Acid Mine Drainage Abatement and Treatment Plan

Huff Run Watershed

January 2000

Acid Mine Drainage Abatement and Treatment Plan for the Huff Run Watershed

Preface

This Acid Mine Drainage Abatement and Treatment Plan (AMDAT) Plan has been prepared for the Ohio Department of Natural Resources (ODNR) by Gannett Fleming, Inc. under purchase order nos. T80582 and T00506. The plan was developed to assess the impacts of acid mine drainage (AMD) and the restoration potential of abandoned mine land projects on the Huff Run watershed. The plan follows the outline for AMDAT preparation developed by ODNR and contains the following key elements:

- Identification of the hydrologic unit,
- Determination of current conditions and the restoration potential of the watershed,
- Establishment of goals for restoration,
- Definition and prioritization of potential projects for funding, and
- Recommendations for future monitoring programs.

Development of the plan was coordinated with ODNR personnel, as well as personnel from the Office of Surface Mining Reclamation and Enforcement and the Natural Resource Conservation Service. Additionally, the Huff Run Watershed Restoration Partnership (HRWRP), a local watershed group that is currently active with restoration activities in the watershed, was involved with the development of the plan.

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List of Acronyms

ACSI	Appalachian Clean Streams Initiative
ALD	Anoxic Limestone Drain
AMD	Acid Mine Drainage
AMDAT	Acid Mine Drainage Abatement and Treatment
AML	Abandoned Mine Lands
CIV	Cumulative Index Value
DMR	Division of Mines and Reclamation
GDM	Grams Per Day Per Square Meter
GIS	Geographic Information System
GPD	Grams Per Day
GPM	Gallons Per Minute
GPS	Global Positioning System
HRWRP	Huff Run Watershed Restoration Partnership
IBI	Index of Biotic Integrity
ICI	Invertebrate Community Index
NRCS	Natural Resource Conservation Service
O&M	Operation and Maintenance
ODNR	Ohio Department of Natural Resources
OEPA	Ohio Environmental Protection Agency
OLC	Open Limestone Channel
OSM	Office of Surface Mining
QHEI	Qualitative Habitat Evaluation Index
SAPS	Successive Alkalinity Producing Systems
USGS	United States Geological Survey
WWH	Warmwater Habitat

Acid Mine Drainage Abatement and Treatment Plan for the Huff Run Watershed

I. Identification of the qualified hydrologic unit.

A. Watershed Characteristics

Huff Run, located in the Muskingum Conservation District, originates in northwestern Carroll County, Ohio, and flows southwesterly into Tuscarawas County, Ohio, where it empties into Conotton Creek. Conotton Creek is a tributary to the Tuscarawas River. Figure 1 presents a location map of the hydrologic unit. The stream is approximately 9.3 miles in length and drains an area of approximately 14.1 square miles. The Ohio Environmental Protection Agency has given Huff Run an aquatic life use designation of Warmwater Habitat, a recreational use designation of Primary Contact, and public water supply use designations of Agricultural and Industrial. The following is a summary of the hydrologic unit:

• Name:	Huff Run
• Conservation District:	Muskingum
• Tributary to:	Conotton Creek
• Length:	9.3 miles
• Drainage Area:	14.1 square miles
• Aquatic Life Use Designation:	Warmwater Habitat
• Recreational Use Designation:	Primary Contact
• Public Water Supply Use Designation:	Agricultural and Industrial

The designated uses are defined as follows:

- Warmwater Habitat: Water capable of supporting balanced, reproducing populations of warmwater fish and associated vertebrate and invertebrate organisms and plants on an annual basis.

- Primary Contact: Suitable for full body contact recreation. The stream must have at least one pool of 100 square feet greater than a depth of three feet to qualify.

- Agricultural and Industrial: Agricultural — Suitable for irrigation and livestock watering without treatment. Industrial — Suitable for industrial and commercial use with or without treatment.

II. Extent to which acid mine drainage is affecting the water quality and the biological resources within the hydrologic unit.

A. Introduction

A required element of any AMDAT Plan is a determination of the extent to which AMD is affecting the water quality and biological resources within the hydrologic unit. Such a determination becomes a key component in deciding what restoration activities have the potential to improve the stream to a condition that provides for its recovery. Making such a determination relies on the availability of sufficient water quality, habitat quality, and biological quality data. Section II of this AMDAT plan is dedicated to explaining the methodology used to arrive at a determination of the extent to which AMD is affecting the water quality and biological resources of Huff Run.

B. Watershed Description

Huff Run has been partitioned into eight stream reaches for purposes of this AMDAT Plan. Based on the characteristics of the watershed and on previous sampling efforts, certain mainstem points were selected as partitions or end points for particular stream reaches. The stream length between each partition is collectively referred to as a reach. These points and their associated reaches are identified in Figure 2. Mainstem sampling points are numbered in a top-down manner, whereas the reaches are numbered in a bottom-up manner.

State Route 800 and State Route 542 are two major state roadways within the watershed. Several medium and light duty roads, both paved and unpaved, can also be found within the watershed. State Route 800 is located toward the western edge of the watershed. It runs through Mineral City, the watershed's only incorporated town. State Route 542 is located toward the eastern edge of the watershed.

Historic land use activities have predominantly consisted of agriculture, surface mining, and oil and gas production. Current land use activities include agriculture, Christmas tree and nursery farms, surface mining, and oil and gas production. Several small manufacturing businesses also exist within the watershed. The land ownership is predominantly private.

The watershed, as a result of its land use history, can be divided into three sections. The eastern section, containing Reaches 7 and 8, extends from State Route 542 northeast to the headwaters and is primarily agriculture and forest. The central section extends from State Route 542 to State Route 800 and contains Reaches 2 through 6. This portion of the watershed consists largely of unreclaimed coal refuse piles and surface mine spoil (both forested and unforested), abandoned deep mine portals, and water-filled impoundments. Portions of this area have been mined recently, the majority of which is located within Reaches 4, 5 and 6. The western section extends from State Route 800 down to Huff Run's confluence with Conotton Creek. This section consists of a mixture of unreclaimed coal refuse piles and surface mines, abandoned deep mine portals, and agricultural land. The western section, closest to Conotton Creek, lies within the inundation area of Dover Dam and is thus very susceptible to flooding. Reach 1 comprises the western or most downstream section of the watershed.

A United States Geological Survey Stream Gauge (No. 03121850) is located on Huff Run at Mineral City, near ODNR sample point HR-28 at the base of Reach 2. The gauge began recording data in November 1997. Currently, verified data for the gauge is available from October 1, 1997 to September 30, 1998. The mean flow for that time frame was 12.8 cfs, with average daily flows ranging from 2 to 221 cfs.

Provisional data is available from the gauge for other time periods, however the data is subject to correction prior to being released. Consequently, given that the gauge is relatively new, the provisional data could be adjusted significantly. All of the gauge data is available from the USGS and is also on their website (http://www-oh.er.usgs.gov).

C. Existing Data and Past Studies

Sufficient data must exist over seasonal conditions to accurately assess the extent to which AMD is affecting the hydrologic unit and to assess the potential for restoration. A first step was to identify previous studies and data sets. The following were identified:

- 1976 United States Geological Survey (USGS) Study
- 1985 Benatec Associates Study
- 1996 Ohio EPA Intern Staff Low Flow Data
- 1996 Mt. Union College Fall Semester Restoration Ecology Class Macroinvertebrate and Habitat Assessment Data
- 1997 Ohio EPA/Mt. Union College Electrofishing Data
- 1997 Mt. Union College Winter Semester Hydrology Class High Flow Data
- 1998 and 1999 Ohio Department of Natural Resources, Division of Mines and Reclamation Monthly Sample Data

The 1976 USGS Study includes flow measurement and water chemistry data for five stations along the mainstem and 24 sample points along various tributaries. The data was collected in late August 1976. A description of the methods used to evaluate the quality and quantity of the flow is not provided in the study. A small map portrays the sampling locations, allowing a rough correlation of the data to the more recent sampling locations.

The 1985 Benatec Associates Study includes a water quality assessment similar to the USGS assessment, but which includes data for an additional 36 tributaries. The report only indicates that the data was collected in "the late Spring of 1985". Results are dated March 29, 1985. A digest of the report indicates that the quality of the flow was determined through the collection of catch water samples. The report acknowledges that "flow rates are estimated with great difficulty and considerable inaccuracy without weir installation" (Benatec, 1985). A map of significantly more detail than the 1976 USGS map is provided as part of the study. All tributaries sampled are shown. Sampling locations on the mainstem are identified by station number. Sampling locations on tributaries are not identified, but the report indicates that "water samples were taken at tributary entries along the stream" (Benatec, 1985).

The 1996 Ohio EPA Intern Staff low flow data includes flow measurement and water chemistry data for 32 sampling locations throughout the entire watershed. The data was collected in late July and early August. A digest of the report indicates that the quality of the flow was determined through the collection of catch water samples. The method used to determine the quantity of flow is not indicated. Sampling locations were located using Global Positioning System (GPS) technology.

The 1996 Mt. Union College Fall Semester Restoration Ecology Class macroinvertebrate and habitat assessment data includes the collection of data and subsequent compilation of Cumulative Index Values (CIV) and Qualitative Habitat Evaluation Indices (QHEI) for nine mainstem stations. The data was collected in October 1996. The CIV is a measure of the density and diversity of macroinvertebrates present. Two different collection techniques were used. With the kick-net technique, a one-meter square area of streambed upstream of a one-meter square net was "kicked" around to dislodge the invertebrates. All dislodged invertebrates then floated downstream and into the net. With the other technique, artificial habitats were placed on the streambed at each site during the month of October. In both cases, all invertebrates collected were taken to the laboratory for identification. The QHEI is a "physical habitat index designed to provide an empirical, quantified evaluation of the general lotic macrohabitat characteristics that are important to fish communities" (OEPA). Data collection consisted of manually rating and scoring stream characteristics using best professional judgement.

The 1997 Ohio EPA/Mt. Union College electrofishing data includes the collection of data and subsequent compilation of Indices of Biotic Integrity (IBI) and QHEI scores for three stations along the mainstem. The data was collected in June and September 1997. The IBI is a measure of fish species diversity and species populations. Data was collected by electrofishing approximately 0.15 kilometer of stream reach at each site. All stunned species were collected, counted, and identified.

The 1997 Mt. Union College Winter Semester Hydrology Class high flow data includes water chemistry data for the same 32 sampling locations identified in 1996. The data was collected in February 1997. A digest of the report indicates that the quality of the flow was determined through the collection of catch water samples. The method used to determine the quantity of flow is not indicated.

The 1998 and 1999 Ohio Department of Natural Resources, Division of Mines and Reclamation data includes monthly sample collections and measurements at prospective project sites. This data focuses on point source discharge sites. The quality of the flow was determined through the collection of catch water samples. The method used to determine the quantity of flow is not indicated.

Tabular presentations of the data discussed herein are presented in Appendices A and B. Original sample location maps from the USGS and Benatec studies are also presented.

Evaluations of the data sets were performed and it was determined that the biological and habitat assessment data was sufficient to evaluate and develop a characterization of Huff Run for the AMDAT plan. The older water quality data (> 10 years), while useful for historical perspectives, was not considered appropriate for the evaluation of current conditions. The more recent (1996 to 1997) data was found to be useful for assessment of the instream conditions. However, this data was found to be insufficient for completion of the AMDAT plan because of the following:

- Flow data from the 1996 and 1997 sample rounds was often inconsistent and missing, so loading estimation and comparison of sites and tributaries was not possible.
- Portions of the watershed were undocumented in the 1996 and 1997 sampling that were identified in 1985 as having some of the highest loads, making it difficult to assess the relative impacts of the individual sites with respect to the watershed as a whole.
- The upper-most sample point (HR-1), appeared to be impacted by AMD, indicating the potential for undocumented upstream sites.

Consequently, additional sampling of the Huff Run and its tributaries was recommended and completed as part of this study in support of the AMDAT plan.

D. New Data Collection

Prior to performing a sampling sweep, Gannett Fleming performed a screening of the majority of the tributaries within the watershed to assess their relative impact and to identify potential new sample locations not identified during the most recent sampling events. The screening was performed on February 11 and 12, 1999. Flows in Huff Run during the screening were relatively high, estimated at being nearly 15 cubic feet per second (cfs). The screening data collected is presented in Appendix A.

The screening consisted of measuring pH and total dissolved solids, and estimating flow at points along Huff Run and at major tributaries and discharges feeding to the stream. New point source discharges and impacted tributaries in Reaches 3, 4, 5 6 and 7 were also identified during the screening. Using data collected during the screening process, a watershed-wide sampling sweep was designed and executed at select mainstem, tributary, and point source locations. The complete sampling network established for the watershed, including the existing 32 sampling sites, is shown in Figure 2.

A sampling sweep of 8 mainstem and 25 tributary and point source samples was conducted on March 1 and 2, 1999. Field testing and measurements were collected for flow, pH, temperature, conductivity, and dissolved oxygen. Tributary and point source flows were measured with a portable flume. Stream flows were measured and calculated using a portable velocity meter and methodology described in *Techniques of Water-Resources Investigations of the United States Geological Survey, Chapter A8, Discharge Measurements at Gauging Stations*. Two grab samples were collected at each sampling location. One sample per sampling location was preserved with acid. Laboratory testing of samples was performed for the following parameters: pH, specific conductivity, total acidity (HOT), total alkalinity, total aluminum, total calcium, hardness, total iron, total magnesium, total manganese, sulfate, total dissolved solids, and total suspended solids. The Ohio Department of Natural Resources performed laboratory testing of all samples. New sampling locations and sampling locations not previously located were located using GPS technology. Questionable existing sampling locations were also relocated. Sampling locations were staked to provide for easy identification during future sampling events. The results of the sampling sweep are presented in Table 1.

Gannett Fleming also performed field reconnaissance of four previously identified point source discharge sites as well as newly identified point source discharge sites. The reconnaissance included an exploration of each individual point source and their corresponding sub-watersheds. Features of significance and potential treatment areas were mapped and surveyed using GPS equipment.

E. GIS and Database Compilation

A Geographic Information System (GIS) project file for the study area was developed using ArcView GIS software. These files contained geographic information collected for the watershed from existing sources and site specific data collected as part of this study from the problems areas using the GPS technology. Existing GIS files were obtained from the ODNR and other sources. Base mapping was compiled for the project from existing digital line graph files developed from USGS quadrangle maps. Coverages for soils, wetlands and abandoned deep mines were obtained from ODNR. Many other features shown on the plan figures in this report were digitized, including Huff Run and its tributaries and subwatersheds. A list of the GIS files compiled and generated for this project is included in Appendix C.

Upon the completion of the March 1999 sampling sweep, all water chemistry data, habitat data, and biological data were entered into an electronic database. The database provides for easy query and retrieval of select data. This allows for an efficient, yet thorough method of tracking and correlating all data. Additionally, the GIS format allowed for the compilation, cataloging, retrieval and evaluation of these data sets. For this study, the GIS and database were used to keep track of the sample data and locations, and allowed for the graphical comparison and modeling of the data to aid in decision making.

F. Data Analysis

The 1999 data in conjunction with the historical data provides water quality, habitat quality, and biological quality data over seasonal conditions representative of both high and low flow conditions. The historical data serves to augment the 1999 data, particularly with its ability to depict long-term mainstem, tributary, and point source trends.

1. Water Quality — pH Trends

The first factor to investigate when it comes to acid mine drainage is pH. Most organisms have a well-defined range of pH tolerance. If the pH falls below this range, death will occur due to respiratory or osmoregulatory failure. Low pH causes a loss of sodium ions from the blood and a loss of oxygen in the tissues. Low pH also increases the permeability of fish gills to water, which adversely affects gill function. Studies have indicated that a pH of 4.5 and a total acidity of 15 mg/L have accounted for complete loss of fish in 90% of streams studied. Concentrations of metals were not taken into account during these studies with respect to lethal toxicity levels. The pH tolerance level of aquatic organisms generally tends to decrease as the concentration of dissolved metals increases. Studies have indicated that a combination of pH less than 5.5 and dissolved aluminum greater than 0.5 mg/L will generally eliminate all fish and most macroinvertebrates (Earle, 1998).

As presented in Figure 3 and Figure 4, the available data indicates that stream pH levels gradually decline below HR-6. Even though stream pH levels gradually decline, the pH rarely reaches a level that would be considered toxic to aquatic life. The data collected to this date only shows the pH dropping below 4.5 and total acidity exceeding 15 mg/L at HR-24 and HR-28 in 1976, HR-28 and HR-32 in 1996, and HR-14 in 1997. Except for the one instance in 1997, all instances have occurred in the lower reaches during low flow conditions. A pH excursion does not have to be continuous to affect aquatic life. It can be an episodic event and still result in the same level of degradation to the aquatic community as a continuous event.

2. Water Quality — Metal Trends

The second factor to investigate when it comes to AMD is dissolved metal concentrations, in particular dissolved aluminum and iron concentrations. Elevated aluminum and iron concentrations can affect both water quality and suitability of habitat. Aluminum and iron can either be found in a dissolved form or in a precipitated form. In the dissolved form, the metals can act as metabolic poisons, mainly by reducing aquatic life pH tolerance levels, increasing carbon dioxide tensions and osmotic pressure, causing synergistic effects, and decreasing oxygen availability as they form precipitates. Once in the precipitated form, they may coat gills and body surfaces (further reducing oxygen transfer), smother eggs, and cover the stream bottom, filling in crevices and rocks. The scouring of the precipitate also increases turbidity which may inhibit fish feeding (Earle, 1998).

Of the two major metals present in mine drainage, aluminum has the most severe adverse effects on stream aquatic life. Aluminum rarely occurs naturally in water at concentrations greater than a few tenths of a milligram per liter. The addition of aluminum ions compounds the effect of low pH by interacting with hydrogen ions, further decreasing sodium uptake, and increasing sodium loss in blood and tissues. Dissolved aluminum is most toxic to fish at a pH between 5.2 and 5.4, and least soluble between pH 5.7 and 6.2. Precipitated aluminum coats the stream substrate, causing slippery surfaces and making it difficult for insects to maintain position in the current. The deposition of aluminum hydroxide particles on macroinvertebrates blocks surfaces important for respiratory or osmoregulatory exchange. Precipitated aluminum can accumulate on fish gills and interfere with their breathing. Aluminum precipitate also eliminates most of the filter feeders, which normally comprise a major portion of total stream macroinvertebrates (Earle, 1998).

Figure 3 and Figure 4 present instream conditions documented at high and low flow conditions. A digest of the data indicates an increase in the dissolved aluminum concentration generally beginning around HR-11. A jump from about a tenth of a milligram per liter to several tenths of a milligram per liter generally occurs around Site 11 and usually culminates at over a milligram per liter in the lower reaches. The data also indicates that Huff Run pH values typically fall within and very close to the pH ranges where aluminum is most toxic to fish and where precipitation is most likely to occur.

Iron precipitates at a pH greater than 3.5. Because iron can form precipitates at a lower pH, it is difficult to separate the effect of iron in solution from the effect of low pH. The precipitation of iron hydroxide, however, is a discernible problem. The precipitation can cause a complete blanketing of the stream bottom. Since iron precipitate particles often cover the bodies of macroinvertebrates that otherwise appear healthy, the iron precipitate itself appears to be less toxic than aluminum precipitate (Earle, 1998).

The high flow data collected in March 1999 provides evidence that significant amounts of metals are precipitating out of solution and depositing in the stream. Figure 5 portrays recorded aluminum and iron loads documented at HR-11 (Reach 5) and HR-17 (Reach 4). The inputs are equivalent to the sum of all of the individual inputs sampled within that reach. Assuming a steady-sate conservative system, a materials balance per reach can be executed by setting the input rate per reach equal to the output rate per reach. The expected concentration at the bottom of a reach can then be calculated and compared to the reported sample concentration. This assessment indicates that larger quantities of aluminum and iron are entering these reaches than are leaving these reaches. This occurrence is strong evidence that metals are precipitating out of solution as a metal hydroxide. However, hydrologic systems are further complicated by the fact that flow has multiple pathways in which it can enter and leave the system. A valid claim, therefore, is that some metals are leaving the system at points other than those sampled, Even if this were the case, the effect would likely be negligible. Further evidence of precipitation is provided by the fact that the optimal pH range for the precipitation of aluminum is between 5.7 and 6.2, which falls very close to the sampled pH levels of Huff Run. Similarly, the same logic can be applied to iron, which precipitates at pH's greater than 3.5.

3. Habitat Quality

Habitat data for the study is represented by the QHEI. The QHEI consists of six principal metrics that are scored individually and summed to provide the total QHEI site score. The maximum QHEI site score is 100. The six principal metric categories are: substrate, instream cover, channel morphology, riparian zone and bank erosion, pool/glide and riffle/run quality, and gradient. The higher the score for each individual metric, the closer that metric is to having characteristics present that are important to fish communities

(OEPA). Figure 6 presents the results of the data collected in 1996 by Mt. Union College. The data set is presented in Appendix B.

A review of the data reveals a marked decline in QHEI between HR-11 and HR-17. Further analysis indicates that the marked decline in the total QHEI score is mostly a result of a decline in the scores for Metrics 1 and 2. Metric 1 evaluates substrate type and quality while Metric 2 evaluates instream cover type and amount. The substrate and instream cover are thus being impaired to a greater extent in the lower four reaches than in the upper four reaches. Sedimentation and the precipitation of metals are likely causes of this degradation.

4. Biological Quality

Biological quality for the study is represented by the CIV and the IBI. The CIV is a measure of the density and diversity of macroinvertebrates present. Three groups of taxa are represented. Results are presented in Figure 6 and the complete dataset is included in Appendix B. Group 1 Taxa are weighted the heaviest and scores can range from 0 to 42. A score less than 11 indicates poor stream quality. Scores between 11 and 16 equate to a fair stream quality. Scores between 17 and 22 depict good stream quality. A score greater than 22 indicates excellent stream quality. An examination of the data indicates that Huff Run has a macroinvertebrate population indicative of good to fair water quality in Reaches 7 and 8 (above HR-1). The macroinvertebrate population, however, changes to one indicative of poor water quality in the lower five reaches. No data was available for Reach 6.

The IBI is a measure of fish species diversity and species populations. Five ecoregions have been identified in Ohio. Characteristics reflecting the biological performance exhibited by natural or least impacted habitats of surrounding area have been identified based on specific reference sites. The IBI consists of twelve principal metrics, each of which is scored individually and then summed to provide the total IBI score. Each metric is scored based on whether its own specific characteristics approximate, partially deviate, or strongly deviate from what is expected in a least impacted stream. The minimum possible IBI score is 12. The maximum possible IBI score is 60. The higher the score, the healthier the aquatic ecosystem (OEPA). Results are presented in Figure 6. A review of the data indicates that the IBI scores for HR-0 and HR-6 are indicative of a much healthier aquatic ecosystem than the score for HR-32. With a score of 16, HR-32 would be considered to strongly deviate from what is expected in a least impacted stream. With scores of 38 and 36, HR-0 and HR-6 are close to representing what is expected in a least impacted stream.

G. Summary

Based on an analysis of the available data, and solely from an AMD perspective, the biological resources of Huff Run are significantly impaired in the lower five reaches as a result of the episodic pH excursions during low flow conditions in Reaches 1 , 2 and 3, and an increase in metal loading below HR-6. Consequently, it is recommended that restoration efforts be focused to address these trends. This restoration philosophy will require the identification and development of abatement projects in Reaches 4 and 5. This is also consistent with a top-down approach to restoration that is often utilized to implement stream restoration projects. With the top-down approach, projects within a watershed are implemented in an upstream to downstream order, extending the benefit over the greatest length of stream being restored.

H. Restoration Goals

1. Long-term Goals

As mentioned in Section I of this plan, Huff Run has been given the aquatic life use designation of Warmwater Habitat (WWH). Ohio EPA uses aquatic life use to evaluate water quality to provide an accurate and comprehensive evaluation of water quality. Aquatic life criteria are generally more stringent than those associated with other beneficial uses because the health, diversity and population of biological communities reflects both short-term and long-term impacts of water quality pollution and degradation. Levels of attainment based on biological data are used to describe whether or not a stream is meeting Ohio's water quality standards. In the Western Allegheny Plateau ecoregion, a stream with a drainage area less than 20 square miles can be considered to be attaining the warmwater habitat designation if it has an IBI of 44 (+/- 4 points) and an Invertebrate Community Index (ICI) of at least 36. In addition, QHEI scores greater than 60 indicate that a stream has the potential to achieve the WWH designation.

An appropriate long-term goal, and the ultimate goal of any AMDAT Plan, would be to restore the stream to a condition that allows it to fully attain its aquatic life designated use class.

2. Short-term Goals

Although long-term goals are more desirable, they are usually not quickly and readily achievable. It is thus important to establish short-term goals that are more easily achieved and that serve as a stepping stone in reaching long-term goals. Appropriate short-term goals for Huff Run would be:

- Buffer the lower reaches of Huff Run against episodic pH excursions during low flow conditions with the addition of alkalinity above HR-24.
- Improve the in-stream habitat and water quality below HR-6 with a reduction in metal loads.

III. An identification of the sources of acid mine drainage within the hydrologic unit.

A. Identification of AMD Problem Areas

1. Geology, Coal Resources and Mining Conditions

The Huff Run Watershed lies within the unglaciated portion of the Appalachian Plateau physiographic province. The province is characterized by nearly flat-lying sedimentary bedrock, with steep-sided, incised valleys forming its drainage ways. The bedrock outcropping within the watershed belongs to the Pennsylvanian System, Allegheny Group. The Allegheny Group in this area consists primarily of cyclic sequences of sandstone, siltstone, and shale, with thinner layers of claystone, limestone and coal. A stratigraphic section of the bedrock within the Huff Run watershed is presented as Figure 7.

A number of significant coal seams are contained within the Allegheny Group which are mined throughout the northern bituminous coal fields, including portions of Ohio. Locally occurring seams include, in ascending order: the Brookville (No. 4) coal, the Lower Kittanning (No. 5) coal, the Strasburg coal, the Middle Kittanning (No. 6) coal and the Upper Freeport (No. 7) coal. These coals range in thickness from approximately 1 to 5 feet. The Brookville coal, the base of the Allegheny Group, outcrops along stream level in much of the watershed, while the Upper Freeport coal, the top of the Allegheny Group, is exposed in only a few locales along the tops of adjacent ridges. Along with the coal, exposures of claystone, or “underclay”, are present within the bedrock directly below the coal seams. These strata, also of economic significance, are as great as 8 feet in thickness.

Coal mining in the vicinity of Huff Run and Mineral City occurred as early as 1810. Documented deep coal and clay mining within the watershed occurred in the Lower Kittanning and Middle Kittanning coals. A map depicting the approximate limits of the documented deep mines within the watershed is presented in Figure 8. Most deep mining within the Huff Run watershed occurred between 1850 and 1930, with the last deep mine closing in 1946. During this time, the underclay of the Lower Kittanning coal seam was also typically removed and used for general refractory purposes. Discharges from many of these abandoned deep mines are located throughout much of the central and western portions of the watershed. These discharges have been observed from both the Lower

Kittanning and Middle Kittanning coals, although mining in the Lower Kittanning seam seems more prevalent. Many of these deep mines were also intercepted during subsequent surface mining, producing additional discharges. A number of discharges have also been observed near the stream level of Huff Run, where no documented mining has occurred. These discharges appear to correspond to the elevations of the Brookville coal and clay, and may represent past undocumented mining of these resources.

After 1950, extensive surface mining of the Lower Kittanning and Middle Kittanning coals started in the watershed. This mining has resulted in most of the surface topography, including numerous exposed highwalls, spoil piles and impoundments which are present within the central portion of the watershed today. Runoff from these areas has also become a source of significant contamination, and are often worsened by related deep mine discharges. The approximate limits of currently unreclaimed surface mined areas within the watershed are presented in Figure 9.

Following the implementation of modern mining laws in the late 1970's, mining operations within the watershed began reclaiming mine sites to their near original surface topography. These operation are also required to maintain discharge water quality. Reclaimed surface mines may be responsible for the drop in instream acidity observed in the last 30 years, and the alkalinity generation that is currently observed in the upper portions of the watershed. Most current surface mining operations extract only the Middle Kittanning coal. The approximate limits of currently active mining permits within the watershed is presented in Figure 9.

2. Previously Identified Problem Areas and Projects

At the commencement of restoration activities within the watershed, ODNR started identifying potential problem areas for the investigation and implementation of projects within the watershed. Five problem areas were identified where projects have been performed, are being planned or data is being collected. These sites include:

- Huff Run AML Reclamation Project,
- Jobes Reclamation Project,
- South Side Tipple Site,
- Lyons Site,
- Harsha Reclamation Project, and
- Linden Mine Bioremediation Project.

The Jobes and Huff Run AML Reclamation Projects were the first major projects in the watershed. The AML-funded projects were completed in 1998 to reduce sedimentation and acid loading from unreclaimed surface mines contributing to Reach 1 of Huff Run. For the Jobes project, 16.1 acres of acid producing spoil was covered and revegetated, 1720 linear feet of stream was restored, and a 3 acre water impoundement was eliminated. The Huff Run project involved the resoiling and revegetation of over 60 acres, 109,000 cubic yards of earthwork, 1600 linear feet of stream reconstruction and drainage and removal of an AMD impoundment.

The South Side Tipple Site is slated for a two-phase reclamation project which will regrade and revegetate 8 acres of spoil, drain a deep mine fed impoundment and develop a possible passive treatment system to treat water discharging to Reach 1 of Huff Run. Phase 1 of the project, currently in design, will regrade and revegetate existing coal refuse, drain an existing impoundment and improve site drainage. ODNR currently collects monthly samples at this location (HR-31 and HR-31A).

The Lyons Site is an exposed, eroding spoil pile and AMD impoundment which currently discharges heavily contaminated water to Reach 2 of Huff Run. A two-phase project is envisioned to reclaim the spoil and impoundment, and to develop a system to treat remaining discharges. ODNR currently monitors two locations at the site. (HR-33 and HR-33A)

The Harsha Reclamation Project is a cooperative project between ODNR, NRCS and C&E Coal, Inc. to remine much of the Middle Kittanning Coal and reclaim Lower Kittanning mine spoil. The Harsha site contributes large quantities of AMD to Reach 4 of Huff Run. Additional consideration is also being given to develop a treatment system for Lower Kittanning deep mine discharges occurring at the site. ODNR currently monitors three individual points on the site (HR-15A, HR-15B and HR-16A). The same property also contains other discharges on the opposite side of Huff Run that are currently being monitored by ODNR as well (HR-17A and HR-17B).

The Linden Mine Bioremediation Project has been proposed to develop a passive treatment system for an AMD discharge impacting Reach 4 of Huff Run. The project has support from the HRWRP and is currently being considered for Appalachian Clean Streams Initiative funding. ODNR has been collecting monthly samples from the site (HR-13A).

Sampling data from the previous investigation discussed in Section II was also reviewed to identify problem areas and projects capable of meeting the restoration goals established. The 1976 USGS and the 1985 Benatec study both identified a large number of areas that had the high water quality impacts that were currently undocumented by the more recent sampling events. Based on the screening data collected, a list of potential problem areas was made to develop the additional sampling locations for this study.

Table 1 presents the results of the sampling event conducted in March 1999. As previously discussed, the sampling sweep was not comprehensive and did not include some of the impacted tributaries that had been previously determined to have significant

AMD impacts. The tributary sampling was concentrated in Reaches 4 and 5, to help delineate and identify the sources of AMD in the areas where short-term water quality goals had been established and the top-down approach would necessitate initial implementation.

3. Problem Area Loading Analysis

The new and existing data collected for the watershed's point sources and tributaries was used to assess the impact of the problem areas present within the watershed and select areas for site investigation and project conceptualization.

Table 2 presents a list of the current sampling locations developed by ODNR and Gannett Fleming. The coordinates of each of these sample locations is presented in the table, and the locations are shown on the watershed map in Figure 2. These locations represent the instream points used to characterize the stream reach conditions, as well as tributary and discharge points used to identify and characterize problem areas. For each reach of Huff Run, the tributaries currently impacted by mining related discharges were included. Also included were point discharges that feed directly to Huff Run, and point discharges that feed a sampled tributary to Huff Run. Reach, tributary and point designations were determined for each location (as presented in Table 2) to assist in generating, sorting and searching the database file containing the project water quality data.

To analyze the relative impact of the various tributaries and point sources that feed to Huff Run, a complete data set was constructed from the highflow data collected in March of 1999 and February 1997. Most of the flow data from the February 1997 sampling event was inconsistent and interpreted to be very inaccurate. To calculate loadings for these sites, flows were estimated based on the March 2, 1999 flow of 20.3 cfs measured for Huff Run at site HR-32 (bottom of Reach 1). Based on a total watershed area of 9044 acres (14.1 mi^2), flows were estimated assuming a flow of 0.0022 cfs/acre of sub-watershed. These flow estimates, while more consistent and accurate, could be off significantly because of the hydrologic complexities associated with mined areas. However, they were felt to be precise enough to allow for relative comparison of the impacted areas.

Figure 10 presents the estimated high flow acid loads from the identified tributaries and point sources directly impacting Huff Run. Similarly, Figure 11 presents the metal (iron and aluminum) loads for the same areas. A graduated color ramp is included in each figure which graphically shows the relative severity of the acid and metal loads from these identified problem areas. Additionally, a ranking system was developed based on the high flow net acid and metal loads to compare the problem areas discharging to Huff Run. Table 3 presents the highflow loading data for each problem area and the resulting rankings. The rankings utilize flow and water quality data compiled as previously discussed.

The most upstream discharge of AMD into Huff Run was located at HR-44, an alkaline seep contributing slight metals loadings to Reach 7 of Huff Run. As seen on Figure 10, a number of alkaline discharges are present in the upstream tributaries below HR-44. These discharges are likely due to the more recently remined and reclaimed areas in these tributaries, as well as the alkaline nature of some deep mine discharges in the No. 6 coal seam. Huff Run also likely benefits from the fact that the No. 5 coal seam is below drainage in this area and was not mined in many places. Slight to moderate metal loadings are present in this area as well, but have not resulted in heavy impacts to Huff Run.

Starting in Reaches 5 and 6, extensive surface and deep mining of both the No. 5 and No. 6 coals have resulted in the inflow of acid and metals loads to Huff Run. The first acidic inflow to Huff Run comes from tributary HR-3. HR-42 represents the most significant and highest ranked discharge in this portion of the watershed. It contributes both acid and metal (primarily iron) loads to Reach 5 and has a significant impact to the aquatic life in Reach 5 of Huff Run.

While Reaches 5, 6 and 7 contain the most upstream AMD discharges, most of the higher ranked problem areas are contained in Reaches 2, 3 and 4.

The highest ranked sites in Reach 4 were HR-16, which collects all of the drainage from the Harsha Site, and HR-12, also known as the Beldon Site, which sits adjacent to the Harsha Site and discharges just upstream from HR-16. These two sites represented the largest acid loads to the stream of the locations sampled in March 1999. Additionally, HR-16 is one of the highest contributors of metals to the stream.

Other locations contributing AMD to Reach 4 included sites HR-13, HR-13A, HR-13B and HR-17A, which are largely point sources that discharge directly to Huff Run. All of these contribute moderate acid loads, except for HR-13A, which was documented in March 1999 as being alkaline.

Reaches 2 and 3 contain the highest number of AMD producing areas in the watershed.

Problem areas HR-20, HR-21, HR-22, HR-23, HR-36, HR-37, HR-38, HR-39 and HR-40 in Reach 3 are contaminated tributaries heavily impacting Huff Run. HR-17B represents the only point source identified as discharging directly to Huff Run in these reaches. HR-25, HR-33 (the Lyons/Haas site) HR-34, HR-35 and HR-36 in Reach 2 are also heavily contaminated and represent some of the largest AMD loads entering Huff Run. These problem areas will have to be investigated and remediated in order to achieve long-term restoration of the entire stream. Projects developed in these reaches will help achieve acidity reduction and buffering of the lower reaches of Huff Run. However, their relative downstream location in Reach 2 makes them less desirable with respect to the metals reduction goals identified previously.

Reach 1 contains two problem areas, HR-31 and HR-46, which contribute only moderate amounts of AMD to the watershed.

A few of the problem areas deserve further mention based on some unique characteristics that were observed. Sites HR-17A, HR-13 and HR-42 are all point discharges in Reaches, 4 and 5 which surface very near to the base elevation of Huff Run. These sites contribute significant loads to the stream, with metal loads, specifically iron, being particularly high. The nature of these discharges is somewhat in question, although they appear to correspond to the Brookville coal.

No data was available to assess the impacts of HR-19 and HR-26. However, based on the screening and previous sampling data, they are likely significant contributors of AMD to Huff Run.

B. Selection of AMD Problem Areas

1. Selection Criteria

A set of qualitative selection criteria was established to determine the best sites to further investigate and develop conceptual projects. These criteria consisted of the following:

- Short-term restoration goals and philosophy
- Contaminant loading
- Feasibility/cost
- Available funding
- Integration with current projects
- Public support
- Technology demonstration

The short-term goals are the key elements that lead to the selection of sites. Combined with the contaminant loading previously discussed, the sites with the most potential impact on water quality are typically those that are most desirable and can be assessed analytically. The information generated and discussed in the previous section were used to help accomplish this.

The other considerations listed are less objective. The feasibility and cost of completing a project can only be assessed in general terms at this stage, because it requires knowledge of the nature and characteristics of the individual sites. Some of this information was available, so a subjective assessment of site feasibility was possible at a number of sites. Funding, project integration and public support are even more difficult to assess, but are important because of the existing efforts currently underway in the watershed and the active involvement of the HRWRP. Technology demonstration is also a key issue that will need to be incorporated into the restoration efforts in this watershed. The Huff Run watershed has a number of unique challenges with respect to geography and water quality chemistry.

2. Selected Problem Areas

The following problem areas were selected for further investigation and project development. A discussion of the key elements leading to each site's selection is presented herein. Figure 10 and Figure 11 show the locations of the problem areas selected and investigated for this AMDAT plan.

a) HR-16 (Harsha Site)

The HR-16 area (also known as the Harsha site) was documented as the largest problem area contributing AMD contamination in the Huff Run watershed in the March 1999 sampling event. Based on the acid and metals loads from the area, and its location in Reach 4, the site is an obvious choice for project consideration. The site is also being currently monitored by ODNR and plans are being considered to remine and perform other reclamation actions at the site.

b) HR-12

HR-12 was the next highest ranked area in Reaches 4 and 5 and represents another very large AMD contaminant load to Huff Run. The area is adjacent to the HR-16 area and could benefit from the potential remining and reclamation activities that span both sites.

c) HR-13A and HR-13B (Linden Site)

HR-13A and HR-13B (also known as the Linden site) are two discharges located relatively close to each other. HR-13A is slightly acidic and HR-13B is heavily alkaline. The proximity of the two discharges provides the possibility of combining the two discharges into a single flow, which can be easily treated using a passive treatment wetland. While the two discharges are not large contributors of AMD to the watershed, the relative simplicity of the treatment offers a possibly cost-effective solution. In addition, funding has been applied for HR-13A to develop a bioremediation project.

d) HR-42

HR-42 is the most upstream discharge sampled in the watershed contributing significant AMD contamination to Huff Run. The site is located in Reach 5, where degradation of Huff Run begins. The site also presents a good opportunity to investigate and address a discharge that may be from the Brookville Coal and provides the challenge of working near the stream.

e) HR-31 (South Side Tipple Site)

HR-31 is a highly visible discharge area near Mineral City. Reclamation actions are currently planned to regrade much of the site and revegetate a large area of coal refuse. The extensive water quality data that has been collected at the site suggests that a low-cost passive treatment system could be utilized. ODNR has landowner cooperation at the site, and a remedial project could be undertaken quickly. Consequently, the project would be very good for gaining public support for restoration efforts in the watershed.

f) HR-33 (Lyons Site)

HR-33 is one of the highest contributors of AMD within the lower reaches of the watershed. Extensive water quality data is available and a water quality improvement project could be developed for the site that would help reduce acid loads to the lower reaches of Huff Run.

g) HR-17A (Harsha Site)

HR-17A is similar to HR-42 with respect to its location and chemistry. Site data indicates that a relatively low cost passive treatment project could be developed at the site to treat the discharge. The site's location and impact on Reach 4 also makes it desirable from a restoration standpoint.

h) HR-17B (Harsha Site)

HR-17B contributes large amounts of metals and acid to the upper end of Reach 3. Water quality and site data indicates that a passive treatment system at the site could be a cost effective project for reducing the loadings to Huff Run just below the Reach 4 area. A large amount of water quality data also exists for this site.

C. Investigation of AMD Problem Areas

1. Field Reconnaissance

Background geologic and mining information was collected for each problem area, and a reconnaissance and mapping exercise was conducted for the selected sites. The mapping consisted of locating and delineating significant features such as sample locations, discharges, hydrology, mining features, topography, cultural features and environmental features, such as existing wetlands. The mapping was conducted using a Trimble Pathfinder backpack-mounted global positioning system (GPS) unit. The sample GPS location data was downloaded, reduced and linked to the testing data. The GPS data was downloaded into the GIS and, along with information from existing maps and aerial photos, was used to generate mapping for each problem area.

During the reconnaissance, physical information about the site was recorded. General information, including discharge types, soil and rock types, mining types, presence and location of wetlands, receiving stream characteristics and site size and accessibility were documented to aid in map preparation and site evaluation. Individual site maps showing the existing features documented are presented in Figure 12, Figure 13, Figure 14 and Figure 15.

2. Site Characterization

The nine selected problem areas were investigated and mapped as part of the field reconnaissance. Individual site descriptions and information are provided below.

a) Problem Areas HR-16 and HR-12 (Harsha and Beldon Sites)

Problem Areas HR-16 and HR-12 are tributaries that enter Huff Run from the north side of Huff Run in Reach 4. The problem areas contain several discharges emanating from abandoned deep mines and runoff from surface mined areas that have heavily degraded both the HR-16 and HR-12 tributaries to Huff Run.

Water quality data collected at the two tributary monitoring points in March 1999 indicates the high flows exceed 0.24 cfs at HR-12 and 0.76 cfs at HR-16, with a low pH near 3, and elevated aluminum, iron, and manganese. Water quality data previously collected through June 1999 by ODNR at HR-16 is summarize as follows:

Parameter	Average	Minimum	Maximum
pH	3.2	3.0	3.4
Acidity (mg/l)	131	58	193
Iron (mg/l)	10.9	0.9	27.5
Aluminum (mg/l)	6.0	2.9	11.0

Manganese (mg/l)	23.8	13.9	47.1
Discharge (cfs)	0.56	0.03	1.04

Figure 12 presents a map of the existing conditions documented for HR-16 and HR-12. Abandoned mine features within the two problem areas include:

- Deep mines in the Lower Kittanning and Middle Kittanning coals,
- Contour surface mining in the Lower Kittanning and Middle Kittanning coals,
- Large exposed highwalls and impoundments in the Middle Kittanning coal,
- Extensive ungraded spoils and toxic coal refuse, and
- Deep mine discharges from both Lower and Middle Kittanning deep mines.

Reconnaissance of these areas indicated that AMD emanates from several discreet locations well upstream of the tributary sampling points. The locations of identified point sources are shown on Figure 12. ODNR has previously collected monitoring data at three locations within the HR-16 Problem Area. The water quality data collected through June 1999 is summarized below:

HR-15A

Parameter	Average	Minimum	Maximum
pH	3.5	3.2	3.6
Acidity (mg/l)	97	74	130
Iron (mg/l)	1.3	0.7	2.5
Aluminum (mg/l)	8.5	6.4	12.0
Manganese (mg/l)	8.8	7.6	9.7
Discharge (cfs)	0.05	0.00	0.16

HR-15B

Parameter	Average	Minimum	Maximum
pH	3.3	3.1	3.4
Acidity (mg/l)	184	133	237
Iron (mg/l)	19.7	11.5	25.5
Aluminum (mg/l)	10.2	8.5	12.0
Manganese (mg/l)	65.7	9.6	371.0
Discharge (cfs)	0.07	0.01	0.21

HR-16A

Parameter	Average	Minimum	Maximum
pH	3.8	3.4	5.2
Acidity (mg/l)	80	31	148
Iron (mg/l)	9.4	2.1	35.4
Aluminum (mg/l)	3.8	2.0	7.7
Manganese (mg/l)	19.2	16.3	25.4
Discharge (cfs)	0.07	0.02	0.22

Sites HR-15A and HR-16A are point sources apparently emanating from deep mine openings. HR-15B collects water from deep mine point sources as well as runoff from the unreclaimed surface mine spoils. These points however, represent only a small amount of the flow and contaminant load recorded for the HR-16 problem area.

Potential locations for passive treatment systems were identified at each site. A possible treatment location was identified for HR-16 that could allow the collection and treatment of flow at a centralized locations. Due to site restrictions, HR-12 would require separate treatment systems for the individual discharges within the problem area.

b) HR-13A and HR-13B (Linden Site)

Problem areas HR-13A and HR-13B, also known as the Linden Mine Site, are discharges that enters Huff Run in Reach 4. The HR-13A sampling point contains a single discharge emanating from a Lower and Middle Kittanning surface mined area with numerous impoundments. Indications are that deep mines may feed these impoundments from multiple locations. HR-13B is an alkaline discharge that enters Huff Run directly downstream of HR-13A. Reconnaissance of the area indicates that alkaline water flowing from a Middle Kittanning deep mine discharge mixes with AMD from a deep mine discharge and runoff from refuse associated with the Lower Kittanning coal.

Water quality data at the sampling points from the March 1999 sampling event indicated HR-13A had a monitored flow of approximately 0.09 cfs, a pH of approximately 5, and relatively low aluminum, iron, and manganese concentrations. HR-13B had a flow of approximately 0.18 cfs, a pH in excess of 6 and with considerable excess alkalinity (greater than 150 mg/L as $CaCO_3$).

ODNR-DMR has previously collected monthly water quality data at HR-13A. Water quality of the discharge through June 1999 is summarized below:

Parameter	Average	Minimum	Maximum
pH	5.6	4.4	6.8
Acidity (mg/l)	14	-21	56
Iron (mg/l)	5.7	0.8	18.7
Aluminum (mg/l)	0.8	0.1	1.5
Manganese (mg/l)	9.5	5.0	13.6
Discharge (cfs)	0.22	0.06	0.86

Figure 13 presents a map of the existing conditions documented for HR-13A and HR-13B. Specific site features of note include:

- Deep mines in both the Lower Kittanning and Middle Kittanning coals,
- Discharges that roughly correspond to the sites mine entries, and
- Extensive impoundments in Lower Kittanning and Middle Kittanning coal spoils above HR-13A.

Three potential passive treatment sites were located for the area. One site would allow for the collection and treatment of the both HR-13A and HR-13B at a central location. Such a scheme could be beneficial because of the high alkalinity present in HR-13B.

c) HR-42

Problem Area HR-42 is a single discharge located directly adjacent to the south side of Huff Run within Reach 5. Reconnaissance of the area indicated that the discharge appears to be an abandoned deep mine entry. The discharge forms a large plume of iron hydroxide precipitate that abuts Huff Run. Water quality data at the sampling point, indicated that the discharge had a flow of approximately 20 gpm, with elevated levels of acidity and very high levels of iron.

The site represents a possible discharge from an undocumented deep mine in the Brookville coal. The discharge location near Huff Run limits use of treatment options for the site due to the lack of space and hydraulic requirements. The location of HR-42 is shown on Figure 13.

d) HR-31 (South Side Tipple Site)

The HR-31 site is located within Reach 1 of Huff Run directly adjacent to Huff Run Road. The site contains the remnants of a tipple from a former deep mine in the Lower Kittanning Coal seam. The mine extracted both coal and clay, and was worked by multiple owners including the Federal Clay Products Co.

Limited contour strip mining in both the Middle and Lower Kittanning seam was conducted at the site as well. The site contains large amounts of unvegetated coal refuse from the tipple. Larger areas of strip mining are present flanking the site to the north and south. At least one impoundment in a Lower Kittanning surface mined area sits adjacent to the tipple site. A project to regrade this area and remove the impoundment, as well as regrade and vegetate the refuse at the tipple site is currently being pursued by ODNR-DMR .

AMD emanates from the site as both surface runoff and deep mine drainage to monitoring points HR-29, HR-30 and HR-31. The majority of drainage comes from a discrete deep mine discharge, HR-31A, which drains to both HR-30 and HR-31. This discharge does not correlate with the mine opening depicted on the abandoned deep mine maps, but appears to correspond in elevation to that of the surface mined Lower Kittanning Coal. The abandoned mine feeding the discharge is part of a network of mines in the adjacent hillside, and may be hydrologically connected to other sites, specifically Site HR-

33. Figure 14 presents a map showing the existing features documented in the problem area.

ODNR-DMR has been collecting monthly water quality data at HR-31A since June 1998. Water quality of the discharge through June 1999 is summarized below:

Parameter	Average	Minimum	Maximum	8/99
pH	3.5	3.14	5.7	5.3
DO (mg/l)	3.83	2.05	6.37	0.6
Acidity (mg/l)	97.4	61	143	143
Total Iron (mg/l)	70.6	42.0	111.0	103.0
Ferrous Iron (mg/l)	-	-	-	90.8
Aluminum (mg/l)	1.0	0.10	6.27	0.31
Manganese (mg/l)	14.7	10.2	18.3	16.2
Discharge (cfs)	0.083	0.025	0.136	0.025

To further characterize the discharge, samples were collected in August 1999 from a location directly at the HR-31A discharge to determine if the discharge was potentially anoxic. Previous sampling had been performed a small distance from the actual discharge point and was possibly affected by oxygenation of the water. The August 1999 data verified that the discharge is anoxic in nature, with a lower dissolved oxygen, higher pH and higher concentrations of ferrous iron than shown in the previous data. Collection of additional data prior to any final design is recommended to determine the long-term nature of the discharge.

e) HR-33 (Lyons Site)

The HR-33 site is located within Reach 2 of Huff Run. The site contains the remnants of extensive contour stripping in both the Middle and Lower Kittanning Coal. The site contains large amounts of unvegetated coal refuse possibly from a former deep mine opening in the Lower Kittanning that was located on the site.

One large impoundment in the Lower Kittanning surface mined area is impounded by spoil and refuse and has no surface outlet. Surface drainage from most of the surrounding area is directed into the impoundment. The impoundment is also likely fed by deep mine discharges. HR-33A appears to discharge from the base of this impoundment and is likely enhanced by deep mine discharges feeding the impoundment. The HR-33 sampling point is located downstream from here, collecting drainage from the entire site. Flows measured at HR-33 are significantly higher than HR-33A, indicating that flow comes from additional diffuse seepage sources that appear in the vicinity of HR-33A.

Several impoundments are located up-slope at the site in the Middle Kittanning strip benches. These impoundments show good quality water and intercept much of the up-slope drainage. Figure 14 presents the existing features observed at the site

ODNR-DMR has been collecting monthly water quality data at HR-33 and HR-33A since July 1998. Water quality of the samples through June 1999 is summarized below:

HR-33

Parameter	Average	Minimum	Maximum
pH	3.1	2.87	3.27
Acidity (mg/l)	213	172	282
Iron (mg/l)	34.3	22.7	58.5
Aluminum (mg/l)	8.4	4.0	13.1
Manganese (mg/l)	23.6	9.6	34.0
Discharge (cfs)	0.34	0.13	1.08

HR-33A

Parameter	Average	Minimum	Maximum
pH	3.18	2.96	3.49
Acidity (mg/l)	167	108	243
Iron (mg/l)	25.2	11.2	64
Aluminum (mg/l)	8.95	5.4	13.6
Manganese (mg/l)	13.8	7.1	18.8
Discharge (cfs)	0.196	0.064	0.3

f) HR-17A (Harsha Site)

Site HR-17A consists of an area of diffuse seepage and discrete discharges adjacent to Huff Run in Reach 4. Seepage emanates from two primary seeps and a large area of wet ground. Both appear to come from the base of a regraded area up-slope. There is no indication that the discharge corresponds to either that Lower or Middle Kittanning Coal seam elevations. The discharges are likely attributed to undocumented mining in the Brookville Coal seam or seepage from surface mining up-slope in the Lower Kittanning seam. The discharges are collected in a small ditch and discharged through a pipe to Huff Run. Initial surveying done at the site indicates that there is approximately 40 ft between the discharge area and Huff Run, with only 4 to 5 feet of elevation between the discharge and the bottom of the stream. A map of the existing features documented at the site is presented in Figure 15.

ODNR-DMR has been collecting monthly water quality data at HR-17A since November 1998. Water quality of the discharge through June 1999 is summarized below:

Parameter	Average	Minimum	Maximum	8/99
pH	3.72	3.09	5.7	5.3
DO (mg/l)	2.75	0.4	4.65	1.6
Acidity (mg/l)	292.1	205	354	316
Total Iron (mg/l)	140	57.3	181.0	180.0
Ferrous Iron (mg/l)	-	-	-	144
Aluminum (mg/l)	0.85	0.10	3.49	0.44
Manganese (mg/l)	45.0	28.8	53.8	53.8
Discharge (cfs)	0.044	0.023	0.074	0.023

To further characterize the discharge, samples were collected in August 1999 from a location directly at the discharge to determine if the discharge was potentially anoxic. Previous sampling had been performed a small distance from the actual discharge point and was possibly affected by oxygenation of the water. The August 1999 data indicates that the discharge is anoxic in nature, with a lower dissolved oxygen, higher pH and higher concentrations of ferrous iron than shown in the previous data. Collection of additional data prior to any final design is recommended to determine the long-term nature of the discharge.

g) HR-17B (Harsha Site)

Site HR-17B consists of a discrete discharge and a line of diffuse seepage adjacent to Huff Run in Reach 3. The site is located directly adjacent to a permitted treatment pond for an active operation next to the site. Seepage emanates from the ground from a primary seep having the appearance of a mine portal. Investigation of the site indicated that a large line of seepage and wet ground extends from the seep, apparently along the toe of spoil of a previously mined area. A regraded and vegetated area up-slope drains to the active ponds; two discharges near and at the same elevation as HR-17B drain to the ponds as well. There is no indication that the discharges correspond to either the Lower or Middle Kittanning Coal seam elevations. The discharges could be attributed to undocumented mining in the Brookville Coal seam, but are likely seepage from surface mining up-slope in the Lower Kittanning seam. The HR-17B discharge flows directly to Huff Run. A map of the existing conditions documented at the site is presented as Figure 15.

Reconnaissance information collected for this report indicates that the site has limited space given the active ponds and adjacent drainage. Approximately 14 ft of elevation exists between the discharge and Huff, so construction of some type of passive system at the site is possible

ODNR-DMR has been collecting monthly water quality data at HR-17B since November 1998. Water quality of the discharge through June 1999 is summarized below:

Parameter	Average	Minimum	Maximum
pH	3.26	2.83	5.7
Acidity (mg/l)	593	457	758
Iron (mg/l)	216	52.3	277
Aluminum (mg/l)	11.7	3.56	29.6
Manganese (mg/l)	70.1	33.0	84.0
Discharge (cfs)	0.028	0.005	0.067

Flow was frequently qualitatively estimated due to the diffuse flow of the discharge. As a result, additional measurements to characterize discharge flows will be necessary prior to final design.

IV. An identification of individual projects and the measures proposed to be undertaken to abate and treat the causes and effects of acid mine drainage within the hydrologic unit.

A. Applicable Remedial Measures

Various remedial alternatives were considered in the evaluation of projects within the five problem areas selected as priority sites. Remedial alternatives for these types of problems include site reclamation, passive treatment, active treatment and instream measures. This study considered primarily reclamation and passive measures. Active treatment options were not considered desirable due to long-term operation and maintenance costs. Instream treatment measures were also not considered because most cannot provide for metal precipitate removal, which has been determined to be a primary objective of this restoration plan.

1. Site Reclamation

Site reclamation is commonly used for abandoned mine sites that were not fully reclaimed following coal extraction or disposal. Typically, these sites were mined prior to passage of the state and federal surface mining laws mandating concurrent reclamation; recent sites involve bankruptcy and/or bond forfeitures of permitted sites. These types of sites are typically left ungraded and unvegetated, and have poor drainage. Often, these sites have exposed highwall cuts and unstable fill slopes. The intent of these activities would be to limit or prevent contact of water with acid forming materials or preclude the passage of oxygen to the subsurface, thus preventing the formation and release of AMD.

Water source control measures are also employed in site reclamation to keep water from contacting and infiltrating acid generating materials on abandoned mined lands, thereby preventing and/or reducing AMD discharges. Mine seals are used to exclude passage of air to the deep mine preventing oxygen from contacting acid-producing minerals where AMD can be produced. They are also used to prevent or control the flow of water at deep mine openings.

Some common reclamation practices include:

<u>Backfilling, Grading and Revegetation</u> — Backfilling, grading and revegetation are common reclamation techniques normally used in combination to address abandoned mine lands and can have positive effects on AMD quantity and quality. Backfilling activities on abandoned mine sites can involve material segregation to isolate acid-producing materials and introduction of alkaline additions (e.g., fly ash and limestone) in the spoil or refuse to aid in buffering waters to inhibit AMD production and neutralize AMD produced. Grading activities are intended to return sites to previous topography or create stable slopes which, when used in combination with diversion channels, can aid in directing stormwater from the site. Revegetation of mine sites often involves topsoiling and soil amendments (e.g., fertilizers, lime and biosolids) to provide conditions for plant growth and soil development. This can also aid in minimizing AMD production by increasing evapotranspiration losses, decreasing oxygen exchange to the spoil/refuse and adding buffering capacity to infiltrating waters.

<u>Remining</u> — Remining is a technique employed where shallow underground mines, abandoned surface mines and coal refuse piles are reopened, using surface mining techniques, to extract remaining coal resources. Coal and coal by-products are frequently a significant contributor to AMD formation in these sites. By removing these materials and reclaiming the site with the above techniques, remining can substantially reduce AMD production, and result in reduced infiltration and pyrite oxidation.

<u>Diversion/Isolation of Water</u> — Diversion/isolation of water techniques prevent surface waters (e.g., streams) from entering or contacting underground mines, mine spoil and/or mine refuse. The methods employed involve new stream channel construction, stream channel lining, retaining wall construction, contact surface lining and stream bed grouting.

Stormwater Interception — Stormwater interception is commonly employed with site reclamation, but can be employed separately. Channels are constructed up-slope of the site and/or at various intervals on the site to collect and channel stormwater runoff from a site. This approach prevents the storm flow from infiltrating into the underground mine workings, mine spoil and/or mine refuse were it can contact acid-producing minerals and produce AMD, reducing the volume and possibly the improving the quality of the AMD. Stormwater interception also benefits abandoned mined lands by decreasing erosion and sedimentation.

Barriers — Barriers are normally placed on top of mine spoil or refuse materials to prevent precipitation and oxygen from contacting the mine spoil and refuse material. This will prevent AMD formation by removing agents that are needed for the acid-producing reactions. Materials used to create barriers are typically geosynthetic materials or natural soil materials, such as compacted clay soils. Grouting barriers have been employed to create a vertical barrier (along a highwall) preventing lateral groundwater flow into the mine spoil and refuse. A grout barrier is created by injecting the grout, as a liquid, in regularly space bore holes along the highwall face.

Dry Mine Seals — Dry seals are placed in openings to prevent oxygen and water passage into the mine. These seals are suitable for openings where there is no discharge water flow that can result in hydrostatic pressure and failure (blow-out) of the mine seal. Dry seals are often constructed on vertical shafts that were built into mine workings to provide ventilation and access.

Wet Mine Seals — Wet seals are designed to prevent the passage of oxygen into the mine while allowing normal mine discharge to flow through the discharge outlet. The discharge outlets in the wet seal are provided with air traps to prevent inflow of air. Wet seals can also be designed to control the discharge flow from a mine opening and are often used in combination with treatment systems at deep mine discharges.

Hydraulic Wet Seal — A variation to the wet seal is a hydraulic seal which prevents air and water flow in either direction. The intent of the hydraulic seal is to flood the mine workings saturating the acid-producing materials in an anoxic environment, thereby reducing the formation of AMD and preventing it from discharging from the mine workings. Failure of a hydraulic seal can result in catastrophic impacts to receiving waters and could potentially be a safety hazard.

2. Passive Treatment

Passive systems for the treatment of AMD include a number of viable treatment technologies which have been developed within the last fifteen years. Passive systems use a variety of substrates, plants, and hydraulic/hydrologic designs to remediate mine drainage via a number of chemical (e.g., precipitation, oxidation, and hydrolysis) and biological processes (e.g., microbial oxidation and reduction). The different passive treatment designs are capable of removing metals (e.g., aluminum, iron, manganese and trace metals) and/or acidity from the mine drainage. Accordingly, these systems provide long-term, low-maintenance treatment and stream restoration.

Given the current body of knowledge of these systems, the goals of this study and the general conditions in the watershed, six passive treatment methods were appropriate for consideration. These methods are the aerobic surface flow wetlands, anaerobic surface flow wetland, anaerobic vertical flow wetland, aerobic vertical flow wetland and anoxic limestone drain. A brief description of each system is provided below. Figure 16 provides a schematic profile and Table 4 lists the design limitations of each system.

Aerobic Surface Flow Wetlands — Aerobic surface flow wetlands are systems normally employed to oxidize, hydrolyze and precipitate metals (e.g., iron and manganese) from alkaline mine waters. This type of system has also been successful at decreasing metals in acidic mine drainage; although rates of removal require substantially larger surface areas. Aerobic wetlands employed by Brodie (1991) contain open water and emergent vegetation (e.g., cattails and rushes) planted in inert soils. Recently constructed systems evaluated by Hedin et al. (1994) and by Dietz (1993) have employed inert stone as the only substrate and have been successful at removing manganese in alkaline discharges and iron from acidic mine waters.

Anaerobic Surface Flow Wetlands — Anaerobic surface flow wetlands are systems that have been successful at removing metals (i.e., aluminum and iron), similar to aerobic surface flow wetlands, and have also had limited success at reducing acidity from mine waters (Hedin et al. 1994; and Dietz et al. 1994). Anaerobic surface flow wetlands contain an organic substrate (e.g., spent mushroom compost) planted with emergent vegetation and variable standing water from one inch to one foot. A number of processes including oxidation, sulfide precipitation, hydrolysis, and absorption have been suggested as important in metal removal within this type of system. Microbial sulfate reduction has been identified as the principal process producing alkalinity.

Anaerobic Vertical Flow Wetlands — Vertical flow wetlands, also known as SAPS, are a relatively recent development in passive treatment technology to remediate acidic mine waters. This type of wetland has achieved substantial acidity removal and alkalinity production for applications in highly acidic (greater than 200 mg/L as $CaCO_3$) mine waters (Dietz and Stidinger 1996; and Kepler and McCleary 1994). This wetland design has also been successful in removing iron and aluminum from highly acidic mine waters. Vertical flow wetlands consist of an organic substrate layer (e.g., spent mushroom compost) placed over a limestone layer. An under drain piping system placed beneath the limestone layer collects the water that has passed through the substrate layers. Vertical flow wetlands may or may not be planted with emergent vegetation and contain standing water from less than one, to greater than three feet. They are often designed and constructed using multi-cell systems. Processes previously mentioned for anaerobic surface flow wetlands, as well as limestone dissolution, have been identified as important mechanisms of mine water remediation in vertical flow wetlands.

Aerobic Vertical Flow Wetlands — This innovative wetland design is similar to the anaerobic vertical flow wetland; however, the organic substrate layer is not needed due to low metal concentrations. The methodology and design of these systems are based on existing open limestone channel (OLC) and anoxic limestone drain (ALD) technology.

Anoxic Limestone Drains — Anoxic limestone drains (ALD), have been used exclusively in remediating AMD. ALDs studied by Hedin et al. (1994) and Brodie et al. (1991) have produced substantial alkalinity which is important in neutralizing acidity and in the hydrolysis and precipitation of iron and aluminum, although ferric iron (greater than 2 mg/L) and aluminum (greater than 5 mg/L) have been found to be detrimental to the long-term performance of ALDs. The systems consist of trenches or basins filled with limestone that are sealed and buried to prevent oxygenation of the mine drainage that can cause armoring of the limestone and/or clogging of the ALD. Mine drainage passes through the trench or basin where calcium carbonate is solubilized from the limestone producing the alkalinity responsible for neutralization of mine water acidity and precipitation of iron and aluminum. ALDs are typically used in combination with aerobic and anaerobic surface flow wetlands which hydrolyze and precipitate iron from the AMD.

Anaerobic Subsurface Flow Wetland — Anaerobic subsurface flow wetlands are systems similar to the design of anaerobic surface flow wetlands except that water flows subsurface in the organic substrate. The systems have been successful at lowering metals (i.e., aluminum and iron), similar to anaerobic surface flow wetlands. In addition, the subsurface flow may slightly improve treatment over anaerobic surface flow wetlands by increasing removal of acidity from mine waters (Hellier 1996; and Dietz *et al.* 1993). Anaerobic subsurface flow wetlands contain an organic substrate (e.g., spent mushroom compost) that may be planted with emergent vegetation. The water level is located from one inch to one foot at depth within the organic substrate. A number of processes including iron reduction, sulfide and carbonate precipitation, and absorption have been suggested as being important in metal removal within this type of system. Microbial sulfate reduction and carbonate dissolution (a component of spent mushroom compost) has been identified as the principal processes producing alkalinity.

An innovative use of anaerobic subsurface flow wetlands is as a pretreatment prior to an ALD to reduce oxidized ferric iron to ferrous iron. This application would be considered experimental. The reducing environment reported by Dietz *et al.* 1993b in spent mushroom compost should be adequate to reduce ferric iron to ferrous iron, a necessary process to prevent precipitation of iron hydroxides in an ALD. Utilizing permeability and retention information reported for spent mushroom compost, along with adequate flow control systems, should permit the use of this passive wetland treatment design as a pretreatment to minimize the impacts of ferric iron on an ALD.

B. Project Formulation

Reclamation and passive treatment projects were formulated that were potentially capable of achieving the stated restoration goals. The only projects considered were those directly related to the sites previously identified. The projects were formulated and selected for conceptualization based on the site conditions, and discussions held with ODNR and the HRWRP. A discussion of the projects formulated for the individual sites follows. Potential passive treatment projects were selected based on the criteria presented in Table 4.

The formulation/conceptualization process involved a number of steps to develop an appropriate plan for the selected sites. These steps included:

- Development of GIS base mapping
- Development typical sections and details
- Evaluation of possible treatment options
- Design of approximate size, location and cost of project elements

C. Conceptual Project Layouts and Designs

1. Problem Area HR-16 (Harsha Site)

The remediation methods applicable for abating the water quality impacts from HR-16 should include a combination of reclamation and treatment options. Reclamation actions involving remining, regrading, and reclamation of portions of the site are currently being planned by ODNR. The current proposed limits of AML reclamation are shown on Figure 17. These actions would likely reduce the AMD flow and/or strength but will not entirely eliminate the water quality impacts on Huff Run.

Treatment of the major contributing discharges using passive wetland treatment systems is recommended. Passive treatment has been found to provide successful treatment of AMD with characteristics similar to that of the degraded water quality found at the HR-16 sampling location. Treatment of the multi-point AMD can be accomplished by treating the combined discreet points at a location where all inputs can be collected. This approach may include higher storm flows and sediment loading which can be addressed in the design by including a settling basin with a high flow bypass prior to the passive treatment system.

Treatment of HR-16 discharges will require a passive treatment system capable of generating alkalinity. In addition to alkalinity generation, the passive treatment system must be capable of lowering the metal concentrations of iron and aluminum. The limitations of each technology are presented in Table 4. The elevated aluminum (2.9 mg/L) and iron (7.8 mg/L) measured at HR- 16 will require the anaerobic vertical flow wetland technology. This system is capable of treating the acidity levels found at HR-16 and providing excess alkalinity (between 100 and 200 mg/L as $CaCO_3$). In addition, this technology has proven to be effective at lowering metal concentrations.

The conceptual location and layout for the anaerobic vertical flow wetland is depicted in Figure 17. As indicated, collection channels and piping will be required to convey the AMD discharges to the system, a settling/detention basin equipped with a high flow bypass for excessive storm flows prior to entering the system will also be needed to collect runoff from the rest of the catchment area. Permanent channels and culvert piping will be required to convey the site discharges to the proposed treatment area.

Data from the March 1999 sampling program at HR-16 and additional data available from ODNR for this site was used to estimate treatment area size; additional sampling may be necessary to characterize the discharge prior to final design. An acid loading of 244,750 GPD (grams per day) was used to determine the treatment area required for the vertical flow wetland treatment system to achieve a zero acidity for the entire site. An acid removal rate of 25 GDM (grams per day per square meter) was used to determine total treatment area size. A design model developed by Gannett Fleming was used to determine optimal number of cells and treatment area in each cell within the vertical flow system. The model considers acid loading, hydraulic detention time and effluent quality from the vertical flow wetland treatment cell; with an assumed alkalinity of 100 mg/L from the underdrain of vertical flow wetland treatment systems.

A multi-cell vertical flow wetland that would achieve prescribed effluent alkalinity would consist of three cells of varying size; Cell 1 containing 22,000 ft^2, Cell 2 containing 18,000 ft^2, and Cell 3 containing 14,000 ft^2. A multi-cell design has several advantages including substantially greater effluent alkalinity and lower metal levels than a single cell design would achieve. In addition, the long term operation and treatment effectiveness is likely to be improved in a multi-cell system containing redundant components. A typical cross section of a proposed treatment cell system is shown as Figure 18.

2. Problem Area HR-12 (Beldon Site)

The remedial methods required for addressing the water quality impacts from HR-12 include both reclamation and treatment actions. Like site HR-16, HR-12 may be developed for future remining or AML projects. Similarly, any reclamation actions in the project area would likely reduce the AMD flow and/or strength but may not entirely eliminate the impacts on water quality in Huff Run. Consequently, treatment of the major contributing discharges using passive wetland treatment systems is also recommended.

Passive treatment has been found to provide successful treatment of AMD with characteristics similar to that of the degraded water quality found at HR-12. Unfortunately, treatment of all of the individual discharges in this area may not be possible at a centrally located site. The treatment of the multiple discharges can be accomplished by diverting as many discharges as possible to the treatment site, and discharging to the HR-12 sampling location. Production of excess alkalinity can be designed into individual treatment system(s) to neutralize untreated AMD. A settling basin or catchment basin could be included at a location downstream of the AMD inputs to remove precipitated metals from the untreated AMD discharge points.

Treatment of the HR-12 AMD discharge location(s) will require a passive treatment system capable of generating alkalinity. In addition to alkalinity generation, the passive treatment system must be capable of lowering the metal concentrations of iron and aluminum. The limitations of each technology was presented in Table 4. The anaerobic vertical flow wetland technology is capable of treating the acidity found in the HR-12 sampling location and providing excess alkalinity (between 100 and 200 mg/L as $CaCO_3$).

In addition, this technology has proven to be effective at lowering metal concentrations. Therefore, the anaerobic vertical flow wetland design is recommended to treat HR-12 AMD.

The conceptual location and layout for the anaerobic vertical flow wetland system is depicted in Figure 17. Additional reclamation actions may be required to develop this project. These conceptual measures, shown on Figure 17, include:

- Draining, regrading and revegetating the existing ponds in the Lower and Middle Kittanning Strip benches adjacent to the treatment system.
- Redirecting and channelizing flow to the treatment system that currently drains to HR-16.
- Installation of a buried highwall seal along the existing Lower Kittanning highwall to reduce seepage and back-up flow to existing discharges.

Data from the March 1999 sampling program at HR-12 and additional data available for this site was used to estimate treatment area size; additional sampling will be necessary to characterize the discharge prior to final design. An acid loading of 116,700 GPD was used to estimate the treatment area required for the vertical flow wetland treatment system to achieve a zero acidity at the HR-12 sample location. This sizing produces excess alkalinity to neutralize other AMD discharges contributing to flow at HR-12. Acid loading was used because acid removal has been demonstrated to be a reliable parameter on which to estimate vertical flow wetland size. An acid removal rate of 25 GDM was used to determine total treatment area size; actual acidity removal is likely to be greater than this value. A design model developed by Gannett Fleming was used to determine optimal number of cells and treatment area in each cell within the vertical flow system. The model considers acid loading, hydraulic detention time and effluent quality from the vertical flow wetland treatment cell; with an assumed alkalinity of 100 mg/L from the underdrain of vertical flow wetland treatment systems.

A multi-cell, vertical flow wetland consisting of three cells of varying size can achieve the required effluent alkalinity. The system would require cells containing 12,000 ft^2, 11,000 ft^2, and 6,000 ft^2 of treatment area. A multi-cell design will yield substantially greater effluent alkalinity and will remove metals to lower concentrations than a single cell design. In addition, the long term operation and treatment effectiveness is likely to be improved in a multi-cell system containing redundant components. A typical cross section of a proposed treatment cell system is shown as Figure 18.

3. Problem Areas HR-13A and HR-13B (Linden Site)

The proximity of the two discharges provides the possibility of combining the two discharges into a single flow. Mixing an acidic water with an alkaline water has the potential of producing a net alkaline water, if alkalinity in HR-13B discharges are adequate to neutralize the acidity contained in the HR-13A discharge. The estimated acid load from HR-13A during the March 1999 sampling was 17,250 GPD while the alkaline load contained in HR-13B was 56,100 GPD. Consequently, HR-13B contains twice the necessary alkalinity to neutralize the discharge, indicating that the mixed discharges will remain alkaline, thereby simplifying treatment of the combined discharges. Continued sampling of both sites will be required to verify that alkalinity exceeds acidity during other flow conditions.

The two sites can be easily treated using an aerobic surface flow wetland. This would be the only required technology because treatment of the combined flow is reduced to oxidation and precipitation of iron. Aerobic wetlands consisting of deep open water and emergent wetlands have been proven to be very successful at treating alkaline mine drainage containing iron.

The conceptual design for the aerobic surface flow wetland is depicted in Figure 19. Site regrading and rip rap channels will be required to convey the HR-13A and HR-13B sources to the treatment site.

The March 1999 water quality data and additional data available for HR-13A was used to determine the iron loading. An iron load of 2,080 GPD and an iron removal rate of 10 GDM were used to estimate the surface area required for the aerobic wetland treatment system. However, due to the low iron concentrations, iron loading may not be reliable for determining adequate treatment area and volume. Predicted surface areas and volumes using this removal rate are likely to result in substantial velocities that may cause shear forces preventing particulate iron from settling. To overcome this problem, volumes and surface areas were determined using an estimated retention time of approximately 12 hours. The retention time was divided into a two-cell system consisting of an initial deeper open water pond followed by a shallow water emergent wetland. The open water pond will contain 4,000 ft^2 with an approximate 4 feet depth. The emergent wetland will contain 8,000 ft^2 with a water depth of approximately 2 feet. A layer of organic substrate will be included in the emergent wetland to enhance plant growth and metal removal. A cross section of the proposed aerobic surface flow cell design is depicted in Figure 20.

4. Problem Area HR-42

Figure 19 shows the location of the HR-42 discharge with respect to Huff Run. The proximity of HR-42 to Huff Run severely limits the remedial measures that may be applicable to the site. Any type of treatment system is severely limited by the lack of sufficient space between the discharge and the stream. Also, the elevation of the discharge will not likely provide sufficient head for a passive treatment system without pumping the effluent. Consequently, the most feasible option for the site is to attempt to eliminate or reduce the discharge flow or loads by installing a hydraulic seal. The site appears to be a good candidate for such a seal because of the area is isolated and the mining is likely very localized. The risk of damage from a blow-out of the seal or the adjacent ground would be limited to a possible catastrophic discharge to Huff Run.

The seal could consist of a concrete plug, sized to withstand pressure from a given head in the mine, buried along the face of the discharge. The seal would need an overflow drain to control the elevation of the water in the mine behind the seal. Additionally, frequent monitoring of the static water levels in the mine via subsurface piezometers would be required. Figure 21 presents a conceptual cross section of the proposed seal. The seal conceptualized was sized to withstand a head of five feet of water above the existing mine roof elevation. Final design for the proposed seal would require a thorough subsurface investigation and characterization of the soil, rock, groundwater and mine conditions.

5. Problem Area HR-31 (South Side Tipple Site)

The currently planned reclamation actions for the site should be sufficient to eliminate contaminated runoff to locations HR-29 and HR-30. Abatement of the HR-31A drainage will require the construction of a passive wetland treatment system to remove acidity and metals. The high discharge pH (> 5), minimal aluminum concentration (< 5 mg/L), low dissolved oxygen (< 2 mg/L) and high ferrous iron percentage of total iron (> 90 %) at HR-31A should allow for the use of an anoxic limestone drain (ALD). An ALD is typically the most cost effective and reliable passive treatment technology for alkalinity generation when discharge conditions do not limit its use. To account for the remaining ferric iron content present in the current discharge, an anaerobic subsurface flow cell has been included. The anaerobic cell is an innovative technology, intended to reduce ferric iron levels entering the ALD. A plan of the proposed project elements is attached as Figure 22. Figure 24 presents a schematic section of the proposed anaerobic subsurface flow cell.

Discharge characteristics indicate that an ALD will likely produce sufficient alkalinity (between 100 and 200 mg/L) to produce a net alkaline water. In addition to the ALD, the discharge will require an aerobic surface flow wetland to remove metals from the ALD treated discharge. Because of the high alkalinity expected in the ALD treated discharge, the aerobic surface flow wetland should consist of a deep (4 to 5 feet) open water pond to allow for oxidation and settling of the iron in the discharge.

The conceptual design for the anaerobic cell, ALD, and aerobic wetland will be to install a wet mine seal to collect the HR-31A discharge and convey it to the anaerobic cell/ALD. The ALD treated discharge will be collected in a collection pipe located at the effluent end of the ALD and will be piped to a channel that will convey the discharge to the aerobic wetland. The channel will contain rock material and splash areas which will aid in the oxidation and precipitation of iron. The aerobic wetland will receive this oxygenated water containing soluble and particulate iron and will allow for continued oxidation, precipitation and settling of the iron in the discharge.

The average flow rate of 38 gpm (0.083 cfs) was used to determine the ALD volume for a contact time of 16 hours, resulting in an ALD volume of 12,000 ft^3. The anaerobic cell volume of 17,500 ft^3 was based on the same flow rate and a contact time of 10 hours The single cell, aerobic wetland was sized using the 20 GDM removal rate and the average discharge flow and iron concentration. The surface area necessary to remove the iron concentration of the ALD treated discharge would be approximately 8,000 ft^2. Maintenance may be necessary to remove solids from the wetland periodically.

Prior to pursuing a project at this site, additional investigation of the ferric iron content of the discharge may be warranted. This could include the installation of a sampling well upslope from the discharge to sample the water prior to its discharge. Another option is to construct the wet mine seal prior to the passive treatment system. The would enable the sampling of the actual water which would be treated by the passive treatment system.

It is also recommended that an additional hydrologic investigation be undertaken to determine its relationship to other sites within the vicinity (HR-33). This investigation would include evaluating the exiting water quality and discharge data from the sites. It may also include items such as: aerial mapping of the sites, well installation, monitoring and sampling of the mine pool(s), monitoring of surface flows, precipitation monitoring, or tracer testing. The intent of the study would be to determine if changes in hydrology at these other sites due to reclamation activities would change the hydrology and chemistry of HR-31A. Costs for the study have been estimated and included in the cost estimate for HR-31.

6. Problem Area HR-33 (Lyons Site)

Because of the extensive surface disturbance, impounded water, and diffuse seepage at the site, reclamation and water control activities are recommended for the site. Abatement of the HR-33A drainage will likely require the construction of a passive wetland treatment system to remove acidity and metals. An anaerobic vertical flow wetland is recommended to treat the acidity levels and provide excess alkalinity. In addition, this technology has proven to be effective at lowering metal concentrations. Figure 22 presents a plan of the proposed reclamation actions and the passive treatment system.

Reclamation actions recommended for the site include removal of the existing impoundment and backfilling of the existing highwall using on-site materials. Prior to backfilling, wet mine seals and a subsurface drain will likely be required along the highwall to promote drainage. Establishment of a drainage channel around the existing spoil to carry storm flows through the site will also be required. Reclaimed areas can be revegetated using soil from stripped areas in the Middle Kittanning Coal seam. This stage of the project would also include construction of a permanent access road into the site. It should be noted that given the elevations of the existing impoundment and the extent of the abandoned deep mine at this location, HR-33 discharges could be connected hydrologically with site HR-31. Further investigation of this is recommended prior to the removal of the impoundment and the subsequent change in the hydrologic conditions.

Data from HR-33 were used to estimate treatment area size for the passive treatment system. The average acid loading of 177,600 GPD was used to determine the treatment area required for the vertical flow wetland treatment system to achieve a zero acidity. An acidity removal rate of 25 GDM was used to determine total treatment area size. A two-cell vertical flow wetland was designed containing a total treatment area of 45,000 ft^2. This multi-cell design will have several advantages including substantially greater effluent alkalinity and lower metal levels than a single cell design would achieve. However, this two cell treatment system was determined to be inadequate to treat higher than average flows (95% Upper Confidence Limit = 240 gpm) and as a result a third cell was included in the design to achieve a net alkaline water at this flow. The three vertical treatment cells included in the system had a total treatment area of 65,000 ft^2. The long term operation and treatment effectiveness is likely to be improved in a multi-cell system containing redundant components.

Again, it should be noted that the treatment system was sized based on the data collected at HR-33. This data is likely conservative with respect to the sizing of the treatment system. Additional sampling should be considered to characterize the discharge following any site reclamation activities which might reduce the flows or change the water quality at HR-33

Estimated costs for the proposed actions at HR-33 are presented in the subsequent section as two separate projects to correspond with: 1) the reclamation activities and 2) the treatment system.

7. Problem Area HR-17A (Harsha Site)

The discreet nature of the HR-16A discharge and the lack of any significant mining features at the site indicates that a passive system is likely the best way to improve the water quality at HR-17A. The high discharge pH (> 5), minimal aluminum concentration (< 5 mg/L), low dissolved oxygen (< 2 mg/L) and high ferrous iron percentage of total iron (> 80 %) should allow for the use of an ALD. An ALD is typically the most cost effective and reliable passive treatment technology for alkalinity generation when discharge conditions do not limit its use. Additionally, an aerobic surface flow wetland is recommended to remove metals from the ALD treated discharge. The preliminary survey data collected indicates that the ALD/aerobic wetland will be constructable at the site. Aplan of the proposed treatment system is presented in Figure 23.

Drainage from the site will be collected in a subsurface drain and piped to the ALD. The ALD treated discharge will be collected and piped to a channel that will convey the discharge to the aerobic wetland. The channel will containing rock material and splash areas which will aid in the oxidation and precipitation of iron. The aerobic wetland will receive this oxygenated water containing soluble and particulate iron and will allow for continued oxidation, precipitation and settling of the iron in the discharge. Additionally, an anaerobic subsurface flow cell could be utilized as pretreatment for the proposed ALD if necessary. Additional investigation of the ferric iron content of the discharge may be required to determine this.

The discharge characteristics indicate that an ALD will not likely produce sufficient alkalinity (between 100 and 200 mg/L) to produce a net alkaline water. If required, additional alkalinity could be generated using an anaerobic vertical flow wetland cell, which was included in the conceptual design. Current site constraints indicate that the ALD and aerobic wetland can be placed on the current site. Space and head limitations may reduce the effectiveness of the aerobic wetland to oxidize metals and may prohibit the use of the vertical flow cell to add additional alkalinity.

The average flow rate of 20 gpm (0.045 cfs) was used to determine an ALD volume of 10,000 ft^3 for a contact time of 16 hours. The single cell, aerobic wetland was sized using a 20 GDM removal rate and the average discharge flow and iron concentration. Based on the average iron loading, the surface area necessary to remove the iron concentration of the ALD treated discharge would be approximately 8,000 ft^2. Maintenance may be necessary to remove solids periodically from the wetland.

To add additional alkalinity to the system following the aerobic wetland, a vertical flow wetland could be considered if site constraints permit. Installation of the ALD would result in approximately 100 mg/L of acidity remaining after treatment. Using this acidity and average flow, a surface area for a single cell vertical flow wetland to produce a net alkaline water was estimated to be 6,000 ft^2. An additional aerobic wetland following the vertical flow cell will also be required to remove remaining iron from the treated water. Based on the estimated average effluent iron concentration of 50 mg/L from the anaerobic vertical flow wetland, an additional aerobic wetland with a surface area of approximately 6,000 ft^2 is required. Again, it should be noted that current space and head limitation at this site may inhibit the use of the additional vertical flow and aerobic cells at the site, resulting in a reduced level of treatment. A more detailed survey of the site will be required to determine this.

8. Problem Area HR-17B (Harsha Site)

Due to the discreet nature of HR-17B discharge, the adjacent permitted operations and reclaimed areas, treatment of the discharge s the best solution for improving the water quality from the site. The elevated aluminum (12 mg/L) and iron (210 mg/L) measured at HR-17B are likely to require an anaerobic vertical flow wetland to reduce the acidity levels, provide excess alkalinity, and lower metal concentrations. This technology may be limited by the high iron concentrations but can be utilized where pretreatment reduces influent iron to acceptable levels. A plan of the proposed treatment system is presented in Figure 23.

A subsurface drain will collect and convey the drainage to a 10,000 ft^2 pretreatment aerobic wetland to remove high iron levels contained in the discharge. The aerobic wetland cell should reduce iron concentrations to acceptable levels for the vertical flow wetland. Data available from ODNR-DMR for this location were used to estimate treatment area size. The average acid loading of 41,000 GPD was used to determine the treatment area required for the vertical flow wetland treatment system to achieve a zero acidity. An acidity removal rate of 25 GDM was used to determine total treatment area size. A multi-cell vertical flow wetland is recommended consisting of two cells of varying size containing a total treatment area of 23,000 ft^2. This multi-cell design will have several advantages including substantially greater effluent alkalinity and lower metal levels than a single cell design would achieve. The long term operation and treatment effectiveness is likely to be improved in a multi-cell system containing redundant components.

It should be noted that the conceptual design presented herein is based on estimated flows that were measured visually. Verification of the flows at the site will be required to utilize this data for final design. Consequently, the size of the final system could be significantly different. Another issue could be the limited space between the discharge, the existing pond and the stream. This could require modifying the system to meet the site constraints, resulting in a smaller system with a reduced level of treatment. A more detailed survey of the site will be required to verify this.

V. The cost of undertaking the proposed abatement and treatment measures, and analysis of the cost effectiveness and environmental benefits.

A. Estimated Project Costs

Preliminary cost estimates for each of the conceptualized projects were prepared for project comparison. The cost estimates were developed using standardized unit prices. Where possible, the unit prices were developed to correspond with existing ODNR pay units. Final engineering and design costs were estimated to be 15 to 20 percent of construction costs, including the cost of additional investigations. All project costs presented in the cost tables annualized to account for future project cost at an annual rate of 7.375 percent. Future project costs associated with O&M were annualized by averaging the costs over the design life of the projects. The assumed design life of all of the projects was 25 years. It was assumed that no real estate acquisition costs will be incurred for the projects.

1. HR-16 Passive Treatment System

A conceptual-level construction cost estimate for the proposed project is provided in Table 5. Capital costs for the project based on the conceptual level design are estimated to be approximately $424,000 (1999 dollars). The total annual equivalent cost, including, construction, design and O&M costs, would be $40,900.

2. HR-12 Reclamation and Passive Treatment System

A conceptual-level construction cost estimate for the proposed project is provided in Table 6. Capital costs for the project based on the conceptual level design are estimated to be approximately $576,000 (1999 dollars). The total annual equivalent cost, including, construction, design and O&M costs, would be $55,600.

3. HR-13A and HR-13B Passive Treatment System

A conceptual-level construction cost estimate for the proposed project is provided in Table 7. Capital costs for the project based on the conceptual level design are estimated to be approximately $71,500 (1999 dollars). The total annual equivalent cost, including, construction, design and O&M costs, would be $9,220.

4. HR-42 Mine Seal

A conceptual-level construction cost estimate for the proposed project is provided in Table 8. Capital costs for the project based on the conceptual level design are estimated to be approximately $173,000 (1999 dollars). The total annual equivalent cost, including, construction, design and O&M costs, would be $16,600.

5. HR-31 Passive Treatment System

A conceptual-level construction cost estimate for the proposed project is provided in Table 9. Capital costs for the project based on the conceptual level design are estimated to be approximately $229,000 (1999 dollars). The total annual equivalent cost, including, construction, design and O&M costs, would be $24,800.

6. HR-33 Site Reclamation (Phase 1)

A conceptual-level construction cost estimate for the proposed project is provided in Table 10. Capital costs for the project based on the conceptual level design are estimated to be approximately $362,000 (1999 dollars). The total annual equivalent cost, including, construction, design and O&M costs, would be $32,700.

7. HR-33 Passive Treatment System (Phase 2)

A conceptual-level construction cost estimate for the proposed project is provided in Table 11. Capital costs for the project based on the conceptual level design are estimated to be approximately $911,000 (1999 dollars). The total annual equivalent cost, including, construction, design and O&M costs, would be $84,200.

8. HR-17A Passive Treatment System

A conceptual-level construction cost estimate for the proposed project is provided in Table 12. Capital costs for the project based on the conceptual level design are estimated to be approximately $225,000 (1999 dollars). The total annual equivalent cost, including, construction, design and O&M costs, would be $24,500.

9. HR-17B Passive Treatment System

A conceptual-level construction cost estimate for the proposed project is provided in Table 13. Capital costs for the project based on the conceptual level design are estimated to be approximately $423,000 (1999 dollars). The total annual equivalent cost, including, construction, design and O&M costs, would be $40,900.

Table 14 presents both the estimated capital and annualized costs for each project, as well as the anticipated water quality benefits of the proposed projects.

B. Anticipated Water Quality Improvements

Based on the data collected at high flows in March of 1999, implementation of the conceptualized projects would result in dramatic decreases in the acid and metal loads that currently emanate from the investigated problem areas, and produce positive changes in the instream water quality of Huff Run.

Water quality data and flows recorded at each of the selected problem areas in March 1999 were compared to anticipated post-project water quality data at each of the identified problem areas. The resulting changes in acid and metal loads for each proposed project were generated. These anticipated water quality changes, represented by the anticipated reduction in acid and metal loads emanating from the problem area, are presented in Table 14.

The anticipated reductions in acidity and metals for each project were compared to the recorded net acid and metal loads at downstream sampling points. This enabled the estimation of the reductions in net acid and metal loads each project may have on downstream reaches of Huff Run. (The stream was net alkaline as sampled in March 1999, so the percent reduction in net acidity actually represents a percent increase in alkalinity.) As shown on Table 14, at high flow conditions, it is anticipated that all eight projects, if implemented, could result in significant reductions in instream metal loads, and provide additional excess buffering alkalinity to Huff Run. Metal load reductions would be realized the most in Reaches 3 and 4, where up to 50 percent of the instream metals could be eliminated. Alkaline addition and acidity reduction would have the greatest impact downstream in the lower reaches where the alkaline load in Huff Run could be increased up to 87 percent in Reach 1.

As far as the individual projects, projects at HR-16 and HR-12 have the greatest benefit with respect to metals reduction and downstream buffering to Huff Run. These projects are also very desirable because of their upstream positions in the watershed and their great impacts on the metal loads in Reaches 3 and 4.

It should be noted that these estimates reflect high flow conditions. Loading values will decrease during low flow conditions. Since the treatment systems are designed around loading values, their performance and impact on Huff Run during low flow conditions should improve.

C. Project Cost Effectiveness

Table 14 also presents the projects showing the anticipated reductions with respect to their cost. The estimated contaminant reduction costs per pound of acidity and metals are provided for each project. This allows for comparisons of the costs of the individual projects against each other, as well as against the average of the eight projects.

Table 14 shows that the treatment system at HR-16 would be the most cost effective with average reduction costs of $0.21/lb of acidity reduction, and $2.55/lb of metals reductions. These values are much lower than the average treatment cost of $0.67/lb acidity and $5.82/lb metals calculated for all of the projects. Other more cost effective projects include HR-17A, HR-17B, HR-42, HR-12 (for acidity reduction) and HR-13A/13B (for metals reduction).

VI. An identification of existing and proposed sources of funding for individual projects.

Current funding for the reclamation efforts in Huff Run comes from a number of sources through both ODNR and the HRWRP. The HRWRP is currently preparing its comprehensive plan for the Huff Run watershed with funds obtained from a Section 319 Non-Point Source Program (EPA) Grant. These funds are administered by the Crossroads Resource Conservation and Development agency. Additional Section 319 funding for projects within the watershed is anticipated pending completion and approval of the plan.

Other funding for AMD projects may come in the form of an ACSI grant from OSM. As previously discussed, the grant was proposed for the Linden Bioremediation Project (Site HR-13A).

Funding for site reclamation actions at the Harsha Site is currently committed from both ODNR and NRCS. The NRCS funding will come from previously uncommitted funds from the Rural Abandoned Mine Program. ODNR funding would come from the State's AML program.

ODNR is reportedly planning other site reclamation actions in the watershed. The AML program is responsible for the single biggest project completed in the watershed to date. Consequently, restoration of the watershed will rely heavily on developing and implementing additional AML-funded projects from both the general reclamation fund and the 10 percent AMD set-aside fund.

VII. A monitoring plan for assessment of actual environmental benefits realized.

Additional monitoring of the Huff Run watershed will be required to implement the projects developed and to assess the future impacts to the aquatic ecology of the stream. The following section discusses recommendations for additional monitoring of the investigated sites, as well as for the watershed as a whole.

A. Problem Area Monitoring

In order to further assess the projects developed in this plan and to collect data for projects design, site specific water quality data will need to be collected at location within and downstream of the problem areas. The primary focus of the monitoring should be to collect data for the development of treatment system designs. Successful passive treatment system design requires a good understand of the hydraulic and contaminant loads that will be entering a system. Sample testing for water quality chemistry, and accurate flow measurements at the identified locations for the passive treatments system is recommended. The installation of permanent weirs or flumes at these sites also is recommended.

ODNR currently monitors specific locations monthly within HR-16 (Harsha) and HR-13A (Linden). Monitoring in these areas should continue. However, these monitoring actions may need to be adjusted based on the proposed locations for the passive treatment systems. Additionally, monitoring at locations within HR-12 and at HR-13A is also recommended. Monitoring at HR-42 is not required, however, investigation of groundwater levels and quality by installation of an up-slope monitoring well or piezometer is recommended. Other monthly monitoring at problem areas in the watershed (HR-33, HR-31, HR-17A, and HR-17B) should continue. This monitoring should include further investigation of the anoxic nature of HR-31A and HR-17A. ODNR may want to consider investigating other sites in Reaches 2 and 3 as well.

In conjunction with the monthly monitoring conducted within the problem areas at treatment locations or discharges, ODNR should periodically sample downstream points. This could include the problem area tributary point or the mainstem reach point downstream of a sampled location. Collecting this data could further help understand the individual problem area's impact on Huff Run at different flow conditions.

Investigations of additional problem areas within the watershed should be conducted to locate and identify additional AMD discharges, assess impacts and formulate additional projects. These investigations should focus on the higher ranked, and higher reach problem areas presented on Table 3, such as HR-25, HR-36, HR-22, HR-20, HR-18, HR-21, HR-39, HR-38 and HR-40.

B. Watershed Monitoring

Additional water quality and biological data collection in the watershed should be pursued to better define the current conditions and impacts, as well as assess restoration efforts.

Current data needs include conducting a water sampling round of the tributary and mainstem points in the lower reaches (below Reach 4/HR-17) to better quantify the impacts of the problem areas in these reaches. Also, a low flow sampling event of the entire watershed would help better define the previously observed low flow pH drops. For both, accurate flow measurements of the tributary and mainstem points must be collected.

Collecting additional biological data for Huff Run would also help better define the stream's current conditions. Currently, fish sampling (IBI) data is available for only three reaches of Huff Run. Macroinvertebrate data could also be updated; no data is currently available for Reach 6 (HR-6). It is also recommended that future macroinvertebrate data be collected as per OEPA biological criteria standards using the Invertebrate Community Index (ICI). This index is used by OEPA to develop stream use designations.

A long-term monitoring program needs to be established to assess the impacts of the ongoing restoration activities in the watershed. Such a program should include both water chemistry and biological sampling. Water sampling events need not encompass all of the sample sites established to date. However, consistency of the sample locations (both water and biological) is key. Mainstem sampling at the eight reach locations established by this study should be included in any watershed-wide effort. Sample events should be coordinated at times of minimal flow variation. Biological sampling should be conducted at the identified mainstem sites and coordinated with water sampling if possible.

Collection of flow measurements at the mainstem, tributary and discharge sites needs to be standardized. Stream flows measured and calculated using a portable velocity meter should follow the methodology described in *Techniques of Water-Resources Investigations of the United States Geological Survey, Chapter A8, Discharge Measurements at Gauging Stations*. For smaller flows, a weir or flume should be used. If volunteers or students are utilized, a hands-on instruction session is recommended prior to any sampling event. The importance of accurate flow recordation must be stressed to all individuals involved in future sampling efforts.

The USGS gauge at Mineral City should be maintained and calibrated based on measured flow conditions. The gauge represents a valuable resource for hydrologic data collection for the watershed.

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