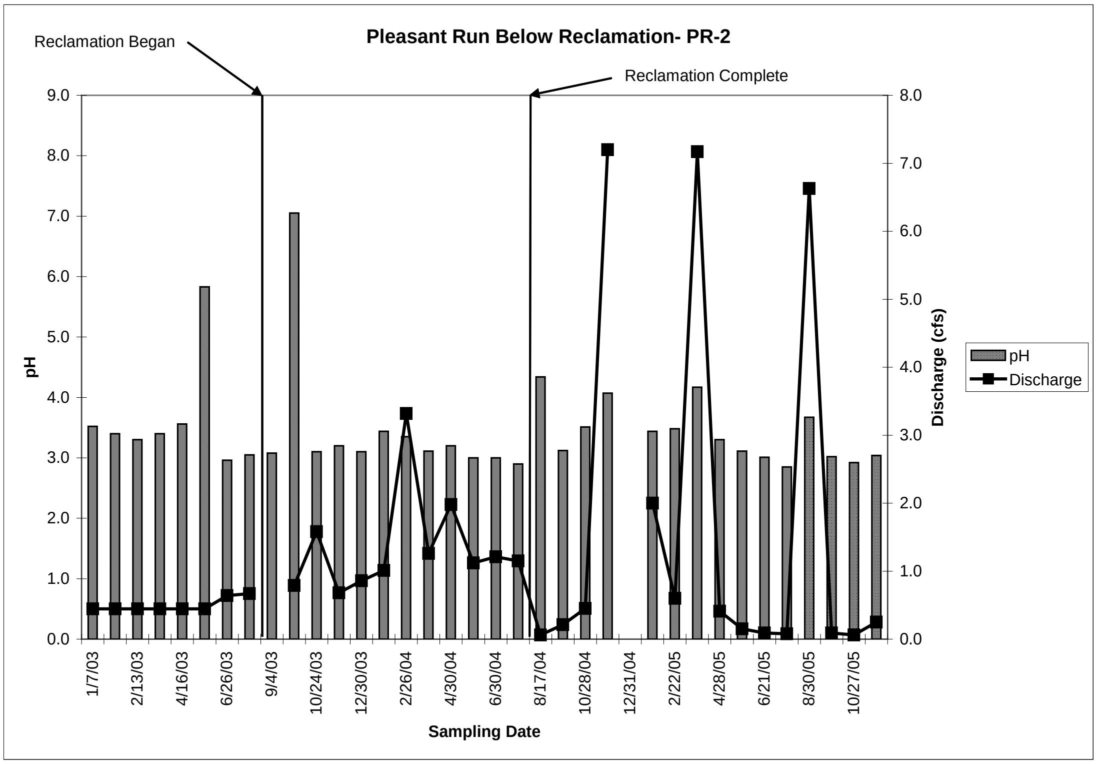



**Figure 18: Discharge and pH values below reclamation work in the Pleasant Run watershed.**

**Acidity concentrations above the reclamation work averaged 129 mg/L $CaCO_3$ (Figure 19). Acidity leaving the work area decreased from an average of 1149 mg/l $CaCO_3$ prior to reclamation to an average of 554 mg/l $CaCO_3$ after reclamation began (Figure 20). Both sampling sites remained net acidic. Acid loading rates did not change drastically after reclamation due to increased flow rates and other acidity sources outside the reclamation work area (Figure 21).**

Iron concentrations (Figure 22) decreased after reclamation started however, higher discharge rates resulted in an overall increase in iron loading (Figure 23). Total and dissolved iron concentrations were reduced by averaged 46 mg/l prior to reclamation and 25 mg/l after reclamation began. Dissolved iron concentrations were reduced by 48% after reclamation began indicating the iron was beginning to precipitate.

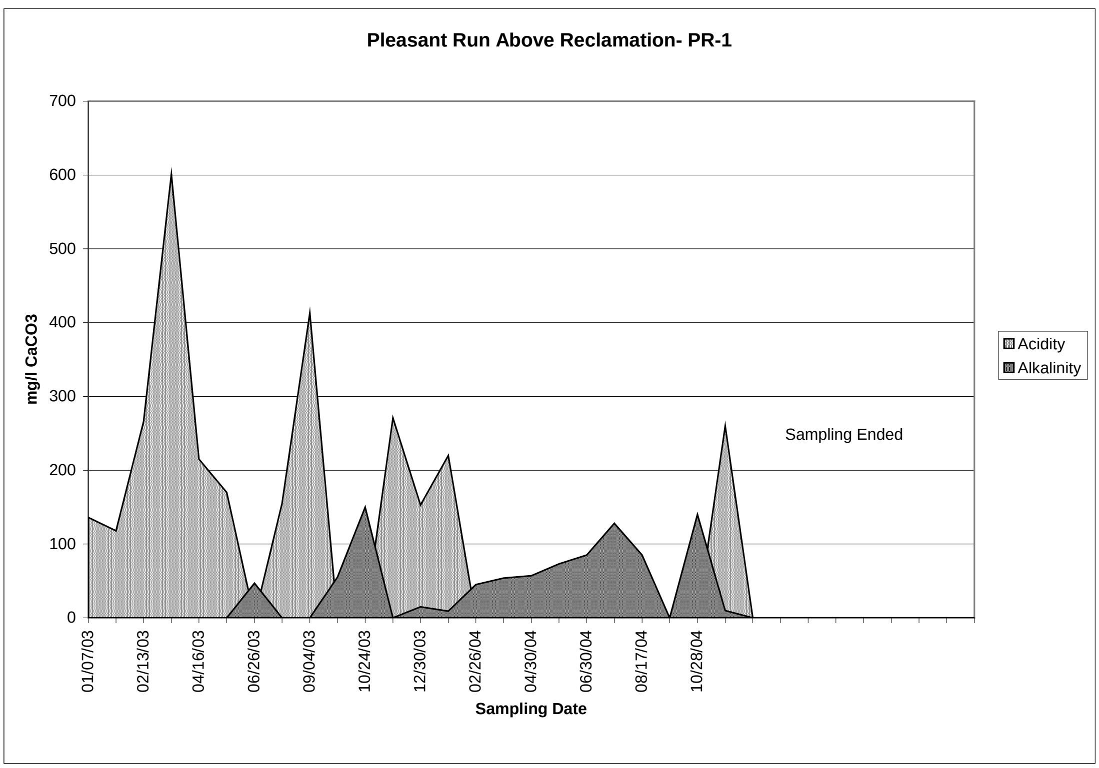



**Figure 19: Acidity and Alkalinity concentrations above the reclamation work in the Pleasant Run watershed.**

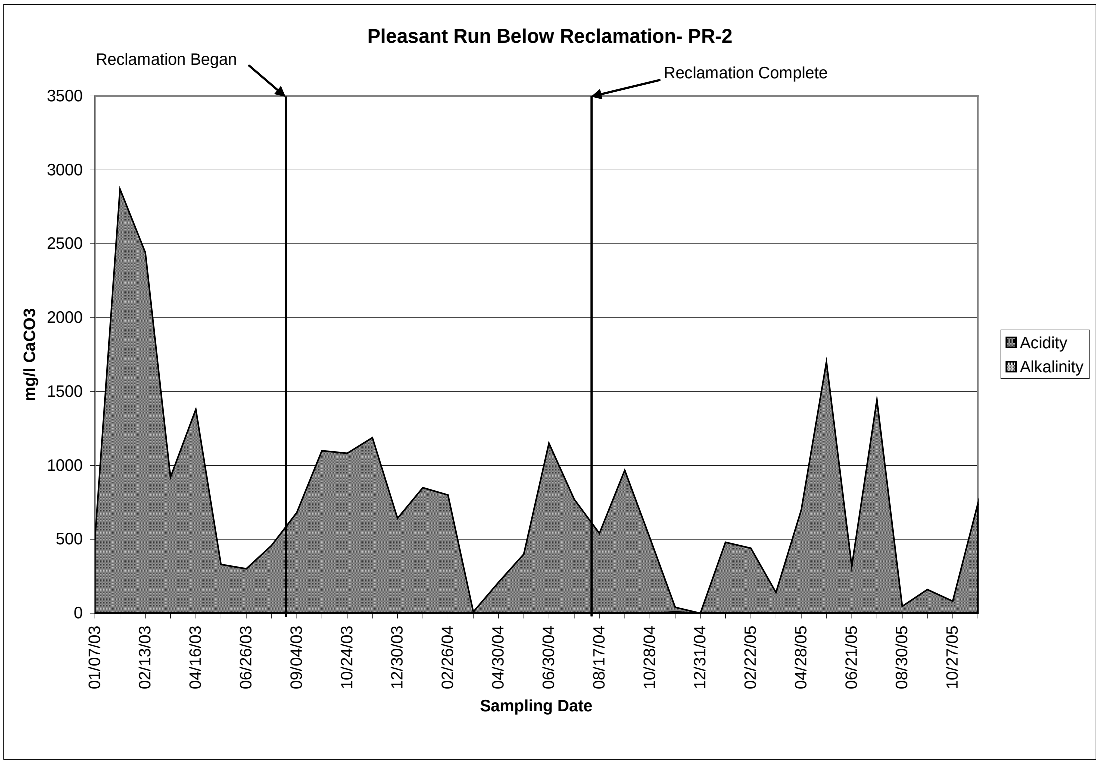



**Figure 20: Acidity and Alkalinity concentrations below reclamation work in the Pleasant Run watershed.**

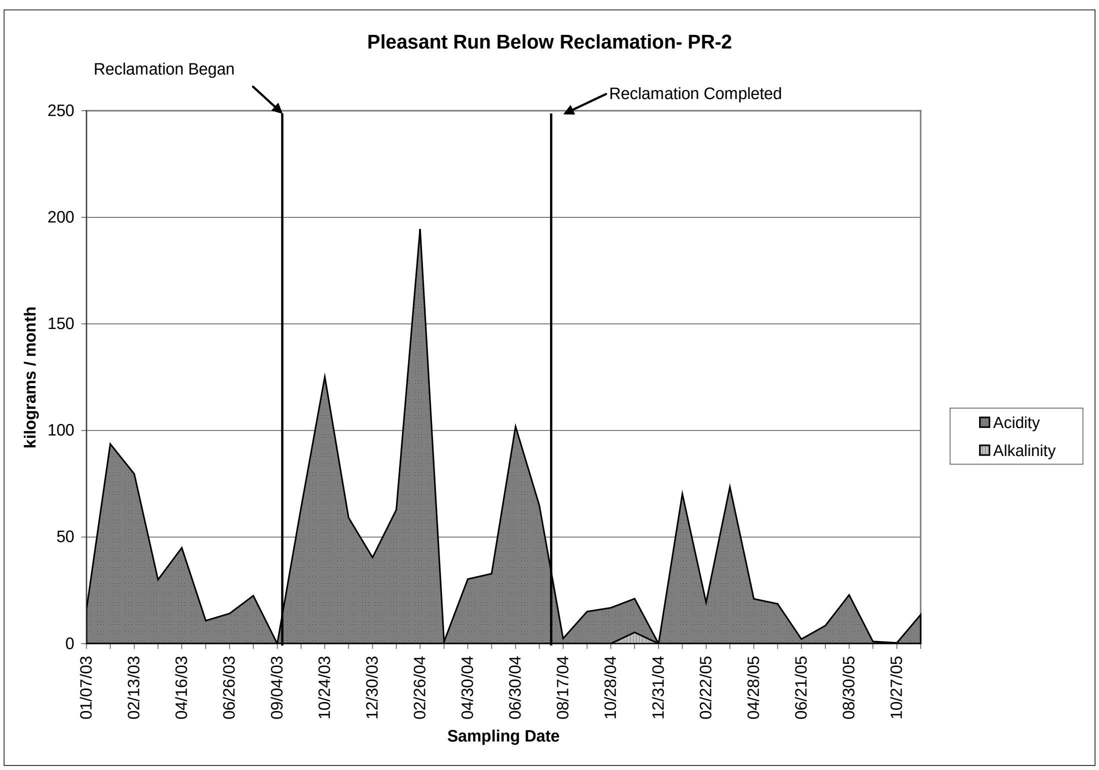


**Figure 21: Acidity and Alkalinity loading below reclamation work in the Pleasant Run watershed.**

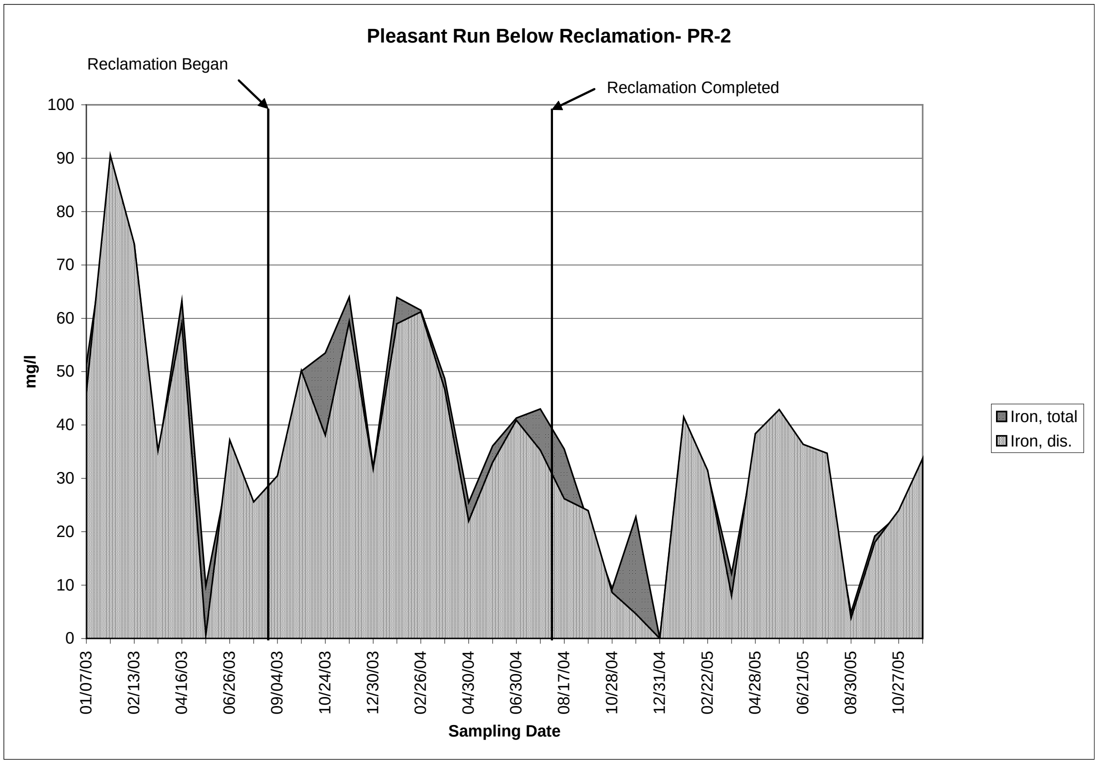



**Figure 22: Iron concentrations below reclamation work in the Pleasant Run watershed.**

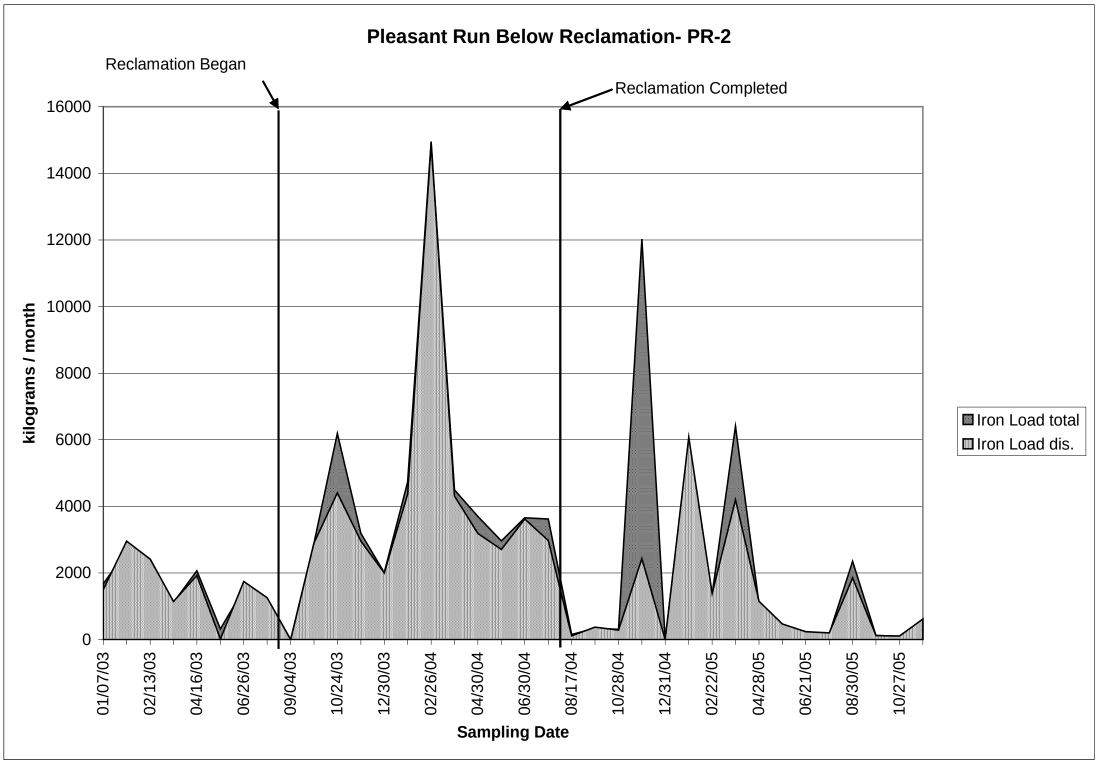



**Figure 23: Iron loading below reclamation work in the Pleasant Run watershed.**

**Total aluminum concentrations were reduced by 40%, from an average of 27 mg/l before reclamation to an average of 16 mg/l after reclamation (Figure 24). Dissolved aluminum concentrations were reduced by 34% from an average of 23.5 mg/l before reclamation to an average of 15.4 mg/l after reclamation (Figure 25). Aluminum loading increased due to higher flow rates in January, March, and August 2005 (Figure 25). Although these three dates had lower concentrations, the higher discharges increased the loads accounting**

**for 50 % of the post-construction total Al and 48 % dissolved Al load.**

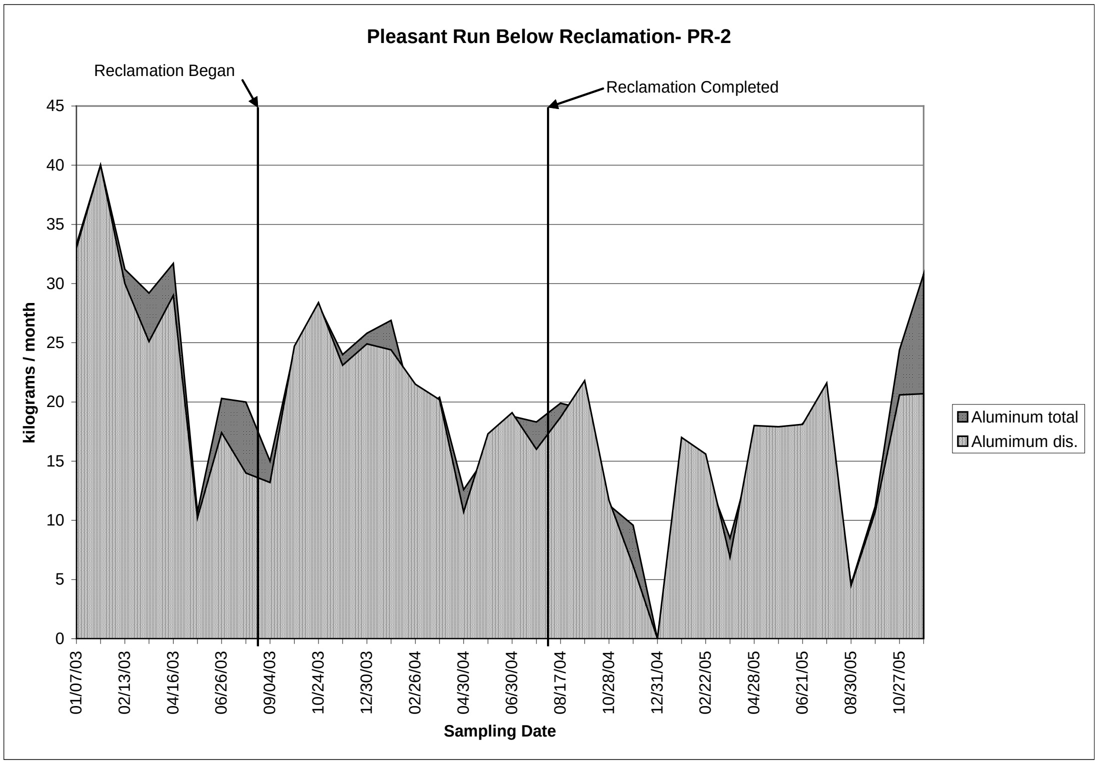
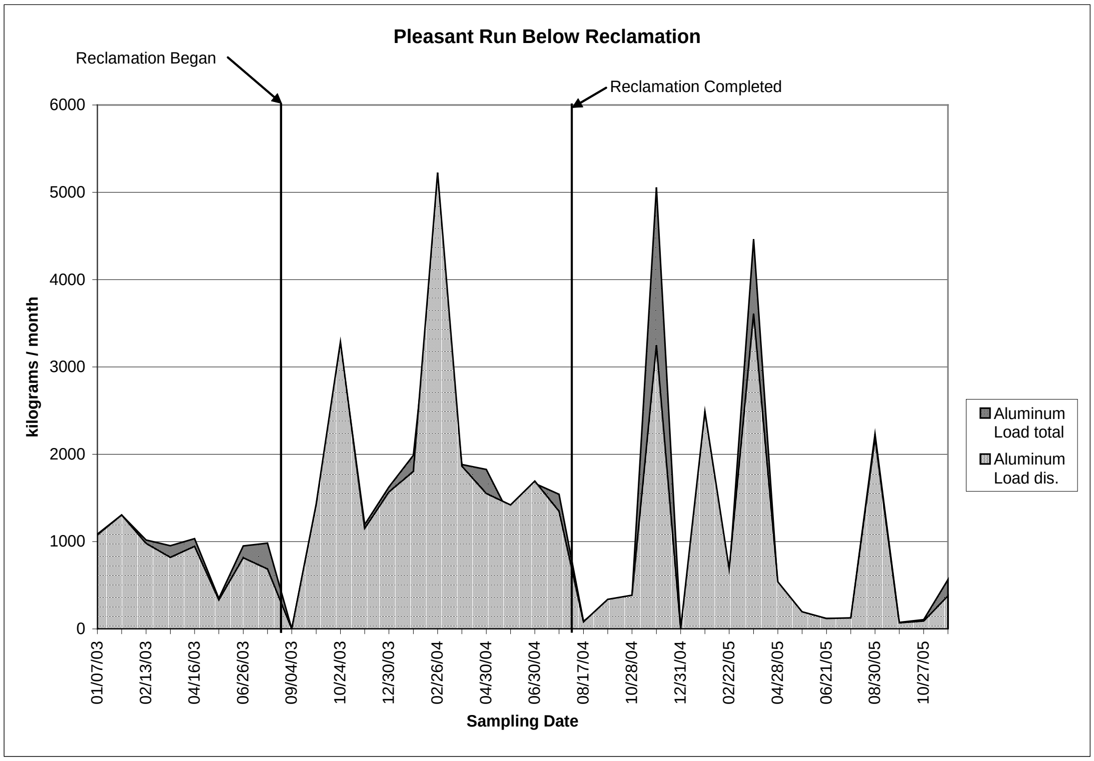



**Figure 24: Aluminum concentrations below reclamation work in the Pleasant Run watershed.**




# Figure 25: Aluminum loading below reclamation work in the Pleasant Run watershed.

The water monitoring at Pleasant Run in the headwaters shows that covering the barren refuse areas and installation of limestone channels decreased the concentrations of metals, however, the complete precipitation of metals will require a greater increase in alkalinity within the watershed. Also, the great increase in acidity and metals between the upper and lower sampling site shows that other pollution sources are still impacting the watershed and will need to be addressed.

The USDA's RUSLE was used for the calculation of potential annual sheet and rill erosion losses of soil/refuse from the worksites each year. It was calculated that the annual soil loss was 4,716 Mg (5,200 tons/year). The refuse samples had an average potential acidity of 77 Mg $CaCO_3$/1,000 Mg soil (tons/kton). The highly weathered surface layer had acidity as low as 27 Mg/1,000 Mg; however the underlying materials have an average potential acidity ranging from 53-127 Mg/1,000 Mg. The actual acid loading is higher due to the formation of sulfur salts in the refuse and subsequent dissolution and runoff of acid into the stream during precipitation events. The RUSLE equation does not account for direct soil loss through gullies. The refuse materials have poor permeability resulting in higher runoff potentials which can convert the surface flows into gullies that act as erodible ditches. The erodible ditches cut into the refuse material and expose new materials for weathering with each precipitation event.

Post-reclamation RUSLE calculations estimate erosion losses at 1,587 Mg/year (1,750 tons/year), a 66% reduction. The potential acidity of the spoil materials ranged from 3.4-52.5 Mg/1,000 Mg, a 64% decrease. Grading the refuse material and construction of erosion control ditches will significantly reduce the erosion losses for the reclaimed areas, and the direct loading of acidity into the streams. Unfortunately, enough alkaline materials could not be added to the spoil materials to eliminate the potential acidity. Instead, acid tolerant plants were chosen for the reclamation areas, and the DAML program has provided maintenance levels of limestone to areas demonstrating the worst plant stress due to acidic soil conditions. In the future the landowner will be responsible for such improvements.

**Fox Run Below the Reclamation Area**

Fox Run above US 62 has a drainage area of 1.83 square miles above an artesian mine borehole beside the stream. The field pH values ranged from 3.0 to 5.8 with an average of 3.7 before and after reclamation began (Figure 26). The increased pH between January and April 2005 was likely due to the limestone added during the reclamation work and higher winter flow rates that minimize the formation of acidic salts. As flows decreased in the summer months, the pH steadily decreased.

**Although flow rates increased 218% after reclamation began, acidity concentrations and loading only increased 9% and 38% respectively (Figure 27). Although the stream remained net acidic, alkalinity was added primarily during the higher flow months of January through April of 2005.**

**Total iron concentrations decreased 50% from an average of 12 mg/l before reclamation to 6 mg/l post reclamation (Figure 28). Dissolved iron concentrations followed a similar reduction after all reclamation work was completed. Total and dissolved iron loading rates (Figure 29) increased due to the higher discharge rates during the post-construction period (39% and 66% respectively). The increased iron concentrations and loading rates may be due in part to the disturbance of the coal refuse and from other sources within the watershed that were outside of the reclamation work area. There are many unreclaimed areas of coal refuse fills and acid impoundments within the watershed.**

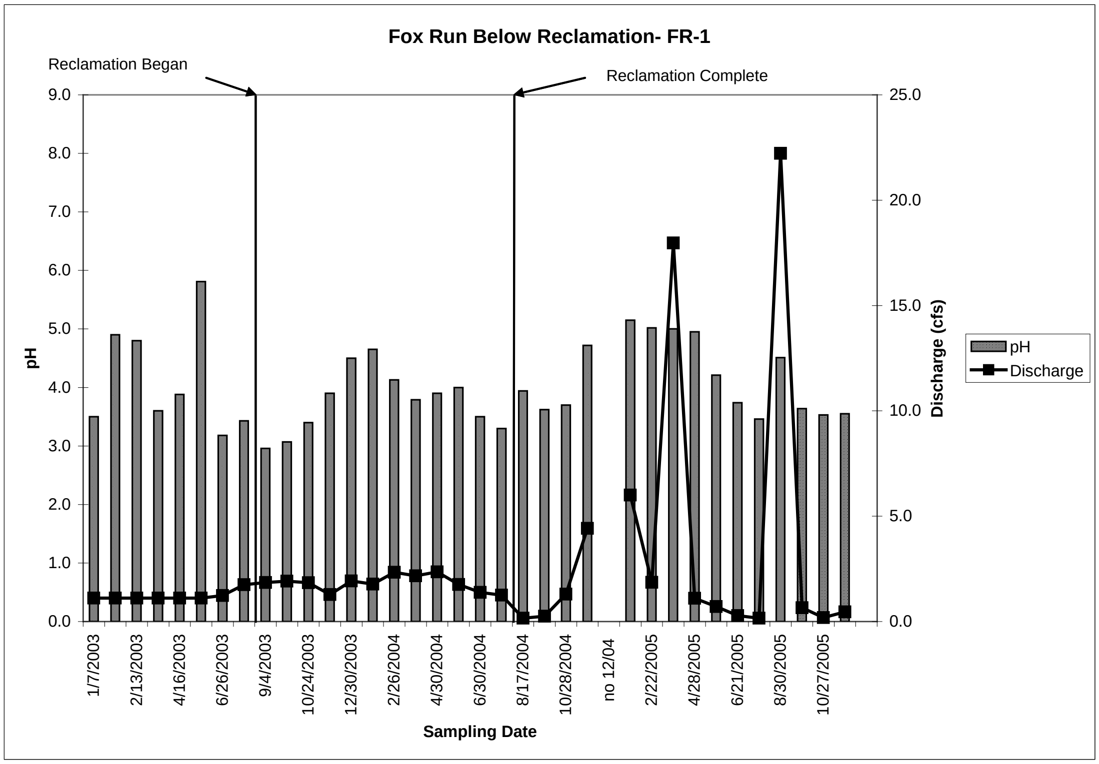



**Figure 26: Discharge and pH values below reclamation work in the Fox Run watershed.**

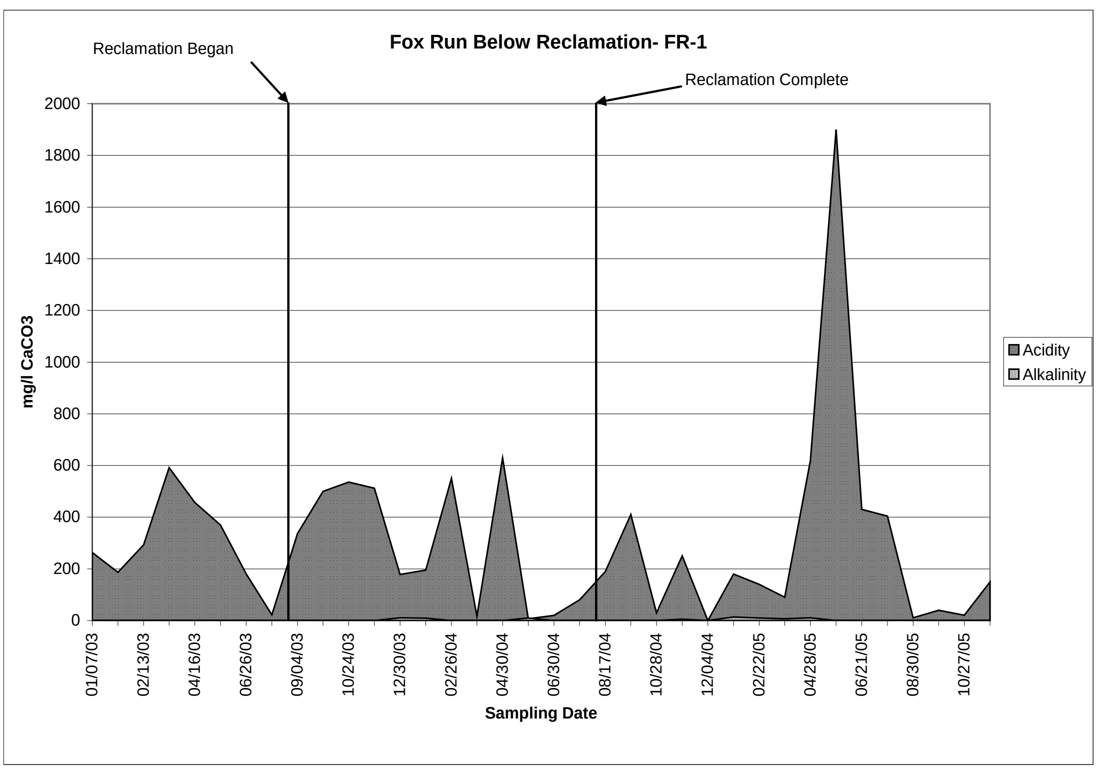


**Figure 27: Acidity and Alkalinity concentrations below reclamation work in the Fox Run watershed.**

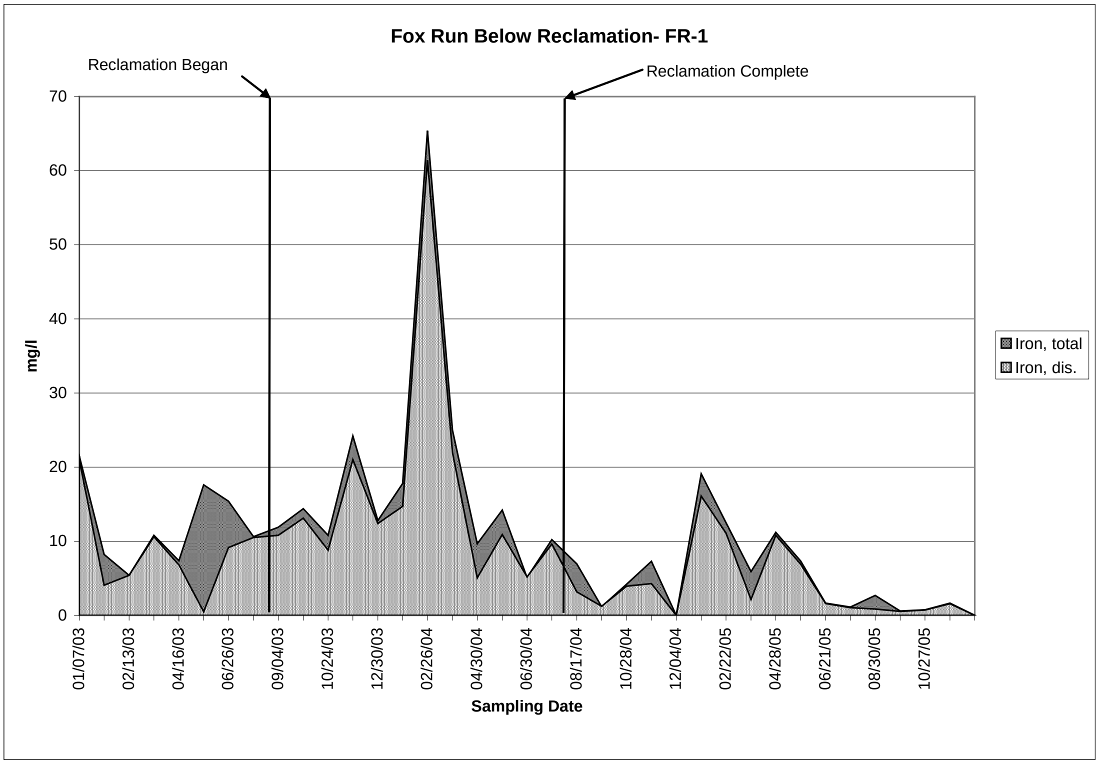



**Figure 28: Iron concentrations below reclamation work in the Fox Run watershed.**

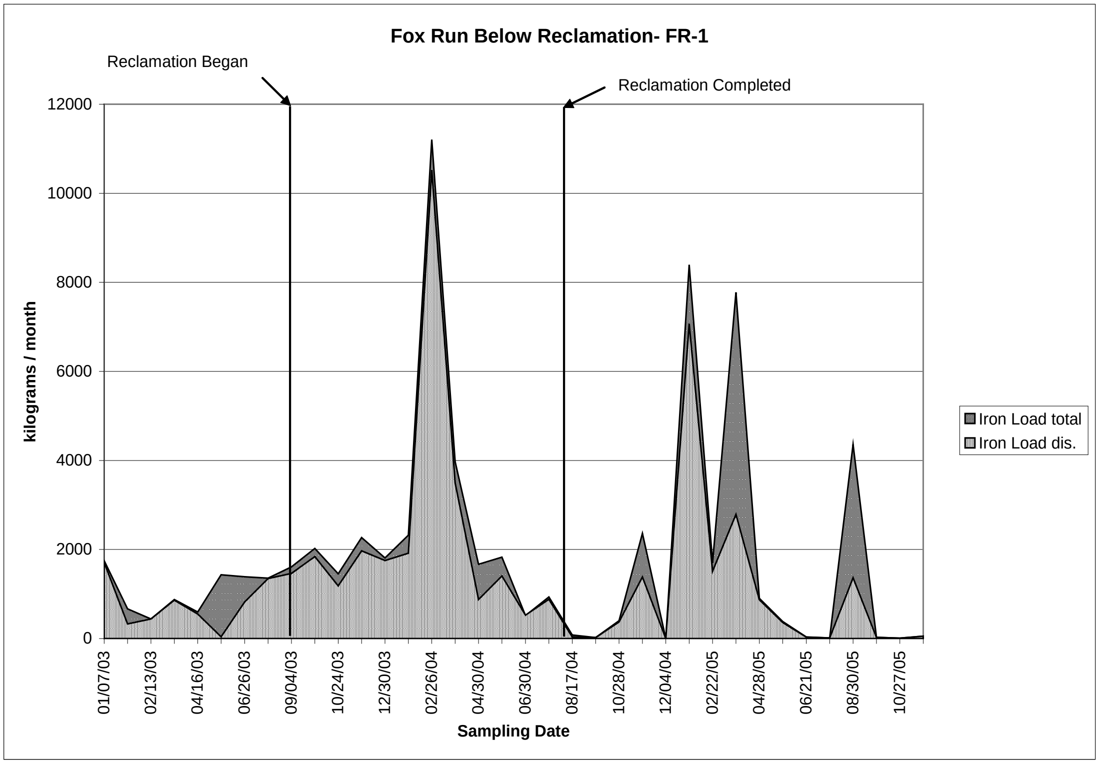



**Figure 29: Iron loading below reclamation work in the Fox Run watershed.**

**Total and dissolved aluminum concentrations had a 6% reduction in total from an average of 15 mg/l before reclamation to an average of 7.5 mg/l after reclamation (Figure 30). Dissolved aluminum loading was reduced by 25% from an average of 1,219 kg/month before reclamation to an average of 911 kg/month after reclamation (Figure 31). The dissolved aluminum loading decreased 16%, indicating precipitation of aluminum was occurring.**

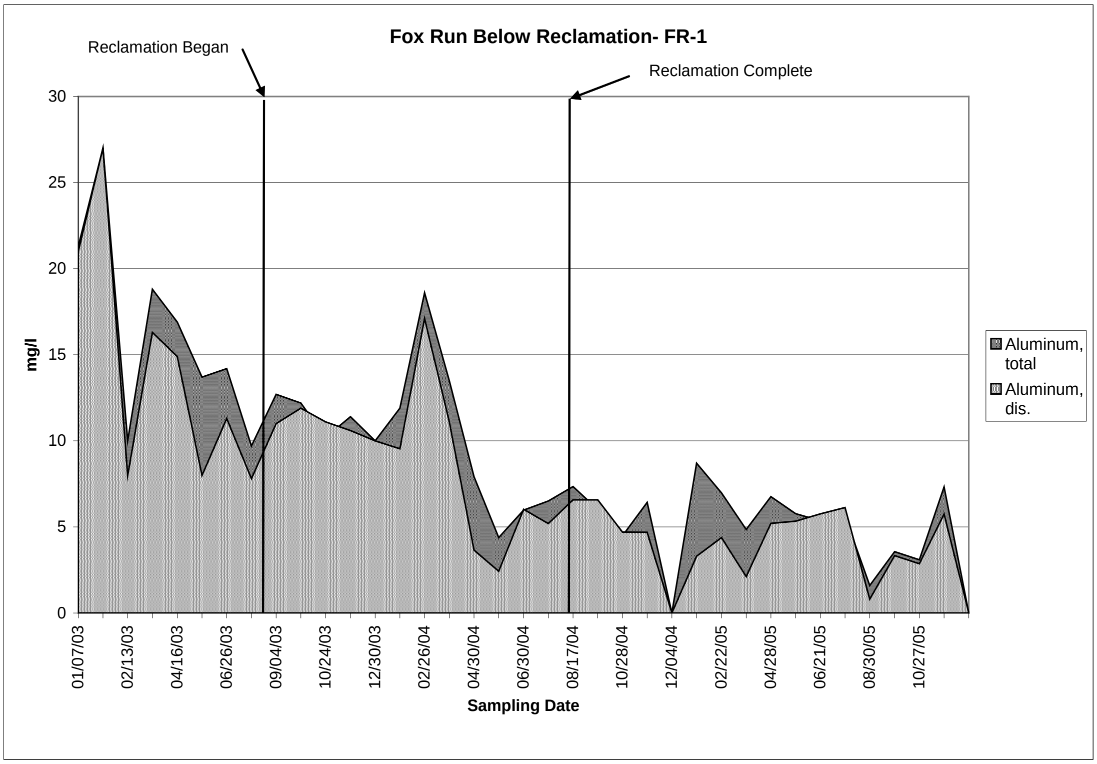
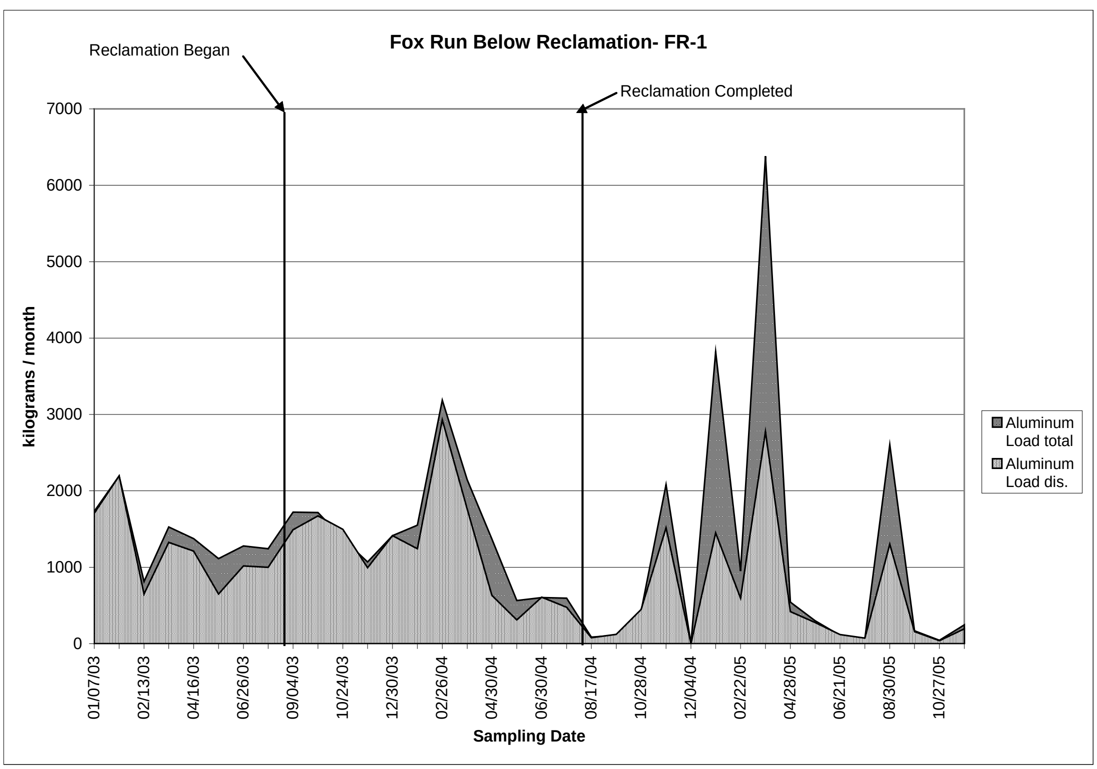



**Figure 30: Aluminum concentrations below reclamation work in the Fox Run watershed.**



## Figure 31: Aluminum loading below reclamation work in the Fox Run watershed.

It is calculated that the annual potential sheet and rill erosion losses of soil/refuse from the worksites was 4,716 Mg (5,200 tons/year). The refuse samples had an average potential acidity of 70 Mg $CaCO_3$/1,000 Mg soil (tons/kton). The actual acid loading is higher due to the formation of sulfur salts in the refuse and subsequent dissolution and runoff of acid into the stream during precipitation events. The RUSLE equation does not account for direct soil loss through gullies.

Post-reclamation RUSLE calculations estimate erosion losses at 1,360.5 Mg/yr (1,500 tons/yr), a 62% reduction. Reclamation resulted in a 64% decrease in the potential acidity loading from the direct erosion of refuse by sheet and rill erosion. Although not all sediment materials would reach the stream channel the eroded materials still generate sulfuric salts when weathered. The combination of the existing refuse pile and the sediments deposited by alluvial forces results in a much greater surface area of potential acidity that is exposed to weathering and subsequent sulfur salts formation. The grading of the refuse to gentler slopes, construction of diversion ditches on steeper slopes, and vegetation, drastically changed the soil loss from the work areas and the exposure of the acidic refuse to weathering. Although erosion and weathering still occur, the diversions act as silt traps greatly decreasing the amount of sediment that reaches Fox Run, and the cover materials limits the exposure of the refuse to the atmosphere. Unfortunately, enough alkalinity materials could not be added to the spoil materials to eliminate the potential acidity. Instead, acid tolerant plants were chosen for the reclamation areas and the DAML program has provided maintenance levels of limestone to areas demonstrating the worst plant stress due to acidic soil conditions.  Future projects could be designed to add alkalinity into the stream channels by using open limestone channels and constructed wetlands.

**Biological Monitoring Results**

**Under this study, two sampling efforts each were made for macroinvertebrates and fish. One sampling effort for each was made prior to construction, while the other was completed following construction. Macroinvertebrate samples were taken in the spring, and fish sampling was conducted during the summer. Macroinvertebrates were found to be sparse throughout all sample stations during both sampling efforts, as can be seen in Tables 1 and 2, below:**

| Order | Family | FinalID | CR-1 | FR-1 | PR-1 | PR-2 |
|---|---|---|---|---|---|---|
| Odonata | Gomphidae | Dromogomphus sp | | 1 | | |
| Plecoptera | Taeniopterygidae | Unid. Taeniopterygid sp | *21 | | | |
| Hemiptera | Corixidae | Hesperocorixa brimleyi | | 1 | | |
| Megaloptera | Sialidae | Sialis sp | | | *1 | |
| Trichoptera | Hydropsychidae | Ceratopsyche sparna | | 1 | | |
| Trichoptera | Phryganeidae | Ptilostomis sp | | 3 | | |
| Coleoptera | Helophoridae | Helophorus sp | 3 | | | |
| Coleoptera | Gyrinidae | Gyrinus sp | | | *1 | |
| Coleoptera | Dytiscidae | Unid. Dyticid sp | 4 | | | |
| Coleoptera | Dytiscidae | Cybister sp | | 1 | | |
| Coleoptera | Dytiscidae | Dytiscus sp | 1 | | | |
| Coleoptera | Elmidae | Dubiraphia sp (adult) | 8 | | | |
| Diptera | Tipulidae | Tipula sp | | 1 | | |
| Diptera | Chironomidae | Chironomus sp | | *16 | | |
| Diptera | Chironomidae | Dicrotendipes sp | | 14 | | |
| Diptera | Chironomidae | Unid. Chironomid sp | 8 | | | 4 |
| Diptera | Chironomidae | Unid. Tanypodinae sp | | | | *6 |
| | | Taxa Richness | 6 | 8 | 2 | 2 |
| | | TNI | 45 | 38 | 2 | 10 |
| | | EPT/Chronomidae | 2.625 | 0.133 | (0+0+0)/0 | 0.000 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | EPT | 1 | 2 | 0 | 0 |
| | | % Ephem | 0 | 0 | 0 | 0 |
| | | % Dom Taxon | 0.467 | 0.421 | 0.500 | 0.600 |

**Table 1: Qualitative and Quantitative Macroinvertebrate Data from the pre-construction April 2, 2003 sampling effort, with computed metrics for Taxa Richness, Total Number of Individuals (TNI), EPT Chironomidae, EPT, Percent Ephemeroptera (% Ephem) and Percent Dominant Taxon (% Dom Taxon). The dominant taxon from each station is marked with an asterisk (*).**

| Order | Family | FinalID | CR-1 | FR-1 | PR-1 | PR-2 |
|---|---|---|---|---|---|---|
| Lumbriculida | Lumbriculidae | Lumbriculus sp | | *2 | | |
| Haplotaxida | Lumbricidae | Unid. Lumbricid sp | 1 | | 1 | |
| Ephemeroptera | Baetidae | Baetis sp | | | | 2 |
| Odonata | Aeshnidae | Aeshna sp | 1 | | | |
| Plecoptera | Leuctridae | Leuctra sp | 2 | | 1 | |
| Megaloptera | Corydalidae | Nigronia serricornis | | | | 1 |
| Megaloptera | Sialidae | Sialis sp | 2 | | 5 | 3 |
| Trichoptera | Rhyacophilidae | Rhyacophila sp | 5 | | | |
| Trichoptera | Rhyacophilidae | Rhyacophila ledra/fenestra | 1 | | | |
| Trichoptera | Polycentropodidae | Polycentropus sp | 1 | | | |
| Coleoptera | Psephenidae | Psephenus herricki | | | | 1 |
| Diptera | Chironomidae | Dicrotendipes sp | *8 | | *17 | 40 |
| Diptera | Chironomidae | Chironomus sp | 7 | | | *51 |
| Diptera | Chironomidae | Rheotanytarsus sp | | | | 13 |
| Diptera | Chironomidae | Eukiefferiella sp | | | | 5 |
| Diptera | Chironomidae | Unid. Chironomid sp | 3 | | | |
| Diptera | Ceratopogonidae | Bezzia sp | | | 1 | 4 |
| Amphipoda | Gammaridae | Gammarus lacustris | 6 | | 3 | |
| Isopoda | Asellidae | Lirceus fontinalis | 5 | | | |
| Isopoda | Asellidae | Unid. Isopoda sp | 2 | | | |
| Isopoda | Asellidae | Unid. Asellidae sp | 1 | | | |
| Decapoda | Cambaridae | Unid. Cambaridae sp | 1 | | | |
| | | Taxa Richness | 15 | 1 | 6 | 9 |
| | | TNI | 46 | 2 | 28 | 120 |
| | | EPT/Chronomidae | 0.500 | (0+0+0)/0 | 0.059 | 0.018 |
| | | EPT | 4 | 0 | 1 | 1 |
| | | % Ephem | 0.000 | 0.000 | 0.000 | 0.017 |
| | | % Dom Taxon | 0.174 | 1 | 0.607 | 0.425 |

**Table 2: Qualitative and Quantitative Macroinvertebrate Data from the post-construction March 16, 2005 sampling effort, with computed metrics for Taxa Richness, Total Number of Individuals (TNI), EPT Chironomidae, EPT, Percent Ephemeroptera (% Ephem) and Percent Dominant Taxon (% Dom Taxon). The dominant taxon from each station is marked with an asterisk (*).**

**All metrics were relatively poor in both qualitative samples.**

**The control site on Cane Run had a much higher diversity during**

**the post-construction sample than the pre-construction sample, increasing from 6 species to 15. In the two stations on Pleasant Run (PR – 1 and PR – 2), the number of species present also increased in the post-construction sample (from 2 to 6, and from 2 to 9, respectively). At all three of these sample sites, the species present following construction were completely different from those present prior to construction. However, the number of species present at the Fox Run station (FR – 1) decreased from 8 to 1, with the only macroinvertebrates found during the second sample being earthworms. The reasons for the collapse of the macroinvertebrate community at this site are unknown. Of a total drainage area of 0.64 square mile (approximately 410 acres) above the sampling point, this project reclaimed 39.3 acres of acidic coal processing waste. Thus, the work area comprised just less than 10% of the drainage area. Other areas within the watershed that produce highly acidic drainage, such as mine pits lined with acidic clays and underground mine portals, were not disturbed or reclaimed under this project. During the midst of reclamation work on this project,**

**on February 25, 2004, a significant spike in iron and aluminum concentrations was noted in the water chemistry data collected at this station. However, this spike was similar to conditions observed the same day at station PR – 1, located on Pleasant Run below the project area. The stream substrate at sampling station FR – 1 was heavily embedded with sediment both before and after construction, and pH readings following construction have remained similar to those observed prior to reclamation of the coal refuse.**

**Following construction, the vast majority of the macroinvertebrates found at both of the Pleasant Run sampling stations were from the family Chironomidae (midges) of the order Diptera (two-winged flies), as shown by both Percent Dominant Taxon for both sites and the low EPT/Chironomidae ratios. Following construction, the genus *Dicrotendipes* makes up a major proportion of the population of the Cane Run control site and both of the Pleasant Run test sites. The genus *Chironomus* is also relatively prevalent, especially at the lower Pleasant Run test site (PR – 02). Chironomidae have been found to be able to exploit**

**extensive ranges of ecological conditions. Some species, possessing blood rich in hemoglobin, are able to live in water with low levels of dissolved oxygen, or in which other conditions, such as a low pH, may make extracting oxygen from the water difficult, simulating a low concentration of dissolved oxygen. While this hemoglobin rich state is not obvious in preserved specimens, it has been repeatedly observed in the field during sampling efforts. Those individuals observed with this pigmentation were most likely of the genus *Chironomus*, with *Dicrotendipes* being another possibility.**

**Quantitative sampling, utilizing the ¼ square meter kick net method, produced even more sparse data than the combination of quantitative and qualitative, as can be seen in Table 3 and Table 4, below:**

| Order | Family | FinalID | mHBITV | CR-1 | n x ά | FR-1 | n x ά | PR-1 | n x ά | PR-0 | n x ά |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Plecoptera | Taeniopterygidae | Unid. Taeniopterygid sp | 4.6 | 12 | 55.2 | | 0 | | 0 | | 0 |
| Hemiptera | Corixidae | Hesperocorixa brimleyi | 9 | | 0 | 1 | 9 | | 0 | | 0 |
| Trichoptera | Phryganeidae | Ptilostomis sp | 6.37 | | 0 | 1 | 6.37 | | 0 | | 0 |
| Coleoptera | Helophoridae | Helophorus sp | 7.57 | 1 | 7.57 | | 0 | | 0 | | 0 |
| Coleoptera | Dytiscidae | Dytiscus sp | 9.1 | 1 | 9.1 | | 0 | | 0 | | 0 |
| Coleoptera | Dytiscidae | Unid. Dyticid sp | 8 | 1 | 8 | | 0 | | 0 | | 0 |
| Diptera | Chironomidae | Dicrotendipes sp | 8.1 | | 0 | 14 | 113.4 | | 0 | | 0 |
| Diptera | Chironomidae | Chironomus sp | 9.63 | | 0 | 8 | 77.04 | | 0 | | 0 |
| Diptera | Chironomidae | Unid. Chironomid sp | 7 | 4 | 28 | | 0 | | 0 | 3 | 21 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |
| | | Taxa Richness | Σ(n x ά) | 5 | 107.87 | 4 | 205.81 | 0 | 0 | 1 | 21 |
| | | TNI | mHBI | 19 | 5.67737 | 24 | 8.57542 | 0 | Nil | 3 | 7 |

**Table 3: Quantitative Macroinvertebrate Data from the pre-construction April 2, 2003 sampling effort, with computed modified Hilsenhoff Biotic Index (mHBI). Taxa Richness, Total Number of Individuals (TNI), mHBI Tolerance Values (mHBITV), product of the number of individuals and the mHBITV for each species (n x ά), and the sum of n x ά ( Σ(n x ά) ) are also shown.**

| Order | Family | FinalID | mHBITV | CR-1 | n x ά | FR-1 | n x ά | PR-01 | n x ά | PR-2 | n x ά |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ephemeroptera | Baetidae | Baetis sp | 5.4 | | 0 | | 0 | | 0 | 2 | 10.8 |
| Plecoptera | Leuctridae | Leuctra sp | 0.67 | 2 | 1.34 | | 0 | | 0 | | 0 |
| Megaloptera | Sialidae | Sialis sp | 7.17 | 1 | 7.17 | | 0 | | 0 | | 0 |
| Trichoptera | Rhyacophilidae | Rhyacophila sp | 0.8 | 5 | 4 | | 0 | | 0 | | 0 |
| Trichoptera | Rhyacophilidae | Rhyacophila ledra/fenestra | 3.86 | 1 | 3.86 | | 0 | | 0 | | 0 |
| Diptera | Chironomidae | Chironomus sp | 9.63 | 7 | 67.41 | | 0 | | 0 | 25 | 240.75 |
| Diptera | Chironomidae | Dicrotendipes sp | 8.1 | 6 | 48.6 | | 0 | | 0 | | 0 |
| Diptera | Chironomidae | Rheotanytarsus sp | 6.4 | | 0 | | 0 | | 0 | 13 | 83.2 |
| Diptera | Chironomidae | Unid. Chironomid sp | 7 | 3 | 21 | | 0 | | 0 | | 0 |
| Diptera | Ceratopogonidae | Bezzia sp | 6.9 | | 0 | | 0 | | 0 | 4 | 27.6 |
| Amphipoda | Gammaridae | Gammarus lacustris | 6.9 | 6 | 41.4 | | 0 | | 0 | | 0 |
| Isopoda | Asellidae | Lirceus fontinalis | 7.85 | 4 | 31.4 | | 0 | | 0 | | 0 |
| Isopoda | Asellidae | Unid. Isopoda sp | 8 | 2 | 16 | | 0 | | 0 | | 0 |
| Isopoda | Asellidae | Lirceus sp | 7.85 | 1 | 7.85 | | 0 | | 0 | | 0 |
| | | | | | | | | | | | |
| | | Taxa Richness | Σ(n x ά) | 11 | 250.03 | 0 | 0 | 0 | 0 | 4 | 362.35 |
| | | TNI | mHBI | 38 | 6.57974 | 0 | Nil | 0 | Nil | 44 | 8.23523 |

**Table 4: Quantitative Macroinvertebrate Data from the pre-construction March 16, 2005 sampling effort, with computed modified Hilsenhoff Biotic Index (mHBI). Taxa Richness, Total Number of Individuals (TNI), mHBI Tolerance Values (mHBITV), product of the number of individuals and the mHBITV for each species (n x ά), and the sum of n x ά ( Σ(n x ά) ) are also shown.**

**Quantitative sampling did not yield any macroinvertebrates at the headwater station on Pleasant Run (PR – 1) during either**

**sampling effort. The post-construction quantitative sample on Fox Run (FR – 1) also yielded no macroinvertebrates, compared with 24 individuals from 4 species in the pre-construction sample. As discussed above, the cause of this collapse is unknown, as a low percentage of the watershed above the sample site was subjected to project-related disturbance, and water chemistry readings at this site did not reveal stronger concentrations of metals or lower pH than at the below construction site on Pleasant Run (PR – 2). The computed mHBI values for both the control site (CR – 1) and site PR – 2 were higher, showing that the macroinvertebrate communities at these sites had an overall higher tolerance of pollutants following construction. However, both taxa richness (diversity) and the total number of organisms had increased at both of these sites following construction. These results may indicate that, while conditions within Pleasant Run are still very poor following the reclamation work conducted under this project, conditions within the stream may have stabilized, with fewer and/or less extreme surges of pollutants and lowered pH levels than prior to**

**construction. However, the control site, which was unaffected by project related activities, also showed an increase in richness and abundance. So, it appears that conditions may have been more favorable for macroinvertebrates throughout the area during the period prior to the post-construction sample. This may be a result of heavy rains in late 2002 and early 2003 producing heavy flows of water and surges of pollutants flowing from coal waste deposits, abandoned surface mine pits and underground mine workings. The extreme amounts of rainfall may have depressed the macroinvertebrate community during that time frame. However, during that period, more macroinvertebrates were in Fox Run than during the more nearly normal seasons leading up to the post-construction sample. One possible explanation for the post-construction collapse of the macroinvertebrate community of in Fox Run is for the remaining acid mine drainage producing areas and features within the watershed to be creating intermittent severe pulses of pollutants and low pH waters that are capable of completely devastating the stream. While a 1,800+ mg/l**

**concentration of acidity was seen at FR – 01 on May 25, 2005, a similarly high pulse of acidity was noted that day at PR – 2. Also, post-construction concentrations of iron and aluminum have been consistently lower at FR – 1 than at PR – 2. Also, intermittently high loading rates for these metals have been noted in both streams, and total loadings appear to be relatively similar. Again, the reason or reasons for the collapse of the macroinvertebrate community in Fox Run are not clear.**

**As noted in the description of the monitoring program, both sampling efforts, taken during the early summer of 2003 and 2005, resulted in the capture of no fish. There are several reasons for the lack of a piscid community within Fox Run and Pleasant Run. First, acidity producing pH readings averaging at or below 4.0 in both streams are not conducive to the existence of fish. Second, high concentrations of dissolved minerals interfere with the osmotic balance of freshwater fishes, consequently affecting the ability to move oxygen and carbon dioxide across gill membranes. Third, flocculants act much the same as silt, physically interfering with**

**respiration through the clogging of gills. Also, there are very few macroinvertebrates in either stream, especially in Fox Run, for insectivorous cyprinids and darters to feed upon. While the absence of competition from these more specialist species would open the streams to population by generalists, omnivores, and herbivores, such as green sunfish, creek chubs, and stonerollers, the very poor physical and chemical water conditions are prohibitive. No fish have been captured at the Cane Run control station (CR – 1) either. However, this may be at least partially a consequence of the small size of this stream.**

### Current and Future Reclamation Projects

In 2006 the KYDAML began the Pleasant Run Acid Mine Drainage Abatement Project. The project consists of reclamation work in Homestead and Nortonville. A final report for the project will be submitted for review in December 2008. The DAML is developing plans for future reclamation projects in the Homestead/Bunt Sisk Hills area where the headwaters of Pleasant Run and Fox Run are located.

## CONCLUSIONS

The reclamation of 30.7 ha of barren, acidic refuse and slurry in the Pleasant Run and Fox Run watersheds reduced the overall pollution loads into both watersheds. The grading, liming, covering, and vegetating of the barren refuse resulted in over 60% reductions in erosion losses. Before reclamation, water and wind erosion would continually remove materials to expose new layers of the refuse for weathering in addition to eroded acidic materials deposited downstream from the mining disturbed areas. The weathering and oxidation processes resulted in fresh acid salts that readily dissolve and degrade the water quality. Reclamation covered the acidic materials, greatly reducing, but not stopping, the weathering processes. The elimination of gullies and the installation of water control structures such as diversion ditches and open limestone channels have greatly reduced the sediment loads that may be washed from the reclamation areas. The construction of open limestone channels and use of agriculture limestone barriers added an alkalinity source to help lower acidity loads. However, the overall acidity loads within both watersheds were immensely greater than the alkalinity produced from limestone placed as apart of this project. Despite the total consumption of all alkalinity added to both watersheds acidity loads did tend to be less flashy after construction in both watersheds. Total acidity concentrations within Pleasant Run were reduced by 52% after construction.

Biological monitoring showed incrementally improved conditions for the macroinvertebrate community within the portion of Pleasant Run between its headwaters and station PR-2 located at Gamblin Cemetery Road. The impacts of this project upon Fox Run are difficult to determine. Establishing or maintaining a healthy macroinvertebrate community within these heavily mined watersheds would be difficult at best.

The technologies used in this project were successful in the reductions of sediments loss from the site. The open limestone channels have been shown at other sites to greatly improve water quality. Most of the channels installed within this project serve as erosion protection and do not received continual flows. The vegetation efforts were moderately successful. Some portions of the project required subsequent revegetation due to adverse weather conditions (drought) and burn-out from acidic hotspots within the cover material. Overall, the revegetation has been greatly improved when compared to the original barren conditions. In future projects, the timing of vegetation efforts should be reviewed. In unsuitable seasons a cover crop may be an alternative method, temporary, vegetation method. The cover crop may also provide a green manure layer to further aid the establishment of the final vegetative cover.

Overall, the reclamation activities have decreased the acid and sediment generation from 37 ha, however, far more acidic and barren spoils and coal processing waste deposits exist within these watersheds outside this projects area. The many other sources of acid mine drainage such as from underground mine works, exposed acidic clays, and refuse piles still continue to degrade both watersheds. Future work in both watersheds is still merited to continue to improve the water quality.

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## APPENDIX A. FINANCIAL AND ADMINISTRATIVE CLOSEOUT

### Budget Summary

| Budget Categories | CWAP Funds | Non-Federal Match | Final Expenditures |
|---|---|---|---|
| Personnel | | | |
| **Supplies** | | | |
| **Equipment** | | | |
| **Travel** | | | |
| **Contractual** | $ 756,286.00 | $556,605.04 | $ 1,311,891.04 |
| **Operating Costs** | | | |
| **Other** | | | |
| Total | **57.6%** | **42.4%** | **100%** |

The final reimbursement to the Kentucky Division of Abandoned Mine Lands listed above includes $1,000.00 that was invoiced and paid upon acceptance of the final report by the KY Division of Water. All dollars were spent; there were no excess project funds to reallocate. This project did generate overmatch provided by the Kentucky Division of Abandoned Mine Lands. This overmatch was not posted to the Grant.

### *Equipment Summary*

There was no equipment purchased for this project.

### Special Grant Conditions

There were no special grant conditions.

## APPENDIX B. QA/QC FOR WATER MONITORING

# QUALITY ASSURANCE PROJECT PLAN
# PLEASANT RUN
# CLEAN WATER ACTION
# PLAN PROJECT

## Nonpoint Source Acid Runoff Pollution at the Homestead Refuse Disposal Site

## KENTUCKY DIVISION OF ABANDONED MINE LANDS

## February, 2003

# PROJECT MANAGEMENT

## Distribution List

| | |
|---|---|
| Steve Hohmann | Director - Kentucky Division of Abandoned Mine Lands (KYDAML) |
| David Bradshaw | Environmental Scientist III – KYDAML |
| Edwin Boone | Environmental Tech III – KYDAML |
| Mark Meade | Environmental Tech III – KYDAML |
| Bob Scott | Design Branch Manager – KYDAML |
| Corrine Wells | Nonpoint Source Section Supervisor – KY Division of Water |
| Michele Koziol | EPA Project Manager – KY Division of Water |
| Rodney Pierce | EPA QA Manager – KY Division of Water |

## Project Organization

The Kentucky Division of Abandoned Mine Lands (AML) will conduct monitoring for this project. The following personnel will be in charge of the monitoring activities:

AML Project Geologist - David B. Bradshaw
2521 Lawrenceburg Road
Frankfort, KY 40601
(502) 564-2141

AML Project Biologist - Ed Boone
Kentucky Division of Abandoned Mine Lands
2521 Lawrenceburg Road
Frankfort, KY 40601
(502) 564-2141

AML Project Agronomist - Mark Meade
Kentucky Division of Abandoned Mine Lands
2521 Lawrenceburg Road
Frankfort, KY 40601
(502) 564-2141

AML Project Engineer - Bob Scott
Kentucky Division of Abandoned Mine Lands
2521 Lawrenceburg Road
Frankfort, KY 40601
(502) 564-2141

David Bradshaw is the project QA manager. Water monitoring will be conducted under the supervision of David Bradshaw – Project Geologist/Manager. Biological monitoring will be conducted under the supervision of Edwin Boone – Project Biologist. Refuse sampling will be conducted under the supervision of Mark Meade – Project Agronomist. Silt load calculations using the Revised Universal Soil Loss Equation (RUSLE) will be conducted under the supervision of Bob Scott – Project Engineer.

The KY DAML will contract with a laboratory for water and soil/refuse analysis. The laboratory being used for water and soil/refuse analysis is McCoy and McCoy Laboratories in Madisonville KY.

# Problem Definition/ Background

## Watershed Information

Pleasant Run (HUC14 05110006040060), a third order stream, originates in central Hopkins County (figure 1) and flows east to discharge into Drakes Creek 13.9 km (8.6 mi) upstream from its confluence with the Pond River (figure 2). The Pond River discharges into the Green River, which flows northward into the Ohio River. Pleasant Run's main stem is approximately 12.7 km (7.9 mi) long and drains an area of 3,259.5 ha (8,054.5 acres (12.6 $mi^2$)). The average gradient is 6.8 m per km (35.5 ft per mi). Elevations for Pleasant Run range from 214 m (700 ft) above mean sea level (msl) in the headwaters to 122 m (400 ft) above msl at the mouth.

The 1998 303(d) list of waters for Kentucky (KDOW 1998) indicates 12.7 km (7.9 mi) of Pleasant Run, from the headwaters to the confluence with the Pond River in Hopkins County, does not meet its designated use for contact recreation (swimming) and for aquatic life.

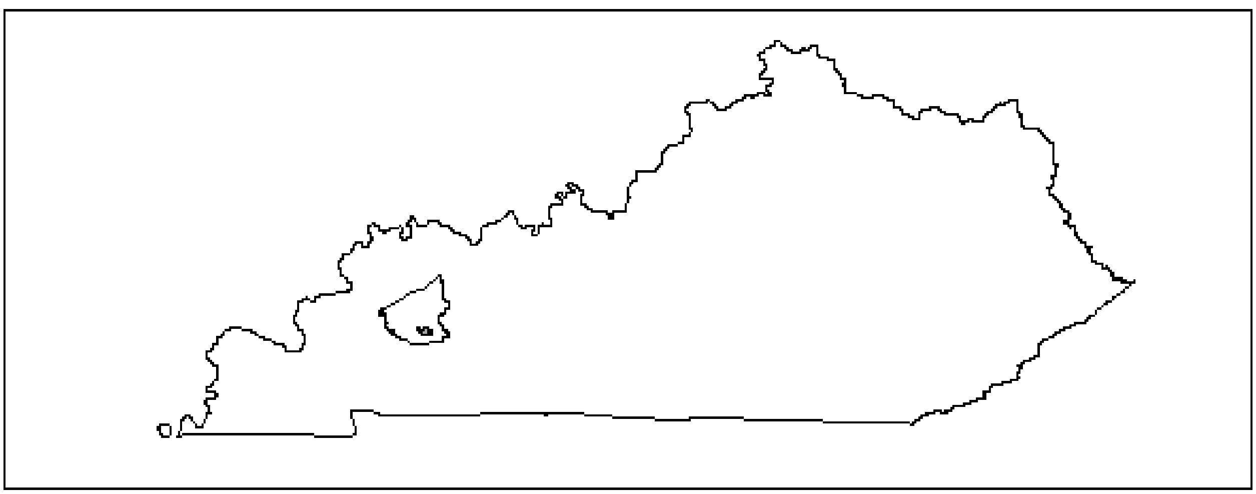


Figure 1. General location of Pleasant Run Watershed (shaded area) and Hopkins County, Kentucky.

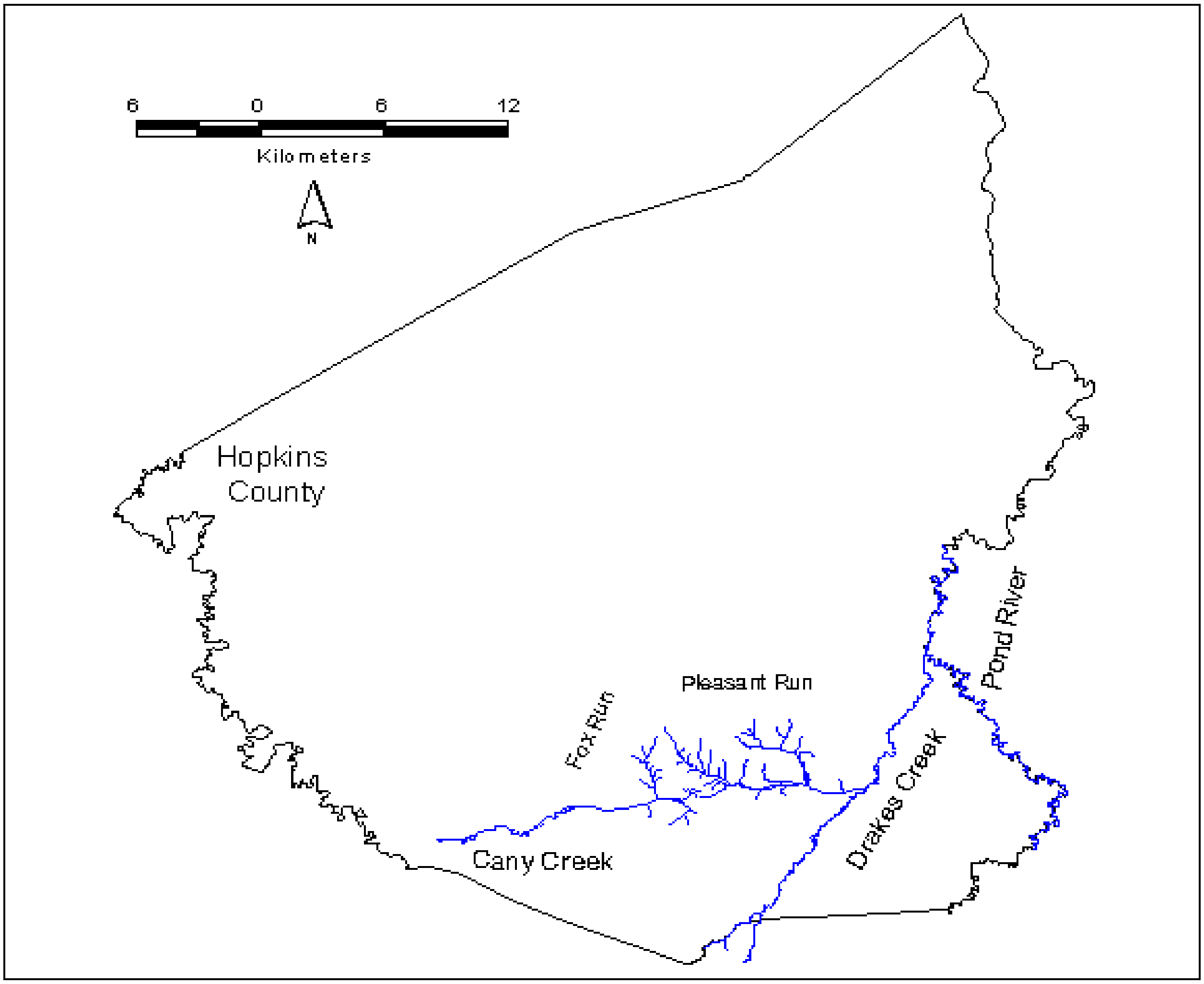



Figure 2. Location of Pleasant Run and Fox Run in Hopkins County, Kentucky.

The Homestead Refuse Reclamation project area selected for BMP implementation was originally mined from the 1940's through 1958 and is a pre law-mining site. The proposed project will reclaim an expanse of abandoned strip and deep mine disturbance in southern Hopkins County, northeast of the community of Saint Charles. The project encompasses nine reclamation sites intermingled with two borrow areas. The nine sites contain pit and ridge formations of severely eroded acidic spoil piles mixed with coal refuse.

## Monitoring History

The waters of Pleasant Run were monitored as early as 1978 by the Division of Water (DOW) as reported in *The Effects of Coal Mining Activities on the Water Quality of Streams in the Western and Eastern Coalfields of Kentucky*, published in 1981 by the Kentucky Department for Natural Resources and Environmental Protection as part of an agreement with the Division of Abandoned Lands. The DOW sampled the three unnamed tributaries to Pleasant Run on April 26, 1978. The three streams had pH values of 4.3, 3.5, and 3.2. The degradation of Pleasant Run is the consequence of acid mine drainage in the watershed as noted by the DOW

In 1997, the DOW conducted a survey of streams in the Western Kentucky Coalfields, including Pleasant Run. The DOW reported a high level of pH impairment, citing acid mine drainage as the principal source. A pH of 2.9 was recorded on July 3, 1997. Based on these readings, the stream was listed as First Priority on the Kentucky 303(d) list of streams not meeting their designated uses. Pleasant Run does not support the designated uses of aquatic life and swimming (KDOW 1998). A draft TMDL for Pleasant Run has been developed and submitted to the Environmental Protection Agency.

## Problem Definition

### Pleasant Run

The 1998 303(d) list of waters for Kentucky (KDOW 1998) indicates 7.9 mi of Pleasant Run, from the headwaters to the confluence with the Pond River in Hopkins County, does not meet its designated use for contact recreation (swimming) and for aquatic life. The Pleasant Run watershed provides a classic example of impairment caused by AMD. Bituminous coal mine drainage, like that found in the Pleasant Run watershed, generally contains very concentrated sulfuric acid and may contain high concentrations of metals, especially iron, manganese, and aluminum.

### Fox Run

Fox Run a first and second order stream drains into Cany Creek (HUC14 05140205030010), which in turn drains into the Tradewater River in Hopkins County. The Tradewater River is listed on Kentucky's 303(d) list. Fox Run is not listed as a pending or active TMDL nor is it on the 303(d) list (KDOW 1998). However, Fox Run watershed receives AMD impacts from the Homestead Refuse site, as does the Pleasant Run Watershed (Figure 2).

# Project Description

The Homestead Refuse Reclamation project area selected for BMP implementation is located along a ridgeline that separates the Pleasant Run and Fox Run watersheds. This site was originally mined from the 1940's through 1958 and is a pre law-mining site.

The proposed project (37 ha (92 acres)) will reclaim an expanse of abandoned strip and deep mine disturbance in southern Hopkins County, approximately 1.6 km (1.0 mi) northeast of the community of Saint Charles. The project encompasses nine reclamation sites (Main site, sites A-H) intermingled with two borrow areas. The nine sites (25 ha (62 acres)) contain pit and ridge formations of severely eroded acidic spoil piles mixed with coal refuse. Sites main, C, and E contain wet-weather/seasonal water-holding areas.

Sediment and erosion from all sites cause infertile deposition, channel filling, and increased swamping of the floodplain. Consequential water quality degradation renders much of the water within the Fox Run, Cany Creek, and Pleasant Run watershed basins to not meet designated aquatic life uses, as well as, public, industrial, and domestic use.

Construction at the main site, a ridge-top coal-refuse fill, and site A, a hillside coal-refuse fill, includes heavy gradework to eliminate large and small gullies and to redirect drainage patterns. Construction at sites B, C, D, and E, coal refuse fills within abandoned sediment structures, and sites F, G, and H, eroding hillsides of coal refuse and soil, includes light gradework to eliminate gullies and to provide a smooth surface for positive drainage. Prior to grading the main site and sites C, and E, water from four wet-weather/seasonal water-holding areas will be treated and released, as needed.

To minimize acid mine drainage and to present a medium capable of supporting vegetation, the graded coal refuse will be capped with an agricultural limestone barrier covered by a minimum of two feet of suitable cover material. A maximum of 12.1 ha (30 acres) will be used within 35.6 ha (88 acres) designated as borrow area. This will minimize surface disturbance and ensure vegetation establishment by allowing the best and most abundant cover material to be located. The cover material consists of ridges of mine spoil vegetated with volunteer trees and scrub. Sufficient cover material will remain within the borrow areas to provide adequate cover for these areas once cover material excavation (sites Main, A-H) is complete. Based on additional soil testing, some areas within sites F, G, and H may not require grading or covering with borrow material.

Except for site A in the head of Fox Run, grading will not disturb any blue-line streams as depicted on the Saint Charles 7.5-minute USGS Quadrangle map. Due to heavy erosion and sedimentation of mine spoil/refuse at site A, the stream channel has already shifted 300 ft to the west. The old channel is no longer discernable and proposed grading will not disturb the existing channel. Channel restoration will not be proposed at this time due to the overwhelming AMD impacts to the area. As AMD impacts are reclaimed, channel restoration activities will be investigated.

Rock, temporarily placed in one location of Pleasant Run and one location of Fox Run, will substitute for bridges and will allow heavy equipment to access the project site. Since these streams are severely impacted by acid mine drainage and sedimentation, the limestone stream crossings should help improve water quality.

Ditches lined with class II/III stone or erosion control blanket will control drainage. Installation and maintenance of hay-bale silt checks and silt traps will minimize sedimentation. All areas disturbed by construction will be covered with suitable cover material and vegetated, as soon as practical, using agricultural limestone, fertilizer, seed, mulch, crimping, and, on steep slopes, netting. All applicable environmental permits will be obtained.

# Quality Objectives and Criteria

A. To collect acid and metal loading data for the Pleasant Run tributary of Drakes Creek. Pleasant Run is being degraded by pyritic coal mine refuse and by seeps discharging acid mine drainage in the Pleasant Run Watershed. Monitoring before and after the reclamation will indicate the efficacy of the acid mine drainage abatement techniques used in the reclamation of the site.
B. To collect acid and metal loading data for the Fox Run tributary of Caney Creek. The Fox Run tributary is being degraded by pyritic coal mine refuse and seeps discharging acid mine drainage in the Fox Run Watershed. Monitoring before and after the reclamation will indicate the efficacy of the acid mine drainage abatement techniques used in the reclamation of the site.
C. To obtain data regarding short term impacts of acid mine drainage mitigation efforts upon the water quality as measured by the aquatic communities of Pleasant Run by means of sampling the macroinvertebrate population. Monitoring macroinvertebrates before, and after reclamation efforts will indicate the short-term effectiveness of this acid mine drainage mitigation project.

D. To obtain site-specific data to populate the Revised Universal Soil Loss Equation (RUSLE). RUSLE will be used to calculate soil loss from the project area before, and after, the Best Management Practices (BMPs) are completed. This will provide a means of estimating the reduction in sediment entering Pleasant Run after completion of the project. Pleasant Run is being degraded by uncontrolled erosion of non-vegetated pyritic coal processing refuse into the creek.
E. To collect soil/refuse analysis data. The refuse analysis will be used in conjunction with the soil loss analysis to calculate the acid load entering the stream before and after reclamation of the refuse from the direct washing of refuse into the stream.

## Special Training/Certification

All personnel involved in the reclamation and monitoring activities on this project are professionals in their fields. No additional training or certification is necessary for the successful completion of the project.

## Documents and Records

The KYDAML project manager will be responsible for disseminating the most current approved version of the QA Project Plan to the individuals responsible for each aspect of the monitoring plan.

Water monitoring data will be reported by the selected laboratory to the Division of Abandoned Lands on the laboratories standard report form. The data will then be entered into a Microsoft Excel spreadsheet.

Biological monitoring data will be reported to the project manager by the project biologist in Microsoft Excel spreadsheet format.

Soil/refuse analysis will be reported to the project manager by the project agronomist on the standard laboratory report form. The project manager will then calculate acid loading due to sediment loss based on the RUSLE calculations.

Soil/refuse loss before and after implementation of the BMPs will be calculated using the RUSLE under the direction of the project engineer. The project engineer will report the results to the project manager in a Microsoft Word document.

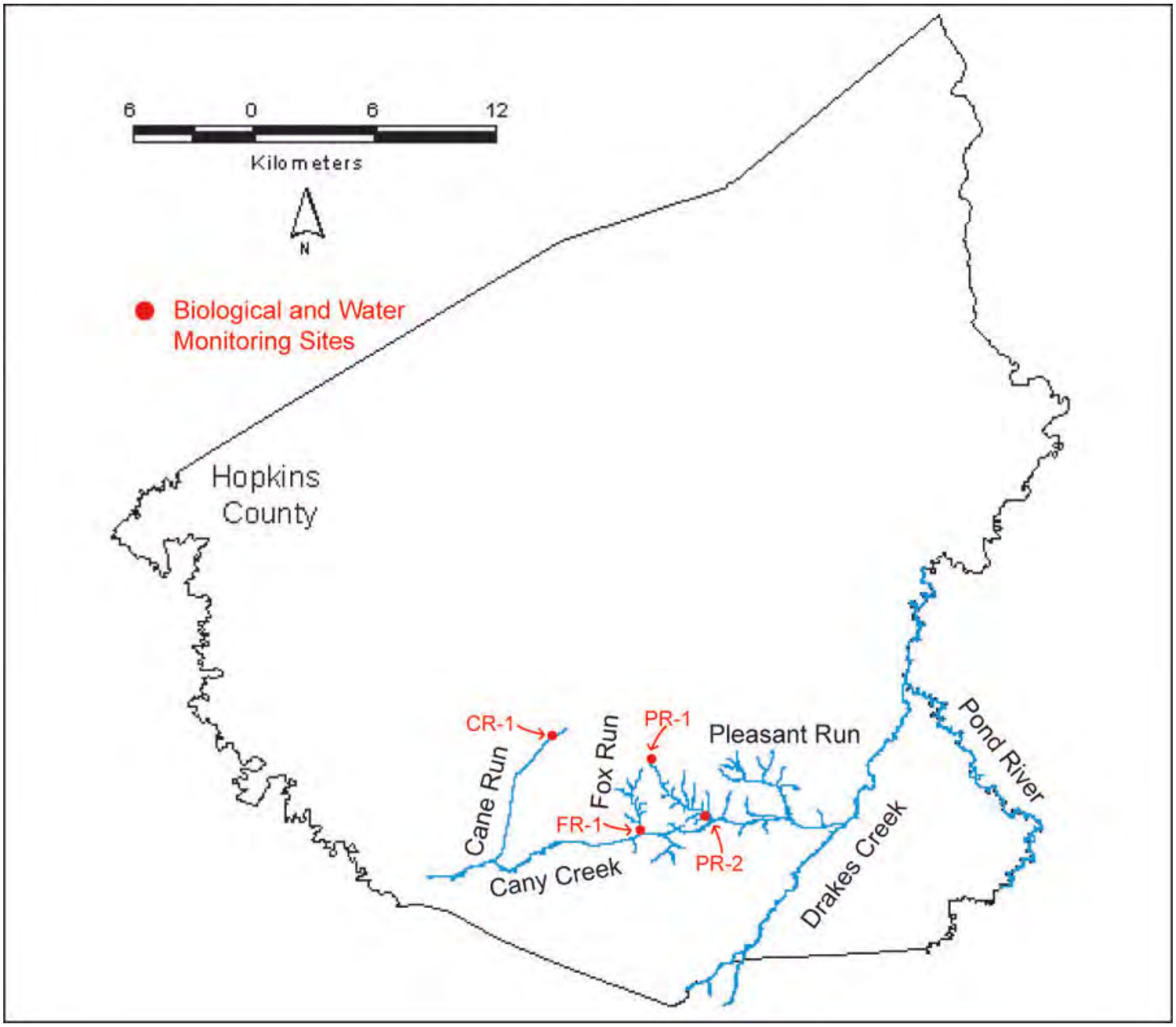
The final report will be submitted in both electronic and print format to the Division of Water using Microsoft Word and Excel formats. All records including but not limited to laboratory analysis, inspection reports, invoices, correspondence, rock weigh tickets, seed tickets, and interim and final reports will be retained by the Kentucky Division of Abandoned Mine Lands at the central office location, 2521 Lawrenceburg Road, Frankfort, KY for a minimum period of five years after acceptance of the final report by the Kentucky Division of Water.

# DATA GENERATION AND ACQUISITON

## Sampling Process Design

### Water Monitoring

Water quality data will be collected in the main stem of Pleasant Run and in the main stem of Fox Run (figure 3).




**Monitoring Site**

| Station Name | Site Number | Lat/Long |
|---|---|---|
| Upper Pleasant Run | PR – 1 | 37° 13' 16" / 87° 31' 12" |

| | | |
|---|---|---|
| Lower Pleasant Run | PR – 2 | 37° 12’ 16” / 87° 31’ 28” |
| Lower Fox Run | FR – 1 | 37° 11’ 02” / 87° 32’ 03” |

Water monitoring sites FR-1 and PR-2 are located at the mouths of the main tributaries contributing the acid and sediment load from the project area. Monitoring at the mouths of the main tributaries accounts for all of the acid drainage sources and any natural buffering which may occur in the watershed. Water monitoring site PR-1 is located near the headwaters of Pleasant Run adjacent to the project area. Monitoring this site will demonstrate the immediate effect of the BMPs implemented on the project.

The following parameters will be tested monthly:

| Parameter | Analyzed By | Method |
|---|---|---|
| Flow | Field | Flow meter/Volumetric |
| pH | Field/Lab | SM 4500-A |
| Specific Conductance | Field/Lab | SM 2510 |
| Alkalinity | Lab | SM 2320 B |
| Acidity | Lab | EPA 305.1 |
| Total Dissolved Solids | Lab | SM 2540 |
| Calcium (total) | Lab | EPA 200.7 |
| Aluminum (total) | Lab | EPA 200.8 |
| Aluminum (dissolved) | Lab | EPA 200.8 |
| Iron (total) | Lab | EPA 200.8 |
| Iron (dissolved) | Lab | EPA 200.8 |
| Manganese (total) | Lab | EPA 200.8 |
| Manganese (dissolved) | Lab | EPA 200.8 |
| Sulfate | Lab | EPA 300.1 |
| Chloride | Lab | EPA 300.1 |
| Sodium | Lab | EPA 200.7 |
| Potassium | Lab | EPA 200.7 |
| Magnesium | Lab | EPA 200.7 |

**Flow -** Flow measurements provide information on the proportional effects that pollution sources have on receiving streams. Flow is being measured so loading calculations can be performed on the parameters being analyzed.

**pH -** The pH of the water is a measurement of the hydrogen-ion activity and gives an indication of the general chemical status of the water, whether the water is acidic or basic.

**Specific Conductance** - Conductivity is a measure of the water's ability to conduct an electrical current. Conductivity is measured to give an approximation of the amount of solids dissolved in the water. AMD pollution produces elevated conductivity readings since the dissolved metals, sulfate, and hydrogen ions can all conduct a charge.

**Alkalinity and Acidity** - Acidity is a measure of the amount of base needed to neutralize acid in a solution. Acidity differs from pH in that pH is a measure of the intensity and acidity is a measure of the amount. Water samples can have the same pH but very different acidity values.

The acidity concentration affects the type of treatment system that may be designed to neutralize the acid. Alkalinity is a measurement of the capacity of the water to neutralize acid. Below a pH of 4.5 no measurable alkalinity will be present in the water.

**Total Dissolved Solids -** Dissolved solids values are used in evaluating water quality and are useful for comparing waters with one another. The residue left after evaporation can be used as an approximate check on the general accuracy of an analysis when compared with the computed dissolved solids value.

**Aluminum, Iron, Manganese** - In coal mine drainage, major contributors to acidity are from ferrous and ferric iron, aluminum, and manganese, as well as free hydrogen ions. Aluminum rarely occurs in solution in natural waters in concentrations greater than a few tenths of a milligram per liter. The exceptions are mostly waters of very low pH such as acid mine drainage impacted waters. Dissolved aluminum in waters having a low pH has a deleterious effect on fish and other forms of aquatic life. Iron concentrations in natural waters are also generally small. The chemical behavior of iron and its solubility in water is dependent on the oxidation intensity and the pH of the system in which it occurs. Water in a flowing surface stream that is fully aerated should not contain more than a few micrograms per liter of dissolved iron at equilibrium in the pH range of about 6.5 to 8.5. Waters that are depleted in oxygen can retain ferrous iron in solution and water with a low pH can retain both ferrous and ferric iron in solution. Manganese is an undesirable impurity in water supplies due to a tendency to deposit black oxide stains. Manganese is often present at concentrations greater than one milligram per liter in acid mine drainage. Manganese usually persists in the water for greater distances downstream from the pollution source than the iron contained in the acid mine drainage. As the acidity is neutralized, ferric hydroxide precipitates first. Aluminum and iron concentrations in acid mine drainage affects the type of treatment systems that can be used for neutralizing the acidity.

**Sulfate** - Sulfur that occurs in reduced form in the sulfide minerals is relatively immobile. When sulfide minerals such as pyrite undergo weathering in contact with aerated water, the sulfur is oxidized to yield sulfate ions that go into solution in the water. Hydrogen ions are produced in considerable quantities in this oxidation process (Hem, 1992).

**Calcium, Magnesium, Chloride, Sodium, Potassium** - Generally calcium is the predominant cation in river water. In some aspects of water chemistry, calcium and magnesium may be considered as having similar effects, as in their contributions to the property of hardness. The tolerance of many aquatic species to low pH and high dissolved aluminum concentrations is hardness dependent. The higher the calcium concentration the more tolerant some fish are to low pH and high aluminum concentrations. The other major cations in natural waters are chloride, sodium, and potassium. Analyzing for these constituents permits anion - cation balance equations to be performed on the sample analysis giving an indication of the accuracy of the analysis.

## Biological Monitoring

Aquatic macroinvertebrates are always in the stream and are continuously exposed to the full range of water quality conditions. Aquatic macroinvertebrates serve as a reflection of stream quality over a period of time. If a pollutant were strong enough it might eliminate many or all of the pollution-sensitive organisms, even though the toxic levels of pollution occurred at irregular intervals. The absence of the sensitive organisms would be a clue that something had upset the stream ecology even though the water might have acceptable chemical quality at the time of sampling.

Biological monitoring stations will be at the following sites on Pleasant Run (PR), Fox Run (FR), and at a control site on Cane Run (CR) (figure 3):

**Monitoring Site**

| Station Name | Site Number | Lat/Long |
|---|---|---|
| Upper Pleasant Run | PR – 1 | 37° 13’ 16” / 87° 31’ 12” |
| Lower Pleasant Run | PR – 2 | 37° 12’ 16” / 87° 31’ 28” |
| Lower Fox Run | FR – 1 | 37° 11’ 02” / 87° 32’ 03” |
| Cane Run | CC – 1 | 37° 12’ 42” / 87° 34’ 36” |

Site selection criteria included ease of repositioning and the ability to determine the effects of AMD treatments within the project area on the main stems of Pleasant Run and Fox Run. All sites are downstream from the AMD impacted tributaries. Data reporting for all collections will be conducted as per Kentucky Division of Water (DOW) accepted methods (See later discussion for details).

Aquatic macroinvertebrates are to be collected in spring by a series of four one-quarter meter kick net samples per station, along with one triangular kick-net sweep to cover all habitat types in the sample area. All whole samples are to be picked in the field, stored in 70% ethanol, and returned to the DAML Frankfort office for sorting and identification to the lowest possible taxon. After sorting and identification, the data will be evaluated using the modified Hilsenhoff Biotic Index (HBI) (Hilsenhoff, 1987, 1988, Lenat, 1993) to determine the overall pollution tolerance of the macroinvertebrate community and the degree to which the habitat is impaired. Other metrics to be used includes the Total Number of Individuals, Ephemeroptera/Plecoptera/Trichoptera Richness (EPT), and Percent Dominant Taxon.

## Soil Loss Monitoring Program

### The RUSLE Model

The Revised Universal Soil Loss Equation (RUSLE, Renard et al., 1997) is a set of mathematical equations for estimating average annual soil loss and sediment yield due to overland flow from undisturbed lands, lands undergoing disturbance, and from newly or established reclaimed lands. RUSLE estimates soil loss from a slope caused by raindrop impact and overland flow, plus rill erosion. It does not estimate gully or stream-channel erosion. Soil loss is defined here as that material actually removed from a particular slope or slope segment. The sediment yield from a surface is the sum of the soil losses minus deposition in macro-topographic depressions, at the toe of the slope, along field boundaries, or in terraces and channels sculpted into the slope.

RUSLE is derived from the theory of erosion processes, more than 10,000 plot years of data from natural rainfall plots, and from numerous rainfall simulation plots. RUSLE was developed by a group of nationally recognized scientists and soil conservationists who had considerable experience with erosion processes (Soil and Water Conservation Society, 1993).

RUSLE retains the structure of its predecessor, the Universal Soil Loss Equation (USLE, Wischmeier and Smith, 1978), namely:

$$A = R\ K\ LS\ C\ P$$

Where: A = Average annual soil loss in tons per acre per year
R = Rainfall/runoff erosivity
K = Soil erodibility
LS = Slope length and steepness
C = Cover management
P = Support practice

The R factor is an expression of the erosivity of rainfall and runoff at a particular location. The value of “R” increases as the amount and intensity of rainfall increases. The data for “R” for the project site will be obtained from the Division of Water, Engineering Memorandum Number 2, (4-30-71) revised (6-1-79) for Hopkins County, Kentucky.

The K factor is an expression of the inherent erodibility of the soil surface material at a particular site under standard experimental conditions. The value of “K” is a function of the particle size distribution, organic matter content, structure, and permeability of the soil or surface material. For disturbed soils such as those encountered at the project site the nomograph equations embedded within the RUSLE program are used to compute appropriate erodibility values.

The LS factor is an expression of the effect of topography, specifically slope length and steepness, on rates of soil loss at a particular site. The value of "LS" increases as slope length and steepness increase, under the assumption that runoff accumulates and accelerates in the downslope direction. This assumption is usually valid for lands experiencing overland flow, as is found in our project area, but may not be valid for forest and other densely vegetated areas. The LS factor for our project site will be determined by actual before and after reclamation surveys of the project area.

The C factor is an expression of the effects of surface covers and roughness, soil biomass, and soil disturbing activities on rates of soil loss at a particular site. The value of “C” decreases as surface cover and soil biomass increase, thus protecting the soil from rainsplash and runoff. The RUSLE program uses a sub-factor method to compute the value of “C”. The sub-factors that influence “C” change through time, resulting in concomitant changes in soil protection. A vegetation database is contained within the computer program that characterizes numerous plant types. RUSLE also contains an operations database file that characterizes the effects of various soil disturbing activities on soil loss rates. These operations alter the roughness, infiltration, distribution of biomass, and runoff properties of the surface. The operations include common tillage activities that may be used in the development of a seedbed at reclaimed sites. C values will be calculated using the RUSLE equations, which consider local conditions.

The P factor is an expression of the effects of supporting conservation practices, such as contouring, buffer strips of close growing vegetation, and terracing, on soil loss at a particular site. The value of “P” decreases with the installation of these practices because they reduce runoff volume and velocity and encourage the deposition of sediment on the slope surface. The effectiveness of certain erosion control practices varies due to local conditions, therefore P values will be calculated through the RUSLE equations based on site specific conditions.

The *Guidelines for the Use of the Revised Universal Soil Loss Equation (RUSLE) Version 1.06 on Mined Lands, Construction Sites, and Reclaimed Lands* (Toy and Foster, 1998) will be used for analyzing the RUSLE data.

**Soil Sampling**

The coal processing refuse will be sampled by the project agronomist at various locations in the project area as determined by the project agronomist. Any areas that have noticeably different soil properties will be sampled and analyzed as separate samples. The soil/refuse samples will be analyzed for Soil Water pH, Buffer pH, Extractable Phosphorus, Extractable Potassium, and Potential Acidity.

The following methods will be used:

| Parameter | Analyzed By | Method |
|---|---|---|
| pH, Soil | Lab | 9045 |
| Potential Acidity | Lab | EPA 60027805 |
| Phosphorus, Available | Lab | Mehlich 3 |
| Potassium, Available | Lab | Mehlich 3 |
| pH, Buffer | Lab | SMP |

**pH, Soil** - Soil pH is analyzed to determine the acidity of the spoil material on-site. pH is an important factor in determining spoil quality for plant growth.
**Potential Acidity** - Potential acidity is used to test for sulfur that may come into solution as weathering occurs. Using this parameter helps to determine the quantity of agricultural limestone needed for maintaining pH at a suitable level for plant growth. Potential acidity is used with the Universal Soil Loss Equation for calculating the acid loading into a stream from the direct washing due to erosion of pyritic coal refuse into the stream.
**Phosphorous, Available** - Phosphorous is an essential element in plant growth and reproduction. It is typically the most limiting factor on mine spoils for plant growth.
**Potassium, Available** - Potassium is a macronutrient as well as phosphorous and nitrogen, essential for plant metabolism. Potassium may be abundant in shaley mine spoils.
**pH, Buffer -** Buffer pH measures the acidity that is available on exchange sites in the soil or spoil matrix. It is useful in determining the proper amount of agricultural limestone to apply when potential acidity is not a limiting or major factor.

# Sampling Methods

## Water Monitoring

All sample collection, preservation, and analysis will be conducted in accordance with *Standard Methods for the Examination of Water and Wastewater (Clesceri et al, 1989).* Discharge will be measured by current velocity meter or by the volumetric bucket and stopwatch method where possible. Three measurements will be taken and the results averaged. Conductivity and pH will be measured on-site using calibrated pH and conductivity meters. The conductivity and pH probes will be triple rinsed with the final rinse using the water to be analyzed to prevent contamination by the previous sample.

Water samples will be collected in new, clean sample bottles, labeled for identification. Three sample bottles will be used for each sample. One sample bottle will contain the untreated or raw sample. This sample will be used for analysis of acidity, alkalinity, sulfate, and chloride. A second sample bottle will be treated with nitric acid to keep metals that might otherwise precipitate in solution. This sample will be used for analysis of total - iron, manganese, aluminum, magnesium, calcium, potassium, and sodium. The third sample bottle will be filtered with a 45 micron filter and treated with nitric acid. This sample will be used to analyze for total dissolved solids, and dissolved - iron, manganese, and aluminum. The samples will be placed on ice and transported to the laboratory on the same day they are collected for analysis.

### Biological Monitoring

Aquatic macroinvertebrates are to be collected in spring by a series of four one-quarter meter kick net samples per station, along with one triangular kick-net sweep to cover all habitat types in the sample area. All whole samples are to be picked in the field, stored in 70% ethanol, in new, clean, glass bottles, and returned to the DAML Frankfort office for sorting and identification to the lowest possible taxon. After sorting and identification, the data will be evaluated using the modified Hilsenhoff Biotic Index (HBI) (Lenat, 1993) to determine the overall pollution tolerance of the macroinvertebrate community and the degree to which the habitat is impaired. Other metrics to be used include the Total Number of Individuals, Ephemeroptera/Plecoptera/Trichoptera Richness (EPT), and Percent Dominant Taxon. Personnel from KY DAML will process macroinvertebrate samples, with aid and advice from cooperating outside sources as necessary. As such, no contracted services will be utilized for sample identification and data analysis.

### Soil/Refuse Monitoring

The coal processing refuse will be sampled by the project agronomist at various locations in the project area as determined by the project agronomist. Any areas that have noticeably different soil properties will be sampled and analyzed as separate samples. The soil/refuse samples will be collected in new, clean, labeled plastic bags. The samples will be delivered to the laboratory on the same day they are collected.

## Sample Handling and Custody

### Water Monitoring

Water monitoring samples will be collected, labeled, preserved with a 1:1 nitric acid solution, placed on ice in a cooler and delivered to the laboratory on the same day collected with the following information:

- Date the sample was taken.
- Station at which the sample was taken.
- Name of the person conducting the sampling.
- Gear and/or method used to obtain the sample.
- General stream conditions at the time of sampling (high or low flow, turbid or clear, etc).
- pH.
- Conductivity.
- Stream Flow.

#### Chain of Custody Procedures

KY DAML personnel will conduct sampling for this project. Chain of custody will be maintained using the KY DAML Water Analysis Worksheet / Chain of Custody form, which is attached.

### Biological Monitoring

Samples taken in the field shall be labeled with the following information:
- Date the sample was taken.
- Station at which the sample was taken.
- Name of the person conducting the sampling.
- Gear and/or method used to obtain the sample.
- General stream conditions at the time of sampling (high or low flow, turbid or clear, etc).
- Water temperature.
- pH
- Conductivity.
- Weather.

Macroinvertebrate samples will be collected, processed, and preserved using a 70% ethanol solution. The samples will be transported by the project biologist to the central office and analyzed by qualified AML personnel.

**Chain of Custody Procedures**

KY DAML personnel will conduct biological sampling and analysis for this project. The project Biologist shall maintain custody of the biological samples. If it becomes necessary to remand custody of the samples the chain of custody will be maintained using the KY DAML Water Analysis Worksheet / Chain of Custody form, which is attached.

## Soil/Refuse Monitoring

Soil/refuse samples taken in the field will be labeled with the following information:
- Date the sample was taken.
- Station at which the sample was taken.
- Name of the person conducting the sampling.
- Gear and/or method used to obtain the sample.

Soil/refuse samples will be collected by AML personnel and taken to and analyzed by a qualified independent laboratory.

**Chain of Custody Procedures**

KY DAML personnel will conduct sampling for this project. Chain of custody will be maintained using the KY DAML Water Analysis Worksheet / Chain of Custody form, which is attached.

# Analytical Methods

## Water Monitoring

McCoy and McCoy Laboratories in Madisonville, Kentucky will analyze the water monitoring samples. Water samples taken in the field shall be labeled, preserved with a 1:1 nitric acid solution, placed on ice in a cooler and delivered to the laboratory on the same day they are collected. All holding times for lab analysis are greater than 24 hours.

Methods of analysis are:

| Parameter | Analyzed By | Method |
|---|---|---|
| Flow | Field | Flow meter/Volumetric |
| pH | Field/Lab | SM 4500-A |

| | | |
|---|---|---|
| Specific Conductance | Field/Lab | SM 2510 |
| Alkalinity | Lab | SM 2320 B |
| Acidity | Lab | EPA 305.1 |
| Total Dissolved Solids | Lab | SM 2540 |
| Calcium (total) | Lab | EPA 200.7 |
| Aluminum (total) | Lab | EPA 200.8 |
| Aluminum (dissolved) | Lab | EPA 200.8 |
| Iron (total) | Lab | EPA 200.8 |
| Iron (dissolved) | Lab | EPA 200.8 |
| Manganese (total) | Lab | EPA 200.8 |
| Manganese (dissolved) | Lab | EPA 200.8 |
| Sulfate | Lab | EPA 300.1 |
| Chloride | Lab | EPA 300.1 |
| Sodium | Lab | EPA 200.7 |
| Potassium | Lab | EPA 200.7 |
| Magnesium | Lab | EPA 200.7 |

Laboratory Analytical Methods are covered in *McCoy & McCoy Laboratories, Inc. - Quality Assurance Program Plan*, attached.

## Biological Monitoring

All whole samples are to be picked in the field, stored in 70% ethanol, and returned to the DAML Frankfort office for sorting and identification to the lowest possible taxon. After sorting and identification, the data will be evaluated using the modified Hilsenhoff Biotic Index (HBI) (Lenat, 1993) to determine the overall pollution tolerance of the macroinvertebrate community and the degree to which the habitat is impaired. Other metrics to be used includes the Total Number of Individuals, Ephemeroptera/Plecoptera/Trichoptera Richness (EPT), and Percent Dominant Taxon.

## Soil/Refuse Monitoring

McCoy and McCoy Laboratories in Madisonville, Kentucky will analyze the soil/refuse samples. The AML agronomist will conduct all soil/refuse sampling for this project. The results will be forwarded to the AML agronomist for interpretation. All holding times for laboratory analysis are greater than 24 hours. The methods of analysis are:

| Parameter | Analyzed By | Method |
|---|---|---|
| pH, Soil | Lab | 9045 |
| Potential Acidity | Lab | EPA 60027805 |
| Phosphorus, Available | Lab | Mehlich 3 |
| Potassium, Available | Lab | Mehlich 3 |
| pH, Buffer | Lab | SMP |

Laboratory Analytical Methods are covered in *McCoy & McCoy Laboratories, Inc. - Quality Assurance Program Plan*, attached.

# Quality Control Procedures
## Water Monitoring

Quality control procedures for parameters analyzed by McCoy and McCoy will follow the procedures outlined in *Quality Assurance Program Plan* – McCoy and McCoy Laboratories Inc., Madisonville, KY (attached).

## Biological Monitoring

Equipment used in biological monitoring will be decontaminated by rinsing in clean water or, in the case of pH and conductivity meters, rinsed with distilled water with a final rinse using the water being sampled. Conductivity meters and pH meters will be calibrated with known calibration solutions prior to each sampling session, and be re-calibrated periodically. Organisms collected from each sample at each sampling station will be collected in a new container. Quality control for biological samples will be provided by replicate samples at each station, and by ensuring that all habitat types at each station are sampled. Variance in organisms and numbers of organisms between sampling stations and trips will reflect improvement or degradation of water quality. In order to explain such variance, factors such as variations in flow from portals and coal waste, weather, and life cycles of aquatic insects will be considered and investigated. Species identification of collected organisms will be cross-checked and verified by outside experts such as DOW and/or Kentucky State Nature Preserves Commission, as necessary.

## Soil/Refuse Monitoring

The RUSLE model will rely on before and after site surveys conducted by a licensed surveyor. The resulting cross sections will be used by an AML engineer for inclusion into the RUSLE model for the project area.

Quality control procedures for parameters analyzed by McCoy and McCoy will follow the procedures outlined in *Quality Assurance Program Plan* – McCoy and McCoy Laboratories Inc., Madisonville, KY (attached).

# Instrument/Equipment Testing, Inspection, and Maintenance

Instrument/Equipment Testing, Inspection, and Maintenance procedures for the laboratory analysis is included in the *Quality Assurance Program Plan* - McCoy and McCoy Laboratories Inc., Madisonville, KY (attached).

# Instrument/Equipment Calibration and Frequency

Instrument/Equipment Calibration and Frequency procedures for the laboratory analysis is included in the *Quality Assurance Program Plan* - McCoy and McCoy Laboratories Inc., Madisonville, KY (attached).

# Inspection/Acceptance of Supplies and Consumables

Inspection/Acceptance of Supplies and Consumables procedures for the laboratory analysis is included in the *Quality Assurance Program Plan* - McCoy and McCoy Laboratories Inc., Madisonville, KY (attached).

# Non-direct Measurements

No non-direct measurement techniques will be used on this project.

# Data Management

## Water Monitoring

Forms used for reporting the results of data analysis for water samples will contain the following information:

- The site of the sampling station, including:
  - Name of County.
  - Name of stream.
- A unique sample identifier, which will include:
  - Sampling station ID number.
  - Date the sample was taken.
- Name and agency of the individual who took the sample.
- The results of the analysis.

AML will report the results of data analysis to DOW for entry into their database. The data will be compiled and recorded in Microsoft Excel, and will be reported to DOW in both software and hardcopy. Each sampling date at each site will be reported on a separate page. The DOW database will be the primary repository for this information. Data analysis including graphs and/or statistical analysis will be reported to DOW in the project's final report.

## Biological Monitoring

Forms used for reporting the results of data analysis for biological samples will contain the following information:

- The site of the sampling station, including:
  - Name of County.
  - Name of stream.
- A unique sample identifier, which will include:
  - Sampling station ID number.
  - Date the sample was taken.
- Name and agency of the individual who took the sample.
- The results of the analysis, including:
  - Taxonomy and number of individuals of each organism identified
  - Summary of HBI or IBI calculation
  - Results of HBI or IBI calculation
  - For macroinvertebrate samples, the HBI tolerance value of each organism identified.

AML will report the results of data analysis to DOW for entry into their database, including the raw data as well as the conclusions of all indices used. The data will be compiled and recorded in Microsoft Excel, and will be reported to DOW in both software and hardcopy. Each sampling date at each site will be reported on a separate page. Each organism will be reported on a separate line, including order, family, genus, species and number encountered. The DOW database will be the primary repository for this information.

### Soil/Refuse Monitoring

Forms used for reporting the results of data analysis for soil/refuse samples will contain the following information:

- The site of the sampling station, including:
  - Name of County.
  - Name of stream.
- A unique sample identifier, which will include:
  - Sampling station ID number.
  - Date the sample was taken.
- Name and agency of the individual who took the sample.
- The results of the analysis.

AML will report the results of data analysis to DOW for entry into their database. The data will be compiled and recorded in Microsoft Excel, and will be reported to DOW in both software and hardcopy. Each sampling date at each site will be reported on a separate page. The DOW database will be the primary repository for this information. Data analysis including loading calculations, graphs, RUSLE analysis and results and/or statistical analysis will be reported to DOW in the project's final report.

# ASSESSMENT AND OVERSIGHT

## Assessments and Response Actions

### Water Monitoring

Water monitoring will be conducted monthly. The project manager will review the results of the water monitoring analysis as they are received from the laboratory. Any errors or deficiencies noted during review of the data will be discussed and corrected by the project manager and the laboratory manager.

Laboratory Assessments and Response Actions are covered in *McCoy & McCoy Laboratories, Inc. - Quality Assurance Program Plan*.

### Biological Monitoring

Biological monitoring will be conducted each spring. The project manager will review the results of the biological monitoring as they are received from AML's biologist. Any errors or deficiencies noted during review of the data will be discussed and corrected by the project manager and the biologist.

### Soil/Refuse Monitoring

Soil/refuse monitoring will be conducted prior to construction activities. The project agronomist will review the results of the soil/refuse monitoring analysis as they are received from the laboratory.  Any errors or deficiencies noted during review of the data will be discussed and corrected by the project agronomist and the laboratory manager.

Laboratory Assessments and Response Actions are covered in *McCoy & McCoy Laboratories, Inc. - Quality Assurance Program Plan*.

**Construction Activities**

Construction activities will be monitored daily by an AML inspector.  The AML Construction Branch Manager, the AML Project Manager, and the AML Regional Office Supervisor will make periodic visits to the site during construction.  The inspector will handle problems or deficiencies during construction.   The Construction Branch Manager will make any changes or deviations from the original plans that are necessary due to site conditions.  Monthly meetings will be conducted with the contractor to discuss the progress to date and invoicing.

## Reports to Management

Daily inspection reports for construction activities will be submitted by the Resident Inspector to the Regional Office Supervisor.  The Regional Office Supervisor, upon approval, will forward the daily inspection reports to the Construction Branch Manager at the Frankfort central office for review.  Monthly invoices will be reviewed and approved by the inspector, Regional Office Supervisor, Construction Branch Manager, and the Division Director before submittal for payment.  Monthly status reports will be prepared by the Construction Branch Manager and submitted to the Division Director.

# DATA VALIDATION AND USABILITY

## Data Review, Verification, and Validation

Water monitoring data will be checked by the project manager for cation - anion balance and total dissolved solids will be compared to specific conductance to check that it falls within the calculated range.  If the data falls within the acceptable range the data will be accepted.  If the data falls out of the acceptable range the data will be rejected.

Laboratory Data Review, Verification, and Validation are covered in *McCoy & McCoy Laboratories, Inc. - Quality Assurance Program Plan*, attached.

## Verification and Validation Methods

The project manager will receive the laboratory analysis data sheets from the laboratory. The analysis will be checked by the project manager for cation - anion balance and the total dissolved solids will be compared to the calculated range using the specific conductance values obtained in the field.  If the data falls within the acceptable range of 20% or less for the cation - anion balance and the total dissolved solids are between 0.55 and 0.75 of the specific conductance the data will be entered into an Excel spreadsheet.

Laboratory Verification and Validation Methods are covered in *McCoy & McCoy Laboratories, Inc. - Quality Assurance Program Plan*, attached.

## Reconciliation with User Requirements

Once the project manager accepts the data the data will be analyzed by graphical and/or statistical methods to document any improvements in water quality post construction. Pre-construction biological monitoring will be compared to post-construction biological monitoring to document changes in the aquatic organisms due to improvements in stream quality. Final results will be compiled and documented in the project final report to be submitted to the Division of Water.

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## APPENDIX D. BMP IMPLEMENTATION PLAN

# BEST MANAGEMENT PRACTICES IMPLEMENTATION PLAN
# for
# HOMESTEAD RECLAMATION: PLEASANT RUN CLEAN WATER ACTION PLAN PROJECT

## Nonpoint Source Acid Runoff Pollution at the Homestead Refuse Disposal Site


**Prepared by**

**Mark Carew – Geologist**

**KENTUCKY DIVISION OF ABANDONED MINE LANDS**


**May, 2003**

# Best Management Practice (BMP) Implementation

The Homestead Refuse Reclamation project area selected for BMP implementation is located along a ridgeline that separates the Pleasant Run and Fox Run watersheds. This site was originally mined from the 1940's through 1958 and is a pre law-mining site.

The proposed project (37 ha (92 acres)) will reclaim an expanse of abandoned strip and deep mine disturbance in southern Hopkins County, approximately 1.6 km (1.0 mi) northeast of the community of Saint Charles. The project encompasses nine reclamation sites (Main site, sites A-H) intermingled with two borrow areas. The nine sites (25 ha (62 acres)) contain pit and ridge formations of severely eroded acidic spoil piles mixed with coal refuse. The Main site and sites C, and E contain wet-weather/seasonal water-holding areas.

Sediment and erosion from all sites cause infertile deposition, channel filling, and increased swamping of the floodplain. Consequential water quality degradation renders much of the water within the Fox Run, Cany Creek, and Pleasant Run watershed basins to not meet designated aquatic life uses, as well as, public, industrial, and domestic use.

Construction at the main site, a ridge-top coal-refuse fill, and site A, a hillside coal-refuse fill, includes heavy gradework to eliminate large and small gullies and to redirect drainage patterns. Construction at sites B, C, D, and E, coal refuse fills within abandoned sediment structures, and sites F, G, and H, eroding hillsides of coal refuse and soil, includes light gradework to eliminate gullies and to provide a smooth surface for positive drainage. Prior to grading the main site and sites C, and E, water from four wet-weather/seasonal water-holding areas will be treated and released, as needed.

To minimize acid mine drainage and to present a medium capable of supporting vegetation, the graded coal refuse will be capped with an agricultural limestone barrier covered by a minimum of two feet of suitable cover material. A maximum of 12.1 ha (30 acres) will be used within 35.6 ha (88 acres) designated as borrow area. This will minimize surface disturbance and ensure vegetation establishment by allowing the best and most abundant cover material to be located. The cover material consists of ridges of mine spoil vegetated with volunteer trees and scrub. Sufficient cover material will remain within the borrow areas to provide adequate cover for these areas once cover material excavation (sites Main, A-H) is complete. Based on additional soil testing, some areas within sites F, G, and H may not require grading or covering with borrow material.

Except for site A in the head of Fox Run, grading will not disturb any blue-line streams as depicted on the Saint Charles 7.5-minute USGS Quadrangle map. Due to heavy erosion and sedimentation of mine spoil/refuse at site A, the stream channel has already shifted 300 ft to the west. The old channel is no longer discernable and proposed grading will not disturb the existing channel. Channel restoration will not be proposed at this time due to the overwhelming AMD impacts to the area. As AMD impacts are reclaimed, channel restoration activities will be investigated.

Rock, temporarily placed in one location of Pleasant Run and one location of Fox Run, will substitute for bridges and will allow heavy equipment to access the project site. Since these streams are severely impacted by acid mine drainage and sedimentation, the limestone stream crossings should help improve water quality.

Ditches lined with class II/III stone or erosion control blanket will control drainage. Installation and maintenance of hay-bale silt checks and silt traps will minimize sedimentation. All areas disturbed by construction will be covered with suitable cover material and vegetated, as soon as practical, using agricultural limestone, fertilizer, seed, mulch, crimping, and, on steep slopes, netting. All applicable environmental permits will be obtained.

The total estimated cost to reclaim the sites including CWAP funds and non-federal funds is $1,812,415.

## BMP Technologies to be Installed

### Refuse Grading, Treatment, and Revegetation

**The Pleasant Run Clean Water Action Plan project will involve the reclamation of areas containing acidic mine refuse with sparse vegetation at the Main site and sites A, B, C, D, E, F, G, and H. Sites B, C, D, and E include coal refuse fills within abandoned sediment structures.**

**The acidic impoundments and wet weather/seasonal water holding areas will be eliminated. The water will be treated before discharging. The impoundments will be graded to provide positive drainage and will be revegetated. The areas containing acidic mine refuse with sparse vegetation will be graded eliminating gullies and providing positive drainage. The graded coal refuse will be capped with an agricultural limestone barrier and covered with a minimum of two feet of suitable cover material.**

**Revegetation efforts will improve the vegetation of the site reducing the sediment load to the stream. The refuse area with sparse vegetation will be seeded with a mix of acid tolerant warm and cool season grasses and legumes. Trees will be planted on the borrow and riparian areas. Bare root stock trees will be planted on the upland borrow areas and live cuttings/live stakes will be planted along the riparian areas. A combination of native grasses and trees and non-native grasses and legumes will be used in the revegetation efforts on the project. While the use of native grasses and trees is preferred, it has been the experience of the Division of Abandoned Mine Lands that a combination of native and non-native species is required for successful revegetation of acidic coal mine refuse. The proposed seed mixture is:**

| Seed Mixture | Seeding Rate (Lb./ac. PLS*) |
| --- | --- |

SPRING SEED MIX

Application Period: February 15 to June 15

| | |
|---|---|
| Orchardgrass | 20 |
| Switchgrass | 10 |
| Redtop | 5 |
| Timothy | 10 |
| Birdsfoot Trefoil | 10 |
| Korean Lespedeza (Hulled) | 10 |
| Medium Red Clover | 10 |
| Ladino Clover | 5 |
| | (80 LBS.) |

SUMMER SEED MIX

Application Period: June 16 to August 14

| | |
|---|---|
| German Foxtail Millet | 15 |
| Switchgrass | 10 |
| Orchardgrass | 10 |
| Deere tounge | 10 |
| Timothy | 10 |
| Korean Lespedeza | 10 |
| Medium Red Clover | 10 |
| Ladino Clover | 5 |
| | (80 LBS.) |

FALL SEED MIX

Application Period: August 15 to February 14

| | |
|---|---|
| Eastern Gammagrass | 20 |
| Switchgrass | 10 |
| Orchardgrass | 10 |
| Timothy | 10 |
| Redtop | 5 |
| Ladino Clover | 5 |
| Medium Red Clover | 10 |
| Birdsfoot Trefoil | 5 |
| Korean Lespedeza | 5 |
| | (80 LBS.) |

The proposed tree species are:

| | |
|---|---|
| Crabapple | 50 each |
| Hawthorne | 50 each |
| Sawtooth Oak | 50 each |
| Persimmon | 50 each |
| Wild Plum | 50 each |
| Cherrybark Oak | 50 each |
| | (300/acre) |

Cuttings for the riparian zone are:

Willow cuttings

Cottonwood cuttings

Seedlings for the riparian zone are:

Sycamore
Green Ash
Bald Cypress

**The Revised Universal Soil Loss Equation and refuse sample analysis will be used to calculate the reduction in silt loading and acid loading by direct washing of the acidic refuse into the streams after completion of the reclamation.**

**The construction cost of grading the refuse, installation of the agricultural limestone barrier, trash/debris disposal, placing soil cover material, liming, and revegetation, including tree planting, at the sites is estimated to be $ 1,130,679.**

## Diversion Ditches

**Surface drainage will be controlled by grass diversion ditches, open limestone channels, and cut in rock ditches. The estimated cost to construct all of the diversion ditches on the project is $576,236.**

### *Grass Diversion Ditches*

**Grass diversion ditches will be installed along the benches. The grass diversion ditches will be lined with erosion control blanket. The erosion control blanket protects the diversion ditch from erosion while the grass is being established in the channel. The estimated construction cost to install the grass diversion ditches on the project is $ 63,980.**

### *Cut In Rock Ditches*

**Cut in rock ditches will be installed in locations where in situ rock is exposed in the diversion ditch channel. A hoe ram will be used to excavate the channel in the rock. The estimated construction cost to install the cut in rock ditches on the project is $ 4,000.**

*Open Limestone Channels*

**Open limestone channels will be constructed with limestone rock and limestone sand and in addition to providing erosion control will treat acid mine drainage before entering the streams. The limestone channels will intercept acidic water from the upper slopes of the refuse fill areas and from seeps providing treatment by increasing alkalinity to the water before discharging into the main tributaries. Open limestone channels will be installed as side drains and terrace diversion channels on the re-graded refuse slopes.**

**Open limestone channels (OLCs) introduce alkalinity to acid water in open channels or ditches lined with limestone rock (Ziemkiewicz et al., 1994). Acid water is introduced to the channel and the acid mine drainage is treated by limestone dissolution. Past assumptions have held that armored limestone (limestone coated with Fe and/or Al hydroxides) ceased to dissolve, but experiments show that coated limestone continues to dissolve at about 20% the rates of unarmored limestone (Pearson and McDonnell 1975). Another problem is that hydroxides tend to settle into and plug the voids in limestone beds forcing water to move around rather than through the limestone. While both armoring and plugging are caused by the precipitation of metal hydroxides they are two different problems. Maintaining a high flushing rate through the limestone bed can minimize plugging of the voids in limestone beds. Armoring, however, occurs regardless of the water velocity. Recent work has demonstrated that the rate of dissolution for armored limestone may be even higher than previous laboratory studies (Ziemkiewicz et al., 1997). Field experiments show considerable treatment by OLCs (Ziemkiewicz et al., 1994). The length of channel and the channel gradient are design factors that can be varied for optimum performance. Optimum performance is attained on slopes exceeding 20%, where flow velocities keep precipitates in suspension, and clean precipitates from limestone surfaces. Dissolved metals sorb onto the surfaces of the precipitates in suspension further reducing the amount of dissolved metals in the water. Open limestone channels may be designed and constructed**

**for long term treatment. Utilizing OLCs with other passive systems can maximize treatment and metal removal. The estimated construction cost to install the open limestone channels is $ 508,256.**

### Silt Control

**BMPs for silt control during construction activities includes staking of silt control bales at the toe of the slopes and above diversions and temporary and/or permanent water diversions. Dug out silt control structures will be used during all construction activities. The estimated cost to install silt control bales and dug out silt control structures is**
**$ 36,200.**

### Access Roads

**Access roads in the project area will be graded and ditched. Water bars may be installed as needed on long steep grades. Culverts will be installed as needed to direct water from road ditch-lines into diversion ditches and/or natural drains. Temporary low water crossings will be installed using limestone riprap at two locations. Roadstone will be applied to access road surfaces to protect the roadbed from erosion. The estimated cost to improve and maintain access roads in the project area is $69,300.**

## Alternative Treatment Options

### Active Treatment Technologies

**Active treatment systems involve treating mine drainage with alkaline chemicals to neutralize acidity, raise water pH, and precipitate metals. Active treatment technologies are effective, however, when the cost of equipment, chemicals, and manpower are considered active treatment is expensive (Skousen et al. 1990). Chemical treatment is a long term never ending process. A variety of active treatment methods can be employed. Most active chemical treatment systems consist of an inflow pipe or ditch, a storage tank or bin to hold the chemical, a means of controlling the chemical**

**application, a settling pond to capture precipitated metal oxyhydroxides, and a discharge point. Chemical compounds used in AMD treatment include:**

**Crushed limestone – rotating drum**
**Hydrated lime**
**Sodium carbonate (soda ash)**
**Sodium hydroxide (solid and liquid forms)**
**Ammonia**
**Pebble Quicklime (Calcium oxide).**

**The above treatment options could possibly be used on the refuse sites. The flow at the toe of the refuse areas would have to be intercepted and directed to a central application site. The treated water would then flow into a settling pond before being discharged into the stream. The costs for construction of an active treatment site and the continuous operation and maintenance of an active treatment site are prohibitive at current funding levels. In addition many of the active treatment options use chemicals that are harmful to biota in their concentrated state. The risk of release of these chemicals in concentrated form by vandalism or accident must be considered before deciding to use them.**

Passive Treatment Options

*Aerobic Wetland*

**An aerobic wetland consists of a large surface area pond with horizontal surface flow. The pond may be planted with cattails and other wetland species. Aerobic wetlands can only effectively treat water that is net alkaline. In aerobic wetland systems, metals are precipitated through oxidation reactions to form oxides and hydroxides.**

**Aerobic wetlands are not suitable for the refuse sites. The water discharging from the sites is net acidic.**

*Compost / Anaerobic Wetland*

**Compost wetlands, sometimes called anaerobic wetlands, consist of a large pond with a lower layer of organic substrate. The flow is horizontal through the substrate layer of the pond. The compost layer usually contains calcium carbonate either naturally as in spent mushroom compost, or added during construction of the wetland. A typical compost wetland will have 12 to 24 inches of organic substrate and be planted with cattails or other wetland vegetation. The vegetation helps stabilize the substrate and provides additional organic matter to perpetuate the sulfate reduction reactions. Compost wetlands can treat discharges that contain dissolved oxygen, ferric iron, aluminum, or acidity in the 500 ppm range.**

**The compost wetland acts as a reducing environment. The compost removes oxygen from the system. Microbial processes within the organic substrate reduce sulfates to water and hydrogen sulfide. The anoxic environment within the substrate increases the dissolution of limestone. Chemical and microbial processes generate alkalinity and increase the pH.**

**The refuse sites may be suitable for compost wetlands. The flow from the refuse would need to be intercepted and directed to the wetlands at the toe of the slopes. Compost wetlands are relatively expensive to construct. This project is concentrating on grading and revegetating barren areas of refuse. Revegetation of the refuse slopes needs to occur before the installation of compost wetlands is considered. Budget constraints do not allow the installation of compost wetlands on the project area at this time.**

*Anoxic Limestone Drains*

**An anoxic limestone drain (ALD) is a buried bed of limestone constructed to intercept subsurface mine water and prevent contact with atmospheric oxygen. Keeping the water anoxic prevents oxidation of metals and prevents armoring of the limestone. The process of limestone dissolution generates alkalinity. The purpose of an ALD is to provide alkalinity thereby changing net acidic water to**

**net alkaline water. ALDs are limited to the amount of alkalinity they can generate based on solubility equilibrium reactions. An ALD is a pretreatment step to increase alkalinity and raise pH before the water is oxidized and the metals precipitated in an aerobic wetland.**

**This project involves acidic refuse material placed on a slope. The water leaving the site has already been oxidized so the use of an ALD on the refuse sites is not possible.**

*Vertical Flow Reactors*

**Vertical flow reactors were conceived as a way to overcome the alkalinity generation limitations of an anoxic limestone drain and the large area requirements for compost wetlands. The vertical flow reactor consists of a treatment cell with a limestone underdrain topped with an organic substrate and standing water. The water flows vertically through the organic substrate that strips the oxygen from the water making it anoxic. The water then passes through the limestone, which dissolves increasing alkalinity. The water is discharged through a pipe with an air trap to prevent oxygen from entering the treatment cell. Highly acidic water can be treated by passing the water through a series of treatment cells. A settling pond and an aerobic wetland where metals are oxidized and precipitated typically follow the treatment cells.**

**Problems associated with vertical flow reactors include plugging of the pipes with aluminum which must be periodically flushed when aluminum loading is high, and precipitation of metals in the organic substrate which may clog, preventing flow into the limestone underdrain.**

**The refuse sites may be suitable for vertical flow reactors. It may prove difficult to intercept all of the acidic water flowing through the refuse and direct it to the treatment cells. Aluminum levels would need to be measured at all sites being considered for the installation of vertical flow wetlands due to clogging concerns with the pipes and limestone underdrains.**

**The Division of Abandoned Mine Lands has designed a modified vertical flow wetland. This design is being included in the plans for this project as an optional component of acid mine drainage treatment on the project. The decision on whether to install vertical flow wetlands on the project will be made during construction of the project based on the water chemistry after treatment by the open limestone channels. Future maintenance concerns including removal of precipitates from the wetland cells dictates that vertical flow systems only be installed when no other option is applicable.**

## Other Options

**Other options include removal of the pyrite-rich refuse, mixing the refuse with agricultural limestone and placing it in a compacted fill. This option is expensive and current funding levels are not adequate for consideration of this option. The estimated cost for this option is in excess of ten million dollars for the refuse sites.**

**Other options also include doing nothing. The acid mine drainage and silt will continue to erode unabated into the streams impacting fish and other aquatic life downstream from the site.**

### DOW – NPS Notification

**The Division of Water Non-Point Source Section will be contacted and kept informed of the BMP implementation by e-mail. DOW personnel will be invited to attend the pre-bid meeting and pre-construction conference. Anticipated start dates will be discussed at the pre-construction conference.**

## Technology Demonstration Financial Plan of Action

## Educational Activities

The Homestead Refuse Reclamation: Pleasant Run Clean Water Action Plan Project will provide an opportunity for education and outreach. By presenting the project at professional meetings issues such as the importance of clean water, acid mine drainage abatement techniques, and the availability of programs involved with environmental restoration will be highlighted.

The Division of Abandoned Mine Lands will present the Homestead Refuse Reclamation: Pleasant Run Clean Water Action Plan Project and results at the Non-Point Source conference; disseminating the information and techniques to other environmental restoration professionals. In addition the Division of Abandoned Mine Lands will prepare a poster session of the project and results to be displayed at various conferences and events.

All final draft educational materials produced by this project will be submitted to the Division of Water for review and approval before production and distribution.

## Budget Synopsis

The total budget for the Homestead Refuse Reclamation: Pleasant Run Clean Water Action Plan Project is $ 1,260,477.00. This includes $ 756,286.00 in CWAP funds and $ 504,191.00 in funds from non-federal matching sources. This equates to a 60/40 cost share between federal and non-federal matching funds for the project. The Kentucky Division of Abandoned Mine Lands may provide additional funds for construction activities on the project to meet the estimated $ 1,812,415.00 total cost of the project.

CWAP funds will be used for BMP implementation in the Pleasant Run Watershed. The non-federal match funds provided by the Kentucky Division of Abandoned Mine Lands will be used for BMP implementation in the Fox Run Watershed and the Pleasant Run Watershed.

## Maintenance Agreement

**The Division of Abandoned Mine Lands continues to monitor all project sites annually for a period of 5 years after the final inspection of the project. All project sites are inspected annually by AML's staff agronomist or his representative. In addition AML responds to any complaints received for maintenance on its project sites. Any maintenance required will be performed under a separate maintenance contract. The Division of Abandoned Mine Lands as part of its annual grants from the Office of Surface Mining budgets a portion of the annual grant for maintenance of reclamation projects completed by AML. Funds for any maintenance work required will be made available through AML's annual grant from OSM. This is standard operating procedure for all AML projects. After the 5-year monitoring period by AML maintenance of the project sites will be performed based on AML's project priority policies.**

## References Cited

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**Skousen, J., K. Politan, T. Hilton, and A. Meek, 1990. Acid mine drainage treatment systems: chemicals and costs. Green Lands 20(4): 31-37.**

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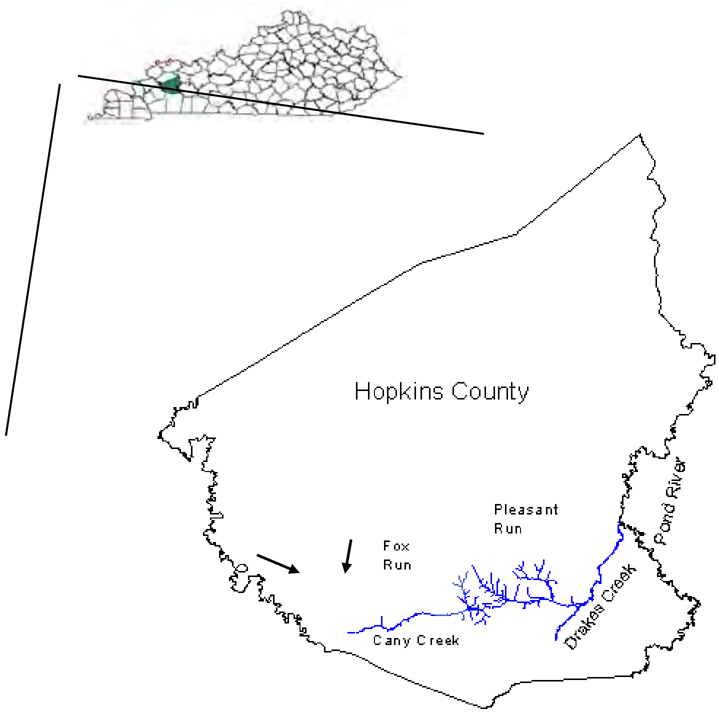
**Ziemkiewicz, P.F., J.G. Skousen, D.L. Brant, P.L. Sterner, and R.J. Lovett, 1997. Acid mine drainage treatment with armored limestone in open limestone channels. J. Environ. Qual. 26:560-569.**

**APPENDIX D. EPA FIELD DAY BROCHURE**




Location of Hopkins County, Pleasant Run, and Fox Run

**As shown above, the Homestead Refuse Reclamation Project is located in southern Hopkins County. This site was originally mined in the 1940's through the late 1950's. The large areas of spoil and refuse mark the location of the wasting area used by the coal company while this site was being actively mined. The Homestead Reclamation Project is a pre law-mining site. The property on which this site is located is now privately owned and is used as a recreational hunting area.**

**There are two watersheds contained within the project boundaries, Pleasant Run and Fox Run. According to the 1998 303(d) list of waters for Kentucky (KDOW 1998), the 12.7 km long mainstem of Pleasant Run does not meet its designated use for contact recreation and for aquatic life because of extremely acidic waters. The Division of Water cites acid mine drainage as the primary source of the pH impairment. Acid mine drainage also influences the pH levels of Fox Run. Also contained within the project area is one main reclamation site and eight smaller satellite**

**sites. These sites mainly consist of piles of acidic spoil and coal refuse that have eroded to form a network of pits and ridges. Multiple water impoundments and two soil borrow areas are also included within the construction boundaries.**

**The reclamation of this area includes of re-grading the existing terrain, applying an agricultural lime barrier on the regraded surface, covering everything with a layer of soil, and finally reseeding the land. The amount of regrading required is determined by the current topography. The main reclamation site will require heavy gradework while most of the smaller sites will require much lighter grading.**

**Both heavy and light gradework include the removal of all gullies and creating a smooth surface for revegetation. In addition to this, heavy gradework also includes redirecting drainage patterns. Approximately 100 tons of agricultural lime will then be applied to every acre reclaimed in order to minimize acid mine drainage and create an environment capable supporting vegetation. A minimum of two feet of soil will be placed on top of the agricultural lime barrier. The soil will be obtained from one of the two borrow sites. Although there are 88.3 acres of land designated as potential cover material harvesting sites, only 30 acres of that may be utilized. This allows the areas with the best and most abundant cover material to be located, thereby minimizing surface area disturbed. Surface ditches lined with Class II/III channel lining will be placed where necessary to facilitate proper surface water drainage and to help increase the pH of surface water runoff. Last, the 61.8 acres of reclaimed land and the 30 acres of land disturbed for soil harvesting will be seeded. Silt traps and hay bales will also be installed where necessary for the control of silt and erosion during construction of the project.**

**During the reclamation process, there will be no gradework within 25 feet of any blue line stream with the exception of a 400 foot section of Fox Run on the northern part of the project and a 250 foot section of Pleasant Run that is currently flowing through**

**a culvert in the northeastern portion of the project. The original stream channel has shifted approximately 300 feet to the west as a result of heavy mine spoil and refuse sedimentation. The flow pattern of this small section may be changed to match the original channel.**

**Aside from the visual improvement of the area, one result that the completion of this reclamation project will have on the surrounding environment is the improvement of the water quality entering the two previously mentioned blue line streams, Pleasant Run and Fox Run. Currently, any water that falls on the refuse piles slowly filters through or flows across the spoil before reaching either stream. By the time this water reaches the streams it has a very low pH and contains large amounts of dissolved metals. With the application of the agricultural lime barrier and use of surface ditches containing Class II/III lining material, the quality of the water flowing to the streams will be improved. In addition to improved water quality, infertile deposition, increased swamping of the floodplain, and channel filling - all caused by sedimentation and erosion - will be greatly reduced. The use of hay-bale silt checks and silt traps will minimize sedimentation while the revegetation of all disturbed areas will help control erosion.**

**Upon completion of the Homestead Reclamation Project, approximately 61.8 acres of refuse will be reclaimed. In addition to this, the water in multiple impoundments will be treated and released. The preliminary total estimate for the Homestead Reclamation Project is approximately $1.35 million.**

*This work was funded in part by a grant from the U.S. Environmental Protection Agency under §319(h) of the Clean Water Act through the Kentucky Division of Water to the Kentucky Division of Abandoned Mine Lands. The non-federal match is being provided through the Kentucky Abandoned Mine Land program.*

**APPENDIX E.  NEWSPAPER ARTICLE**

SUNDAY LIFESTYLES

C

# Reclaiming Homestead

*$1.5 million project seeks to neutralize mining's scars*

# APPENDIX F. LABORATORY DATA

Site PR 1 - Pleasant Run Above Reclamation

**Laboratory results**

| Sampling date | Discharge cfs | pH | Conductivity uS 25C | Alkalinity mg/l CaCO3 | Acidity mg/l CaCO3 | TDS mg/l | Calcium, total, mg/l |
|---|---|---|---|---|---|---|---|
| 1/7/2003 | 0.02 | 4.6 | 1674 | 0 | 136 | 2440 | 344 |
| 1/28/2003 | 0.02 | 4.9 | 2310 | 0 | 118 | 1850 | 242 |
| 2/13/2003 | 0.04 | 4.8 | 1850 | 0 | 266 | 2532 | 337 |
| 3/24/2003 | 0.04 | 3.9 | 2460 | 0 | 601 | 2638 | 422 |
| 4/16/2003 | 0.02 | 5.3 | 2540 | 0 | 215 | 2720 | 453 |
| 5/6/2003 | 0.02 | 5.8 | | 0 | 170 | 2260 | 25.3 |
| 6/26/2003 | 0.17 | 6.2 | 2440 | 47 | 0 | 2860 | 381 |
| 7/22/2003 | 0.20 | 3.1 | 2560 | 0 | 155 | 3081 | 425 |
| 9/4/2003 | 0.12 | 3.6 | 2510 | 0 | 413 | 2540 | 395 |
| 9/26/2003 | 0.12 | 6.4 | 3340 | 55 | 0 | 3430 | 468 |
| 10/24/2003 | 0.00 | 5.3 | 4010 | 150 | 0 | 3900 | 451 |
| 12/8/2003 | 0.19 | 4.6 | 3000 | 0 | 271 | 2903 | 446 |
| 12/30/2003 | 0.27 | 4.7 | 3310 | 15 | 153 | 2708 | 410 |
| 1/29/2004 | 0.29 | 4.7 | 2820 | 9 | 220 | 2555 | 416 |
| 2/26/2004 | 3.20 | 3.2 | 3200 | 45 | 0 | 3076 | 432 |
| 3/29/2004 | 0.03 | 5.5 | 3170 | 54 | 0 | 2868 | 468 |
| 4/30/2004 | 1.23 | 6.7 | 2426 | 57 | 0 | 2461 | 355 |
| 5/28/2004 | 0.69 | 6.3 | 2927 | 73 | 0 | 3126 | 468 |
| 6/30/2004 | 0.62 | 6.8 | 3007 | 85 | 0 | 3204 | 550 |
| 7/28/2004 | 0.55 | 6.8 | 2830 | 128 | 0 | 3566 | 453 |
| 8/17/2004 | 0.00 | 7.7 | 3260 | 85 | 0 | 3966 | 520 |
| 9/27/2004 | 0.00 | | | | | | |
| 10/28/2004 | 0.00 | 7.0 | 1649 | 140 | 0 | 3652 | 433 |
| 11/30/2004 | 0.21 | 5.0 | 1407 | 10 | 260 | 1807 | 306 |

Site PR 1 - Pleasant Run Below Reclamation

**Laboratory results**

| Sampling date | Aluminum, total, mg/l | Aluminum, dis., mg/l | Iron, total mg/l | Iron, dis. mg/l | Manganese total, mg/l | Manganese, dis., mg/l | Sulfate, dis. mg/l |
|---|---|---|---|---|---|---|---|
| 1/7/2003 | 21.0 | 21.0 | 4.0 | 3.4 | 7.2 | 7.1 | 1769 |
| 1/28/2003 | 9.6 | 9.6 | 8.1 | 4.9 | 3.5 | 3.5 | 1286 |
| 2/13/2003 | 24.5 | 24.0 | 6.1 | 6.1 | 8.5 | 8.5 | 2193 |
| 3/24/2003 | 28.4 | 25.7 | 8.5 | 8.1 | 8.3 | 8.6 | 1880 |
| 4/16/2003 | 20.2 | 13.3 | 9.2 | 2.0 | 6.4 | 6.4 | 1939 |
| 5/6/2003 | 15.1 | 18.0 | 8.2 | 0.4 | 4.7 | 6.4 | 1530 |
| 6/26/2003 | 10.4 | 0.1 | 7.1 | 1.1 | 3.5 | 3.8 | 1713 |
| 7/22/2003 | 19.0 | 12.4 | 11.1 | 10.1 | 9.9 | 6.1 | 2023 |
| 9/4/2003 | 17.0 | 15.3 | 11.7 | 11.5 | 10.1 | 11.8 | 1882 |
| 9/26/2003 | 1.0 | 0.1 | 24.1 | 22.2 | 4.9 | 10.6 | 2230 |
| 10/24/2003 | 0.6 | 0.2 | 59.2 | 54.8 | 8.9 | 8.2 | 2690 |
| 12/8/2003 | 17.7 | 15.9 | 6.6 | 6.2 | 10.3 | 9.5 | 1250 |
| 12/30/2003 | 16.9 | 16.6 | 7.7 | 7.2 | 7.9 | 7.8 | 1938 |
| 1/29/2004 | 22.7 | 18.6 | 9.6 | 8.6 | 10.5 | 9.1 | 1700 |
| 2/26/2004 | 4.8 | 4.1 | 7.6 | 6.9 | 7.6 | 7.4 | 2295 |
| 3/29/2004 | 1.7 | 1.6 | 8.1 | 7.8 | 8.3 | 7.5 | 2693 |
| 4/30/2004 | 0.8 | 0.1 | 3.8 | 3.6 | 5.4 | 5.0 | 2197 |
| 5/28/2004 | 0.3 | 0.2 | 18.9 | 15.9 | 6.6 | 5.7 | 2882 |
| 6/30/2004 | 0.1 | 0.0 | 15.9 | 14.6 | 5.6 | 5.1 | 2263 |
| 7/28/2004 | 0.1 | 0.1 | 28.1 | 24.6 | 7.8 | 7.5 | 2310 |
| 8/17/2004 | 0.1 | 0.1 | 20.6 | 0.3 | 10.0 | 9.7 | 2442 |
| 9/27/2004 | | | | | | | |
| 10/28/2004 | 0.0 | 0.0 | 16.1 | 15.6 | 4.4 | 4.1 | 2200 |
| 11/30/2004 | 16.7 | 5.6 | 12.1 | 0.8 | 5.9 | 5.6 | 792 |

Site PR 2 - Pleasant Run Below Reclamation

**Laboratory results**

| Sampling date | Discharge cfs | pH | Conductivity uS 25C | Alkalinity mg/l CaCO3 | Acidity mg/l CaCO3 | TDS mg/l | Calcium, total, mg/l |
|---|---|---|---|---|---|---|---|
| 1/7/2003 | 0.45 | 3.5 | 2470 | 0 | 495 | 2570 | 300 |
| 1/28/2003 | 0.45 | 3.4 | 2870 | 0 | 2870 | 3282 | 393 |
| 2/13/2003 | 0.45 | 3.3 | 2045 | 0 | 2440 | 2840 | 311 |
| 4/23/2003 | 0.45 | 3.4 | 2730 | 0 | 920 | 2880 | 420 |
| 4/16/2003 | 0.45 | 3.6 | 2880 | 0 | 1380 | 3020 | 408 |
| 5/6/2003 | 0.45 | 5.8 | | 0 | 330 | | 18.2 |
| 6/26/2003 | 0.64 | 3.0 | 2840 | 0 | 301 | 3340 | 373 |
| 7/22/2003 | 0.67 | 3.1 | 2580 | 0 | 458 | 2906 | 346 |
| 9/4/2003 | | 3.1 | 2510 | 0 | 681 | 2540 | 309 |
| 9/26/2003 | 0.79 | 7.1 | 3450 | 0 | 1100 | 3160 | 395 |
| 10/24/2003 | 1.58 | 3.1 | 3450 | 0 | 1082 | 3310 | 412 |
| 12/8/2003 | 0.68 | 3.2 | 2900 | 0 | 1188 | 2768 | 371 |
| 12/30/2003 | 0.86 | 3.1 | 3230 | 0 | 642 | 2673 | 360 |
| 1/29/2004 | 1.01 | 3.4 | 3.07 | 0 | 850 | 2528 | 349 |
| 2/26/2004 | 3.32 | 3.4 | 3350 | 0 | 800 | 3015 | 349 |
| 3/29/2004 | 1.26 | 3.1 | 3360 | 0 | 10 | 2865 | 374 |
| 4/30/2004 | 1.98 | 3.2 | 2190 | 0 | 209 | 2144 | 280 |
| 5/28/2004 | 1.12 | 3.0 | 2825 | 0 | 400 | 2894 | 400 |
| 6/30/2004 | 1.21 | 3.0 | 3109 | 0 | 1150 | 3163 | 460 |
| 7/28/2004 | 1.15 | 2.9 | 2777 | 0 | 770 | 3282 | 406 |
| 8/17/2004 | 0.06 | 4.3 | 3050 | 0 | 540 | 3425 | 430 |
| 9/27/2004 | 0.21 | 3.1 | 1680 | 0 | 967 | 3489 | 415 |
| 10/28/2004 | 0.45 | 3.5 | 1048 | 0 | 510 | 2074 | 290 |
| 11/30/2004 | 7.20 | 4.1 | 837 | 10 | 40 | 962 | 157 |
| 12/31/2004 | | | | | | | |
| 1/28/2005 | 2.00 | 3.4 | 2690 | 0 | 480 | 2617 | 377 |
| 2/22/2005 | 0.60 | 3.5 | 2550 | 0 | 440 | 2467 | 353 |
| 3/28/2005 | 7.17 | 4.2 | 1379 | 0 | 140 | 1214 | 195 |
| 4/28/2005 | 0.41 | 3.3 | 2890 | 0 | 700 | 2800 | 404 |
| 5/25/2005 | 0.15 | 3.1 | 3090 | 0 | 1700 | 3140 | 395 |
| 6/21/2005 | 0.09 | 3.0 | 3260 | 0 | 318 | 3252 | 430 |
| 7/27/2005 | 0.08 | 2.9 | 3300 | 0 | 1443 | 3242 | 427 |
| 8/30/2005 | 6.63 | 3.7 | 1334 | 0 | 47 | 850 | 150 |
| 9/27/2005 | 0.09 | 3.0 | 3030 | 0 | 160 | 2672 | 300 |
| 10/27/2005 | 0.06 | 2.9 | 2390 | 0 | 82 | 2731 | 431 |
| 11/30/2005 | 0.25 | 3.0 | 2930 | 0 | 741 | 2888 | 384 |

Site PR 2 - Pleasant Run Below Reclamation

**Laboratory results**

| Sampling date | Aluminum, total, mg/l | Aluminum, dis., mg/l | Iron, total mg/l | Iron, dis. mg/l | Manganese total, mg/l | Manganese, dis., mg/l | Sulfate, dis. mg/l |
|---|---|---|---|---|---|---|---|
| 1/7/2003 | 33.3 | 33.0 | 51.3 | 46.0 | 12.0 | 11.6 | 1888 |
| 1/28/2003 | 40.0 | 40.0 | 81.7 | 90.6 | 15.0 | 15.0 | 2455 |
| 2/13/2003 | 31.2 | 30.0 | 74.0 | 74.0 | 14.0 | 13.9 | 2549 |
| 4/23/2003 | 29.2 | 25.1 | 34.2 | 35.2 | 11.2 | 11.3 | 1980 |
| 4/16/2003 | 31.7 | 29.0 | 63.3 | 59.0 | 13.5 | 13.0 | 1380 |
| 5/6/2003 | 10.7 | 10.2 | 9.9 | 0.6 | 4.4 | 4.7 | 1030 |
| 6/26/2003 | 20.3 | 17.4 | 32.4 | 37.2 | 11.0 | 12.3 | 1939 |
| 7/22/2003 | 20.0 | 14.0 | 25.2 | 25.6 | 9.7 | 10.6 | 1871 |
| 9/4/2003 | 15.0 | 13.2 | 27.6 | 30.5 | 9.8 | 10.4 | 1520 |
| 9/26/2003 | 24.4 | 24.7 | 50.1 | 50.2 | 16.8 | 17.1 | 2098 |
| 10/24/2003 | 28.2 | 28.4 | 53.5 | 38.1 | 18.0 | 18.3 | 2480 |
| 12/8/2003 | 24.0 | 23.1 | 64.0 | 59.4 | 15.6 | 14.5 | 1166 |
| 12/30/2003 | 25.8 | 24.9 | 32.0 | 31.8 | 12.0 | 11.0 | 2446 |
| 1/29/2004 | 26.9 | 24.4 | 63.9 | 59.0 | 12.8 | 12.0 | 1740 |
| 2/26/2004 | 18.8 | 21.5 | 61.5 | 61.2 | 14.0 | 15.7 | 2520 |
| 3/29/2004 | 20.4 | 20.2 | 48.7 | 46.7 | 14.6 | 14.0 | 2737 |
| 4/30/2004 | 12.6 | 10.7 | 25.5 | 22.0 | 7.5 | 6.7 | 2117 |
| 5/28/2004 | 15.6 | 17.3 | 36.1 | 33.0 | 12.6 | 11.6 | 2723 |
| 6/30/2004 | 18.8 | 19.1 | 41.3 | 40.9 | 15.3 | 15.1 | 2315 |
| 7/28/2004 | 18.3 | 16.0 | 43.0 | 35.3 | 14.5 | 13.2 | 2213 |
| 8/17/2004 | 19.9 | 18.7 | 35.5 | 26.2 | 16.1 | 14.9 | 2360 |
| 9/27/2004 | 19.4 | 21.8 | 21.8 | 24.0 | 17.5 | 19.8 | 2272 |
| 10/28/2004 | 11.3 | 11.7 | 9.3 | 8.6 | 9.4 | 10.0 | 1200 |
| 11/30/2004 | 9.6 | 6.2 | 22.8 | 4.6 | 3.5 | 2.8 | 641 |
| 12/31/2004 | | | | | | | |
| 1/28/2005 | 15.4 | 17.0 | 41.0 | 41.5 | 9.0 | 9.4 | 1800 |
| 2/22/2005 | 14.0 | 15.6 | 31.0 | 31.5 | 9.1 | 9.8 | 1600 |
| 3/28/2005 | 8.5 | 6.9 | 12.2 | 8.0 | 3.7 | 4.0 | 860 |
| 4/28/2005 | 16.0 | 18.0 | 35.7 | 38.4 | 10.7 | 12.0 | 1950 |
| 5/25/2005 | 15.7 | 17.9 | 39.0 | 42.9 | 10.3 | 12.7 | 2110 |
| 6/21/2005 | 18.2 | 18.1 | 36.1 | 36.4 | 18.1 | 17.5 | 2450 |
| 7/27/2005 | 20.2 | 21.6 | 29.8 | 34.7 | 17.6 | 21.0 | 2200 |
| 8/30/2005 | 4.6 | 4.5 | 4.8 | 3.8 | 3.1 | 3.1 | 700 |
| 9/27/2005 | 11.2 | 10.7 | 19.2 | 18.0 | 16.2 | 15.5 | 1450 |
| 10/27/2005 | 24.4 | 20.6 | 23.2 | 24.0 | 19.1 | 20.0 | 2300 |
| 11/30/2005 | 30.8 | 20.7 | 33.4 | 33.7 | 20.0 | 20.5 | 2020 |

Site 1 - Fox Run Watershed Below Reclamation

**Laboratory results**

| Sampling date | Discharge cfs | pH | Conductivity uS 25C | Alkalinity mg/l CaCO3 | Acidity mg/l CaCO3 | TDS mg/l | Calcium, total, mg/l |
|---|---|---|---|---|---|---|---|
| 1/7/2003 | 1.11 | 3.5 | 1726 | 0 | 263 | 1610 | 178 |
| 1/28/2003 | 1.11 | 4.9 | 1883 | 0 | 187 | 2804 | 413 |
| 2/13/2003 | 1.11 | 4.8 | 1640 | 0 | 293 | 1574 | 198 |
| 3/24/2003 | 1.11 | 3.6 | 1720 | 0 | 592 | 1688 | 225 |
| 4/16/2003 | 1.11 | 3.9 | 1328 | 0 | 457 | 1670 | 213 |
| 5/6/2003 | 1.11 | 5.8 | | 0 | 370 | | 478 |
| 6/26/2003 | 1.23 | 3.2 | 2030 | 0 | 181 | 2240 | 263 |
| 7/22/2003 | 1.75 | 3.4 | 2010 | 0 | 22 | 2155 | 279 |
| 9/4/2003 | 1.85 | 3.0 | 2510 | 0 | 337 | 2540 | 193 |
| 9/26/2003 | 1.92 | 3.1 | 2530 | 0 | 500 | 2170 | 290 |
| 10/24/2003 | 1.84 | 3.4 | 2510 | 0 | 536 | 2290 | 311 |
| 12/8/2003 | 1.28 | 3.9 | 1780 | 0 | 512 | 1610 | 230 |
| 12/30/2003 | 1.93 | 4.5 | 1580 | 11 | 178 | 1301 | 174 |
| 1/29/2004 | 1.78 | 4.7 | 1.67 | 9 | 195 | 1238 | 184 |
| 2/26/2004 | 2.34 | 4.1 | 2340 | 0 | 550 | 2174 | 261 |
| 3/29/2004 | 2.17 | 3.8 | 2070 | 0 | 17 | 1667 | 228 |
| 4/30/2004 | 2.36 | 3.9 | 1298 | 0 | 629 | 1187 | 144 |
| 5/28/2004 | 1.76 | 4.0 | 1982 | 10 | 7 | 1972 | 271 |
| 6/30/2004 | 1.38 | 3.5 | 2255 | 0 | 20 | 2242 | 370 |
| 7/28/2004 | 1.25 | 3.3 | 2001 | 0 | 80 | 2284 | 314 |
| 8/17/2004 | 0.16 | 3.9 | 2190 | 0 | 190 | 2452 | 370 |
| 9/27/2004 | 0.25 | 3.6 | 1233 | 0 | 410 | 2459 | 348 |
| 10/28/2004 | 1.30 | 3.7 | 1002 | 0 | 30 | 1963 | 278 |
| 11/30/2004 | 4.42 | 4.7 | 880 | 5 | 250 | 1036 | 139 |
| 12/4/2004 | | | | | | | |
| 1/28/2005 | 6.00 | 5.2 | 1869 | 14 | 180 | 1730 | 266 |
| 2/22/2005 | 1.86 | 5.0 | 1607 | 10 | 140 | 1490 | 215 |
| 3/28/2005 | 17.97 | 5.0 | 851 | 7 | 90 | 665 | 102 |
| 4/28/2005 | 1.10 | 5.0 | 1882 | 11 | 619 | 1788 | 266 |
| 5/25/2005 | 0.71 | 4.2 | 1993 | 0 | | 1958 | 276 |
| 6/21/2005 | 0.28 | 3.7 | 2250 | 0 | 430 | 2174 | 330 |
| 7/27/2005 | 0.16 | 3.5 | 2320 | 0 | 404 | 2274 | 379 |
| 8/30/2005 | 22.22 | 4.5 | 870 | 1 | 11 | 610 | 89 |
| 9/27/2005 | 0.65 | 3.6 | 2160 | 0 | 40 | 1978 | 229 |
| 10/27/2005 | 0.19 | 3.5 | 2390 | 0 | 21 | 2300 | 540 |
| 11/30/2005 | 0.46 | 3.6 | 2100 | 0 | 149 | 1956 | 303 |

Site FR 1 - Fox Run Watershed Below Reclamation

**Laboratory results**

| Sampling date | Aluminum, total, mg/l | Aluminum, dis., mg/l | Iron, total mg/l | Iron, dis. mg/l | Manganese total, mg/l | Manganese, dis., mg/l | Sulfate, dis. mg/l |
|---|---|---|---|---|---|---|---|
| 1/7/2003 | 21.3 | 21.0 | 21.5 | 21.0 | 4.5 | 4.5 | 1136 |
| 1/28/2003 | 27.0 | 27.0 | 8.2 | 4.1 | 8.9 | 8.9 | 1973 |
| 2/13/2003 | 10.0 | 8.0 | 5.4 | 5.4 | 3.8 | 3.7 | 1296 |
| 3/24/2003 | 18.8 | 16.3 | 10.8 | 10.6 | 5.2 | 5.1 | 1190 |
| 4/16/2003 | 16.9 | 14.9 | 7.4 | 6.8 | 5.1 | 4.7 | 1169 |
| 5/6/2003 | 13.7 | 8.0 | 17.6 | 0.5 | 2.4 | 2.6 | 492 |
| 6/26/2003 | 14.2 | 11.3 | 15.4 | 9.1 | 5.6 | 5.7 | 1238 |
| 7/22/2003 | 9.7 | 7.8 | 10.6 | 10.5 | 5.0 | 4.9 | 1409 |
| 9/4/2003 | 12.7 | 11.0 | 11.9 | 10.8 | 5.5 | 6.2 | 1020 |
| 9/26/2003 | 12.2 | 11.9 | 14.4 | 13.1 | 7.1 | 7.1 | 1600 |
| 10/24/2003 | 10.2 | 11.1 | 10.8 | 8.8 | 7.3 | 6.1 | 1700 |
| 12/8/2003 | 11.4 | 10.6 | 24.2 | 21.0 | 7.2 | 6.6 | 959 |
| 12/30/2003 | 10.0 | 10.0 | 12.8 | 12.4 | 4.8 | 4.7 | 1136 |
| 1/29/2004 | 11.9 | 9.5 | 17.8 | 14.7 | 5.7 | 4.9 | 920 |
| 2/26/2004 | 18.6 | 17.1 | 65.4 | 61.4 | 6.9 | 6.2 | 1769 |
| 3/29/2004 | 13.5 | 11.1 | 25.0 | 22.0 | 5.4 | 4.5 | 1461 |
| 4/30/2004 | 7.9 | 3.7 | 9.7 | 5.1 | 4.0 | 3.7 | 1199 |
| 5/28/2004 | 4.4 | 2.4 | 14.2 | 10.9 | 5.3 | 5.0 | 1765 |
| 6/30/2004 | 6.0 | 6.0 | 5.1 | 5.2 | 6.6 | 6.2 | 1523 |
| 7/28/2004 | 6.5 | 5.2 | 10.2 | 9.6 | 5.9 | 5.4 | 1628 |
| 8/17/2004 | 7.4 | 6.6 | 6.9 | 3.2 | 6.3 | 5.6 | 1824 |
| 9/27/2004 | 6.0 | 6.6 | 1.2 | 1.2 | 5.4 | 6.1 | 1760 |
| 10/28/2004 | 4.5 | 4.7 | 4.2 | 3.9 | 5.0 | 5.2 | 1200 |
| 11/30/2004 | 6.4 | 4.7 | 7.3 | 4.3 | 3.7 | 3.4 | 640 |
| 12/4/2004 | | | | | | | |
| 1/28/2005 | 8.7 | 3.3 | 19.1 | 16.1 | 4.7 | 4.7 | 1150 |
| 2/22/2005 | 7.0 | 4.4 | 12.5 | 11.1 | 4.0 | 4.4 | 800 |
| 3/28/2005 | 4.9 | 2.1 | 5.9 | 2.1 | 2.5 | 2.5 | 470 |
| 4/28/2005 | 6.8 | 5.2 | 11.2 | 10.8 | 4.7 | 5.2 | 1190 |
| 5/25/2005 | 5.8 | 5.3 | 7.3 | 6.9 | 4.0 | 4.4 | 1300 |
| 6/21/2005 | 5.4 | 5.8 | 1.7 | 1.6 | 6.0 | 6.0 | 1660 |
| 7/27/2005 | 5.6 | 6.1 | 1.1 | 1.0 | 4.9 | 6.5 | 1520 |
| 8/30/2005 | 1.6 | 0.8 | 2.7 | 0.8 | 1.8 | 1.8 | 520 |
| 9/27/2005 | 3.6 | 3.3 | 0.6 | 0.5 | 3.5 | 3.5 | 1540 |
| 10/27/2005 | 3.1 | 2.9 | 0.7 | 0.7 | 4.4 | 4.4 | 1760 |
| 11/30/2005 | 7.3 | 5.8 | 1.7 | 1.6 | 6.5 | 6.7 | 1290 |