Lower Kettle Creek Restoration Plan

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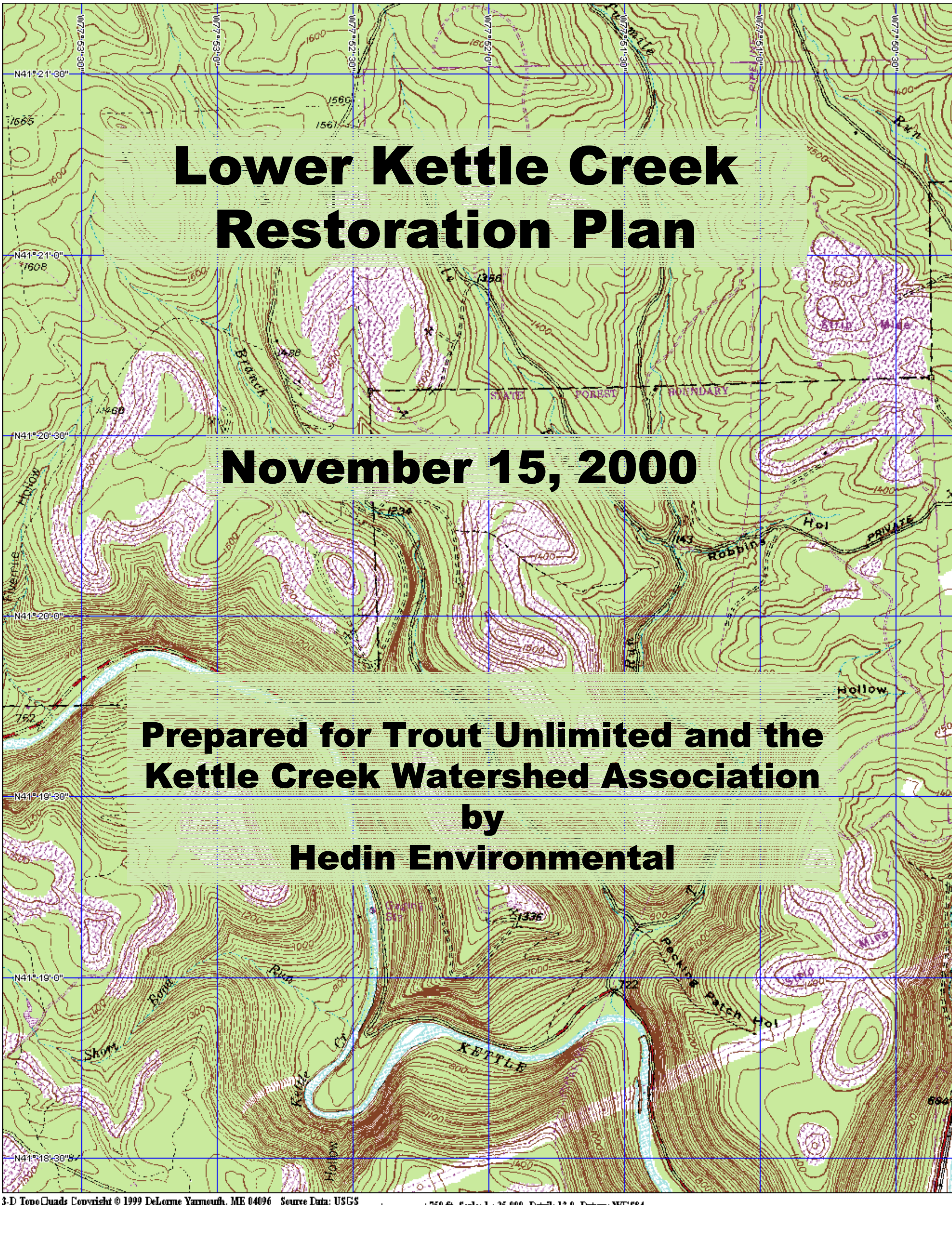
Prepared for Trout Unlimited and the Kettle Creek Watershed Association

by

Hedin Environmental



Executive Summary

Kettle Creek is a highly valued stream whose watershed covers 244 square miles in Clinton, Potter, and Tioga Counties in north-central Pennsylvania. The watershed is dissected by the Alvin R. Bush dam. Above the dam, the upper Kettle Creek watershed is renown as containing some of the best trout waters in Pennsylvania. Downstream of the dam, the lower portion of the watershed is severely impacted by acid mine drainage (AMD). The source of the degradation is highly acidic flows from long-abandoned deep mines and surface mines. Twomile Run, the only major tributary system to the lower Kettle Creek watershed, is the largest source of AMD. This restoration plan focuses on the Twomile Run because of the benefits that can be obtained within the Twomile Run watershed as well as downstream in lower Kettle Creek.

The restoration of Twomile Run and lower Kettle Creek is being coordinated by the Kettle Creek Watershed Association (KCWA) with support from Trout Unlimited, PA Department of Environmental Protection Bureau of Abandoned Mine Reclamation, PA Department of Environmental Protection Hawk Run District Mining Office, PA Department of Conservation and Natural Resources, PA Fish and Boat Commission, USDA Natural Resources Conservation Service, Clinton County Conservation District, and the Twomile Run Gun Club.

Within the Twomile Run watershed, AMD pollutes Middle Branch, Huling Branch, Robbins Hollow, and the main branch of Twomile Run. Upstream of discharges, the streams support wild trout. Downstream of the discharges, no fisheries exist. The PA Bureau of Abandoned Mine Reclamation (BAMR) and Kettle Creek Watershed Association have monitored discharge and stream flows since 1995. The discharges tend to be highly acidic with pH values of 3-4, acidity concentrations of 250-1,000 mg/L, Fe of 15-100 mg/L, and Al of 10-70 mg/L. Flow rates of AMD from discharge zones range as high as 500 gpm. The average total loading of acidity produced by all AMD discharges in the Twomile Run watershed is approximately 2,000 lb/day as $CaCO_3$.

Remediation recommendations for the watershed include the reclamation of spoil piles and the treatment of discharges using passive and chemical techniques. BAMR has recently constructed an experimental passive system on Middle Branch. The performance of this system should be monitored because it will provide guidance for the design and construction of other passive systems in the watershed. A large surface mine that discharges AMD to upper Twomile Run and Robbins Hollow should be reclaimed. Residual AMD flowing from the reclaimed area should be monitored and a passive system should eventually be built to treat the flow. A passive treatment system should be constructed in Robbins Hollow to treat discharges that will not be affected by the reclamation. Diffuse discharges of AMD occur over large areas in the Huling Branch watershed. As a first step in treatment, the discharges should be collected with a drainage collection system and monitored for flow and chemistry. At this time, the highly contaminated nature of the Huling Branch AMD makes passive treatment unreliable. Chemical treatment should be considered.

If these recommendations are successfully implemented, over 8 miles of streams in the Twomile Run watershed and 6 miles of Kettle Creek will be greatly improved. The re-establishment of a quality fishery to these waters should be possible.

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I. Watershed Description

A. Introduction

The Kettle Creek Watershed covers 244 square miles in Clinton, Potter, and Tioga Counties in north-central Pennsylvania. For the purposes of this Restoration Plan, only the portion of the watershed downstream of the Alvin R. Bush Dam will be discussed in detail. This area is often referred to as *lower Kettle Creek*. This portion of Kettle Creek will also be referred to as the *drainage area* for the purpose of this report.

Map 1 shows the location of Kettle Creek within Pennsylvania and highlights the area known as lower Kettle Creek. Map 2 highlights the lower watershed and shows the locations of all historic and recent sampling locations. Throughout this report, sample locations from Map 2 will be denoted as "Map #", followed by the appropriate number. Map 3 shows the Twomile Run watershed. A few important sampling locations are indicated.

While upper Kettle Creek is renown as one of Pennsylvania's premier trout streams, lower Kettle Creek is polluted by acid mine drainage and has marginal fishery value. The principle source of AMD to lower Kettle Creek is the Twomile Run watershed. Streams in this watershed are severely polluted by acid mine drainage flowing from abandoned surface and underground coalmines. AMD remediation efforts are already underway in the Twomile watershed. However, complete remediation of Twomile Run and lower Kettle Creek will require sustained and substantial restoration efforts and commitments. This Plan is intended to provide a quantitative description of water quality conditions in the lower watershed and make recommendations regarding the remediation of AMD and the eventual restoration of the streams.

B. Location, Geography and Population

Lower Kettle Creek watershed is contained almost entirely within the Sproul State Forest. The Kettle Creek State Park, a popular destination of sport fishermen, encompasses an area of Kettle Creek surrounding the Alvin R. Bush Dam. The dam was constructed to provide flood control for Westport and downstream villages. The middle watershed of Kettle Creek is contained within the F.H. Dutlinger Natural Area and the proposed Hammersley Wild Area. Ole Bull State Park is also located in the middle of the watershed along the main branch of Kettle Creek. Much of the headwaters of Kettle Creek watershed flow through the Susquehannock State Forest in Potter County. Kettle Creek is designated as a Class A wild trout fishery above its confluence with Little Kettle Creek.

There are no major settlements in the lower Kettle Creek drainage area. The small village of Westport is located at the mouth of Kettle Creek where it enters the West Branch of the Susquehanna River. A few year-round residences are located in the drainage area, as well as many seasonal camps.

C. Mining History

The lower Kettle Creek watershed is underlain by Kittanning coals that have been mined for the last 100 years. Underground mines operated in the Lower Kittanning coal in the late 1800s and early 1900s. A very large underground mining complex was operated by Kettle Creek Coal Company on the west side of Kettle Creek in the Bitumen area. Company records were lost in fire shortly after the company closed in 1929. The few remaining maps indicate that the Bitumen area is underlain by seven interconnected mines. The mines extend westward into the Cooks Run watershed. Most of the Lower Kittanning coal, however, was removed from entries located ½ mile northwest of Bitumen in the Kettle Creek watershed. The Upper Kittanning coal, which occurs near hilltops in the watershed, was also deep mined. The isolated nature of these reserves resulted in small isolated mines.

Deep mining also occurred in the Twomile watershed in the Lower Kittanning coal bed, but the dissected topography resulted in isolated mines. The Neilan Engineering Operation Scarlift map shows separate deep mines in the Huling Branch, Middle Branch, and upper Twomile/Robbins Hollow watersheds. No Upper Kittanning deep mines existed in the Twomile watershed.

In the 1930's, many of the abandoned deep mine entries were sealed through efforts by Franklin Roosevelt's Works Project Administration (WPA). While many of the seals were destroyed by later surface mining activities, surviving seals generally remain functional today. Most of the viable mine seals are located in the western portion of the watershed on steep slopes above Kettle Creek and in the Short Bend Run basin[1].

Both the western and eastern sides of Kettle Creek were extensively surface mined in the 1950's, 1960's and early 1970's. Upper Kittanning reserves in the Bitumen area, Huling Branch and Middle Branch watersheds were almost completely removed. Lower Kittanning reserves were mined by contour and area methods to a depth of about 60 feet. Negligible reclamation was done. Most of the abandoned mines consist of unreclaimed spoils that follow the coal crop and encircle remaining deep mine workings.

D. Aquatic Environment

Above the dam, the upper Kettle Creek watershed is classified by the PA DEP as an exceptional value watershed (DEP Chapter 93 Water Quality Standards). The Kettle Creek reservoir is a high quality trout-stocking fishery. Lower Kettle Creek is designated as a trout-stocking fishery. This classification is accurate for approximately 3 miles downstream of the dam. Beyond this point, inflows of acid mine drainage degrade the stream. Below the inflow of Twomile Run, 6 miles below the dam, the stream does not support a fishery.

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[1] On USGS maps, this stream is referred to as *Short Bond Run*. Because the local name for the stream is *Short Bend Run*, that name is used throughout this document.

The Twomile Run watershed includes the main stem of Twomile Run, Robbins Hollow, Mackintosh Hollow, Middle Branch, and Huling Branch. The streams have moderate to steep gradients and generally flow beneath a forest canopy. Unpolluted headwater sections support native trout populations and are designated as Class A waters by the Pennsylvania Fish and Boat Commission. Below inflows of AMD, Twomile, Middle Branch, Huling and Robbins Hollow are devoid of fisheries.

E. Water Quality

<u>Historic Water Quality Assessments</u> Water quality in the lower Kettle Creek watershed has been assessed periodically during the last 40 years as a consequence of mining and reclamation activities. PA DEP mining records contain water sampling information for permits issued in the 1960s and 1970s. Between 1970 and 1972, an Operation Scarlift investigation was conducted by Neilan Engineers (SL-115). The Commonwealth was not satisfied with the final report and never officially accepted its findings or recommendations. In the early 1980's the PA DEP sampled streams on a regular basis. In 1995 the Bureau of Abandoned Mine Reclamation (BAMR) initiated a sampling program of the Twomile Run watershed that continues today through joint activities of KCWA, Trout Unlimited and PA DEP (See Map 3). In 1999/2000 the Hawk Run District Mining Office (DMO) conducted a Total Maximum Daily Load (TMDL) study in the Twomile Run watershed (See Map 3). The goal of this statewide program is to measure pollutant loadings so that strategies can be developed to bring streams into compliance with their designated use. The Twomile Run TMDL study involved measurements of flow and contaminant loadings at various points along main stem of the stream. Data collection aspects of the TMDL study were completed when this Plan was prepared, but a final report was not yet available.

All of the data referenced above has been collected into an Excel database. Copies of the database were provided to Trout Unlimited, Kettle Creek Watershed Association, and the Hawk Run District Mining Office. A listing of all the data included in the database is contained in Appendix A.

The quality of the Operation Scarlift data is suspect. Flow measurements were sparse and affected by Hurricane Agnes. Acidity and metal concentrations in the report appear to be erroneously high. In cases where direct comparisons are possible, Operation Scarlift acidity concentrations are 5-10 times higher than permit and DMO data collected for the same points at the same time.

<u>Current Water Quality Conditions</u> Unpolluted surface water in the lower Kettle Creek is marginally alkaline or acidic and contains low concentrations of metals and sulfate. Table 1 shows the chemical characteristics of unpolluted streams in the area. The weakly buffered nature of the waters makes then vulnerable to inflows of acidic mine water.

Table 1. Chemical Characteristics of Unpolluted Streams in the Lower Kettle Creek Watershed

	Period	pH	Alk mg/L	Acid mg/L	Fe mg/L	SO4 mg/L
Kettle Creek at USGS gauge near Westport (Map #107)	1980-83	6.4	14	1	0.3	33
Twomile Run above AMD	1968-83	5.9	6	8	0.3	31
Twomile Run above AMD	1994-95	5.9	5	17	0.4	<20
Huling Branch above AMD	1980-83	5.7	6	8	0.2	23
Middle Branch above AMD	1994	5.5	3	14	<0.1	21

Unpolluted streams in the watershed contain viable fisheries. Lower Kettle Creek supports cold-water and warm-water fisheries upstream of the inflow of Twomile Run. A DCNR campground is located in this section and the stream is heavily fished. Unpolluted headwaters in the Twomile Run watershed support native wild trout. Surveys of the biological communities in the Twomile Run watershed have been conducted by BAMR and the PA Fish and Boat Commission. Table 2 shows summary results of the BAMR study for Twomile Run sampling stations. Both groups found a good diversity of pollution intolerant invertebrates and wild trout in streams above AMD inflows. No fish and few invertebrates were encountered below major inflows of AMD.

Table 2. Results of BAMR's Biological Survey of Twomile Run and Middle Branch. Samples collected in 1998. "above" and "below" refer to AMD inputs.

		Alk	Acid	Fe	Al	SO4	Invertebrate Taxa	
	pH	mg/L	mg/L	mg/L	mg/L	mg/L	E&P*	total
Twomile above	5.9	5	17	0.4	0.2	<10	5	19
Twomile below	3.7	0	63	0.7	4.8	95	0	2
Middle above	5.5	3	14	<0.1	0.1	21	5	10
Middle below	4.2	0	41	0.1	4.0	44	0	2

** number of taxa included in the Ephemeroptera and Plecoptera orders*
From: Hydrologic Unit Plan for Twomile Run and Shintown Run, PA DEP BAMR, November 1998

Kettle Creek flows 8.5 miles from the Alvin R. Bush dam to the West Branch of the Susquehanna in Westport. Kettle Creek is degraded by AMD inflows from both the western and eastern portions of the watershed. Table 3 shows average stream chemistry at three stations below the dam. Most of the discharges from the western watershed are from entries connected to the Bitumen mine complex. Several drainage-producing entries are located on the western bank of the Kettle Creek and discharge down steep slopes directly to Kettle Creek. Three such discharges are located downstream of Slide Hollow, 3.0-3.5 miles below the dam (Map #78). These flows create visibly discolored zones along the western creek bank.

Several discharges are located in the Short Bend Hollow watershed which enters Kettle Creek 5.2 miles below the dam. Downstream of the inflow of Short Bend Hollow, the western side of Kettle Creek is stained orange. The center and eastern side of the Creek are not visibly or biologically degraded by the mine drainage.

Table 3. Average chemical characteristics of lower Kettle Creek and Twomile Run.

	Period	N	pH	Alk mg/L	Acid mg/L	Fe mg/L	SO4 mg/L
Kettle Creek at USGS Westport gauge (above Twomile Run)	1980-83	24	6.4	14	1	0.3	33
Twomile Run mouth	1966-83	66	3.4	0	194	12	406
Kettle Creek above Butler Hollow (below Twomile Run)	1967-83	38	5.8	8	10	0.6	55
Kettle Creek mouth at Westport (below Twomile Run)	1965-83	59	5.3	11	19	1.0	62

"N" is the number of samples

Twomile Run enters Kettle Creek 6.7 miles below the dam. It is the only substantial flow of water to lower Kettle Creek from the eastern side of the watershed. Twomile's large flow of highly acidic water (Table 3) significantly degrades Kettle Creek, discoloring it with metal precipitates, eliminating most invertebrates, and shifting the stream condition from alkaline to neutral or acidic.

Table 4 shows the flow rates and net acidity loadings of Kettle Creek at the USGS gauge near Westport and the mouth of Twomile Run. Only four flow rates are available for the mouth of Twomile Run. As shown, Kettle Creek contains enough alkalinity (net acidity) to neutralize Twomile Run on the dates shown. However, Twomile Run also adds over 2,000 pounds per day of iron to Kettle Creek.

Table 4: Flow and Net Acidity Comparison for Kettle Creek and Twomile Run

Date	Kettle Creek*		Twomile Run**			
	Flow (GPM)	Net Acidity (PPD)	Flow (GPM)	Net Acidity (PPD)	Iron (PPD)	% Flow (Twomile / KC)
7-Oct-99	19,298	-3,011	350	815	117	1.8 % (1 : 55)
23-Nov-99	23,338	-3,641	276	643	93	1.2 % (1 : 83)
16-Dec-99	361,284	-56,360	8,300	19,322	2,782	2.3 % (1 : 43)
8-Mar-00	172,339	-26,885	6,394	14,885	2,143	3.7 % (1 : 27)

Average acidity and alkalinity used to calculate net acidity loadings
** Flow measured by the USGS gauging station near Westport above confluence with Two Mile Run, Station 01545000. Negative net acidity indicates alkaline conditions*
*** Flow measured at the mouth of Two Mile Run by DEP during TMDL assessment. Net acidity and iron taken from average concentrations*

Approximately 1.1 miles downstream of the mouth of Twomile Run, a substantial flow of AMD from the Bitumen complex flows from Butler Hollow into Kettle Creek. Approximately 0.6 mile downstream of Butler Hollow, Kettle Creek enters the West Branch of the Susquehanna.

Twomile Run watershed is the primary focus of this Restoration Plan and current remediation efforts because of both its primary effect on Kettle Creek and the opportunity for substantial stream restoration within the Twomile watershed. Table 5 shows a breakdown of the impaired nature of the streams in the Twomile Run Watershed. Of the 16.6 miles of stream, 51% are impaired by AMD.

Table 5. AMD-Impacted Stream Lengths in the Twomile Watershed.

	Unimpaired	AMD impaired	Total
Twomile Run	11,880 ft	27,414 ft	39, 294 ft
Robbins Hollow	977 ft	1,853 ft	2,930 ft
MacIntosh Hollow	4,877 ft	0 ft	4,877 ft
Middle Branch	5,533 ft	5,533 ft	11,066 ft
Huling Branch	19,846 ft	9,816 ft	29,662 ft
TOTAL	43,113 ft	44,716 ft	87,829 ft
TOTAL	8.1 miles	8.5 miles	16.6 miles
TOTAL	49%	51%	

Distances measured include all blue line streams on the USGS 1:24,000 topographical maps. Twomile, McIntosh Hollow, and Huling Branch distances based on known locations of AMD degradation. Middle Branch estimate assumes 50% of stream length degraded. Robbins Hollow estimate assumes 66% of stream length degraded.

As is apparent from Table 5, the Twomile Run watershed can be divided into four smaller AMD-producing hydrologic units: the main stem of Twomile Run, Robbins Hollow, Middle Branch, and Huling Branch. Data have been collected from streams and major AMD discharges in these basins since 1995. Table 6 summarizes the Twomile Run data. Map 3 shows the locations of major AMD-producing areas and BAMR monitoring stations.

Two Mile Run The main stem of Twomile Run is polluted by discharges from a large surface mine located above Robbins Hollow. The mine spoils encircle an abandoned underground coal mine. AMD from the Robbins Hollow mine flows directly into Twomile Run and also Robbins Hollow itself. Diffuse seepage over a large area to the east of the mine spoils has created a large kill zone that is referred to as the "Swamp." The analyses of three samples of seeps in the Swamp collected in December 1999 are shown in Table 6. The cumulative flow from the Swamp basin (ground water and surface water) is monitored at BAMR weir 6 (Map #85, also known as the "Texas Pipeline site"). The AMD is highly acidic and contaminated with elevated concentrations of Fe and Al.

Robbins Hollow AMD flowing from Robbins Hollow enters Twomile Run 2,400 feet downstream of the Swamp inflow. Weir 5 (Map #84) is located in the channel of Robbins Hollow below most inflows of AMD. The loadings measured at this station approximate the total contaminant production by this drainage basin. Weir 10 (See Map 3) is located close to a seepage zone and represents the quality of the mine drainage, generally undiluted by surface water. Additional samples of AMD flows in Robbins Hollow are also shown in Table 6.

Middle Branch Middle Branch enters Twomile Run from the north-northwest just upstream of Robbins Hollow. At least four seeps have been identified in Middle Branch.

Four of these flows (BAMR 3, 7, 8 and 9; Map #82, 86, 87, and 88 respectively) are being treated by a system recently constructed by the PA BAMR.

Table 6. Average Characteristics of Discharges and Streams in the Twomile Run Watershed.

Point ID	Map # (See Map 2)	Description	Period	N	Flow	pH	Acid	Fe	Al	Mn	Sulfate	Acid load	Fe load	Al load
BAMR 6	85	Weir below Swamp	Aug 95 – May 00	46	72	3.1	526	77	41	31	888	385	31	38
BAMR 6B	145	Seep in Swamp	Dec 1999	1	Na	2.8	228	1	32	10	432			
BAMR 6C	146	Seep in Swamp	Dec 1999	1	Na	2.7	1166	30	161	33	1390			
BAMR 6D	147	Seep in Swamp	Dec 1999	1	Na	2.7	384	5	58	11	671			
BAMR 5	84	Weir in Robbins Hollow	Aug 95 – May 00	46	167	3.9	79	2	9	8	219	98	2	10
BAMR 10	See Map 3	Discharge to RH	Aug 99 – May 00	7	Na	3.3	370	115	15	22	944			
BAMR 10B	Not shown	Culvert to RH	Dec 99	1	Na	3.1	254	5	33	19	609			
BAMR 10C	Not shown	Ditch to RH	Dec 99	1	Na	3.1	324	10	42	12	550			
BAMR 2	81	MB mouth	Apr 95 – May 00	48	556	4.2	42	<1	5	2	58	245	<5	24
BAMR 3	82	Seep at MB tipple	Apr 95 – May 00	47	27	3.1	489	4	68	20	555			
BAMR 7	86	MB seep	Mar 96 – Mar 99	26	10	2.9	614	14	73	19	545			
BAMR 8	87	MB seep	Feb 97 – Oct 99	6	7	3.1	317	8	51	20	616			
BAMR 9	88	MB seep	Feb 97 – May 98	2	3	3.1	598	10	78	19	450			
BAMR 4	83	HB below tipple and kill area	Apr 95 – May 00	46	110	2.7	692	72	54	23	845	751	68	62
BAMR 4B	Not shown	Seep to HB kill area	Dec 99	1	Na	2.9	554	47	69	17	747			
BAMR 4C	Not shown	Seep to HB kill area	Dec 99	1	Na	3.8	86	<1	13	5	200			
BAMR 4D	Not shown	Seep to HB kill area	Dec 99	1	Na	3.1	222	16	26	6	379			
BAMR 4E	Not shown	Seep to HB kill area	Dec 99	1	Na	2.7	718	102	63	30	1100			
BAMR 11	140	Seep to lower Twomile	Dec 99 – May 00	3	7	6.3	<0	23	<1	2	202	-3	2	<1

"N" is the number of samples; flow is gpm, acidity is mg/L $CaCO_3$; metals are mg/L; loadings are lb/day
"Na" indicates data is not available

Huling Branch Huling Branch is the largest tributary to Twomile Run. The watershed is degraded by abandoned mines located on both sides of the stream in the middle of the watershed. The western portion of the watershed contains abandoned deep mine entries, coal refuse, and barren mine spoils. However, AMD flowing to Huling Branch from the west is not substantial. The eastern portion of the watershed contains unreclaimed surface mine spoils, refuse and a tipple site. Most of the AMD that pollutes Huling Branch flows from the eastern side of the basin and enters the stream at the tipple site. A large kill zone containing numerous diffuse acidic seeps exists above the tipple. Most of the AMD draining from the eastern side of the basin flows through BAMR weir 4 (Map #83). Table 6 shows the chemistry of this summed flow as well as several seeps at their discharge points. Some AMD (estimated at 5-10% of the tipple flow) bypasses BAMR weir 4 and flows directly to Huling Branch.

Huling Branch contains the most contaminated mine water found in the Twomile Run watershed. Contaminant loadings are double those measured for the Swamp discharges.

While Table 6 provides good information on the AMD flows in the Twomile Run watershed, it is not as useful for evaluating the relative contaminant contributions of the various streams. TMDL data collected at the mouth of each tributary stream provides a better measurement of relative pollution loads. Table 7 shows summarized data for the TMDL data. Four sampling dates contained full rounds of sampling, which were used to calculate average loadings and percent contributions for the major sources of AMD. Loadings for the streams are higher than is suggested by the BAMR weir data in Table 6 because the TMDL data do not contain any low-flow (low-loading) months, and because the TMDL stations were placed downstream of all AMD inputs to the respective stream.

Table 7: Acidity sources in the Twomile Run watershed and stream restoration potentials. Based on TMDL data collected 10/7/99, 11/23/99, 12/16/99, and 3/8/00 by the Hawk Run District Mining Office.

Target	Average Flow (GPM)	Average Acid load lb/day	Average Percent of total load* (Range)	Potential stream recovery**
"Swamp" Area	134	488	20% (12 – 30%)	2,350 ft of Twomile Run
Middle Branch	393	142	4% (0 – 8%)	7,410 ft of Middle Branch and 240 ft of Twomile Run
Robbins Hollow	105	98	4% (3 – 6%)	2,420 ft of Robbins Hollow and 8,500 of Twomile Run
Huling Branch	1,310	1,087	61% (46 – 74%)	10,200 feet of Huling Branch, 1,500 ft of Twomile Run, and 5,690 ft of Kettle Creek (to Butler Hollow)

** Loading percentages from each of the four sampling dates was averaged. This represents the average proportion of Twomile Run's acid loading at the mouth of Twomile Run (average 3830 GPM, 2,099 lb/day acidity below Huling Branch inflow); 11% of measured load below inflow of Huling Branch is unaccounted for (may be due to inaccuracies resulting from different flow measuring methods)*

*** distance between the AMD source and the next stream-destroying source of AMD*

F. Local Importance

Tourism plays a huge role in the Kettle Creek area. Hunting and fishing camps are widespread and receive members from all around Pennsylvania and several other states. The local economy relies heavily on seasonal tourists who visit the area to hunt, fish, hike, and observe the recently released elk herd. The DCNR has developed the Commonwealth's largest public ATV trail in the Huling Branch basin of the Twomile Run watershed. The trail, which is heavily visited, is comprised of old woods roads, old coal mining roads, and unreclaimed surface mining areas. Several parking areas are provided for loading and unloading vehicles. Camping along the trail is also allowed with a permit. Because of the importance of the ATV trail, any surface reclamation in the Huling Branch area such as regrading of spoil piles or revegetation must take into account the needs of the ATV users.

While lower Kettle Creek is highly visible and accessible to the public, its recreational value is substantially decreased by its degraded condition. Of the 8.5 miles of Kettle Creek between the dam and mouth, six miles are degraded by AMD. Of the 16.6 miles of streams in the Twomile Run watershed, 8.5 miles are degraded by AMD.

G. Stream Restoration Potential

The only substantial water pollution in the lower Kettle Creek watershed is AMD. Most of the polluted streams flow through forested watersheds that have excellent physical habitat. Streams in the watershed that are not polluted by AMD support high quality fisheries. Twomile Run, Middle Branch, and Huling Branch all are viable aquatic ecosystems above the inflows of AMD. Elimination of the AMD inflows to these streams should result in the immediate reestablishment of high quality aquatic conditions and rapid biological recolonization.

While lower Kettle Creek receives a high loading of AMD, the high flow rate above Twomile Run (90,000 gpm on average) dilutes the contamination substantially. Polluted portions of lower Kettle Creek are generally characterized by pH values between 5 and 6, net acidities of 10-15 mg/L, and metal concentrations less than 2 mg/L. Moderate improvements of these conditions could result in a rapid reestablishment of the stream fishery.

H. Partners and Participants

The Kettle Creek Watershed Association (KCWA) is active in the protection and improvement of upper Kettle Creek and has taken a lead role in the restoration of lower Kettle Creek. The KCWA, Trout Unlimited (TU), and the many partners agree that addressing the AMD problem in the lower watershed should be among the first priorities in the Kettle Creek conservation program, and subsequently formed the KCWA AMD Committee in 1998 to pursue these efforts. Committee members include the DEP, BAMR, PA Fish & Boat Commission, DCNR Bureau of Forestry, Natural Resources Conservation Service, Clinton County Conservation District, and local conservation groups and sportsmen clubs.

The KCWA is an incorporated nonprofit organization that has been active in the watershed since 1997. The four main objectives of the KCWA are to: 1) develop a watershed management plan, 2) reclaim the lower Kettle Creek through acid mine drainage treatment, 3) improve aquatic habitat throughout the watershed, and 4) implement a community-based information and education program that will strengthen and sustain conservation efforts in the future.

The KCWA's goals and its conservation work are strengthened and supported through the TU Home Rivers Initiative. In spring of 1998, TU formally accepted the conservation work in the Kettle Creek watershed as their third Home Rivers Project. TU's Home Rivers Projects are multi-year efforts that integrate scientific research, community outreach, on-the-ground restoration, and the development of long-term conservation management strategies and tools. Trout Unlimited has hired a full-time watershed coordinator committed to conservation work in the Kettle Creek watershed.

Valuable support has been obtained from partner organizations and agencies. Involved agencies include the following:

- PA Department of Environmental Protection, Hawk Run District Mining Office;
- PA Department of Environmental Protection, Bureau of Abandoned Mine Reclamation;
- PA Department of Conservation and Natural Resources, Bureau of Forestry;
- PA Fish & Boat Commission;
- US Department of Agriculture, Natural Resources Conservation Service;
- Clinton County Conservation District; and
- Twomile Run Gun Club.

II. Problem Identification

Below the dam, the watershed is heavily contaminated by several inflows of acid mine drainage (AMD). Deep mine openings are the primary source of pollution flowing into Kettle Creek from the western side of the drainage. The eastern drainage is heavily impacted by surface mines, many of which are not properly vegetated or backfilled.
The AMD problem was first studied in the early 1970's through an Operation Scarlift Project. In the 1980's, streams and mines were sampled as part of active or proposed mining permits. In 1995, BAMR began sampling mine discharges and streams in the Twomile Run watershed. In 1999 responsibility for sampling activities was transferred to the Kettle Creek Watershed Association. In 1999/2000, the Hawk Run DMO conducted a TMDL study of the Twomile Run watershed. All of these studies have documented a serious AMD problem that is not substantially ameliorating with the passage of time.

In 1999, efforts were initiated to quantify AMD pollution on the western side of lower Kettle Creek. Volunteers from the KCWA and Twomile Run Gun Club collected and analyzed water samples. In 2000, BAMR initiated sampling and hydrologic investigations in the area. Results to date indicate a complicated interaction of deep mine complexes and unreclaimed surface mines. Hydrological and chemical studies of the western discharges are likely to intensify in the next five years.

The lower watershed is sparsely populated and undeveloped. Other than mine drainage, no other substantial point or non-point water pollutants have been identified.

III. Expectations and Objectives

The purpose of this restoration plan is to provide a framework for restoring and protecting the lower Kettle Creek watershed, specifically in the area of concern. The priorities of this plan are to:

1. Restore viable fisheries to Twomile Run and its tributaries from the headwaters down to the mouth of Twomile Run.
2. Restore the viable fisheries of Kettle Creek from the Alvin R. Bush dam to its mouth at Westport.
3. Restore productive land uses to poorly reclaimed mining areas.

Secondary objectives of the Plan are to:

1. Instigate the sampling and characterization of AMD discharges in the western portion of the Basin.
2. Recognize and promote the contribution of the primary restoration objectives to the continued restoration of the West Branch of the Susquehanna.
3. Use the experience and successes of the Twomile Run and Kettle Creek restoration to expand interest and efforts to restore adjacent watersheds.

IV. Evaluation Criteria

The success of projects will be assessed by comparing downstream post-project chemical measurements to pre-project chemistry and to standards established by the Commonwealth for cold-water fisheries. Fishery restoration will be evaluated by comparing the results of down stream post-project biological surveys (fish and invertebrates) to results obtained at comparable upstream undegraded stations.

V. Site-Specific Project Opportunities

A. Western Drainage Area

The Western Drainage area is poorly characterized with regard to AMD flows and chemistry. Most upstream discharges – those between Slide Hollow and Duck Hollow – have not been sampled since the Operation Scarlift effort. There are two good reasons for this lack of activity. First, many of the discharges are located in remote, steep, inaccessible locations where treatment systems will be difficult (or impossible) to install. Second, surveys of lower

Kettle Creek have shown clearly that the primary pollution to Kettle Creek is from Twomile Run. Restoration of discharges from the western side of the basin will not improve Kettle Creek until the AMD from Twomile Run is eliminated.

Deep mines in the Bitumen area produce a substantial flow of highly acidic mine water. Most of this flow enters lower Kettle Creek through Butler Hollow, downstream from the inflow of Twomile Run and only 0.6 mile from Kettle Creek's mouth. Remediation of the Butler Hollow discharges will not improve Kettle Creek until Twomile Run is remediated.

The lack of recent, reliable flow and chemistry for discharges in the western basis of lower Kettle Creek makes useful recommendations impossible. Assuming that the Twomile Run remediation proceeds, a monitoring program for the western discharges should be implemented.

Discharges should be monitored as close to their sources as possible. At a minimum, flow rate, pH, alkalinity, acidity, iron, aluminum, and manganese should be monitored. Generally, such monitoring programs occur once a month for at least one year. This type of assessment will allow the discharges to be prioritized in order of their impact on the receiving stream.

B. Eastern Drainage Area

AMD Source: Mine Discharges to Robbins Hollow
Receiving Stream: Robbins Hollow
Map Point # (See Map 2): 4, 84, 143, 148

Site Description: AMD flows from a large surface mine that is located in the northern portion of the Robbins Hollow watershed. The surface mine is connected to an abandoned underground mine. Discharges from the mine complex also degrade upper Twomile Run and Shintown Run. A reclamation project has been proposed for a portion of the mine that will affect upper Twomile Run and Shintown Run. The reclamation project will not affect discharges from the southern portion of the mine that flow to Robbins Hollow.

The AMD originates as numerous diffuse seeps that generally discharge 10-30 feet below the toe of the surface mine spoils. Most of the flow is captured by ditches along a dirt road, crosses the road in culverts or as surface flows, and flows through woods to Robbins Hollow. The chemistry of the AMD near its discharge is shown in Table 7 by samples collected at BAMR weir 10 (See Map 3). During wet weather the weir also collects surface water – a condition that likely explains some of the data variability. The mine water generally has an acidity of 400-500 mg/L and contains 100-200 mg/L Fe, 5-20 mg/L Al, and 15-25 mg/L Mn. Robbins Hollow has the highest iron concentrations of any sampling point in the Twomile Run basin.

Data are also shown for points 10B and 10C. These points are culverts that carry drainage across the road and represent the mine water 100-200 feet below the seepage points. Compared to the seepage sample (BAMR weir 10; see Map 3), the flows have similar acidity, lower pH, lower Fe and higher Al. The chemical differences likely arise from the precipitation of iron and the solubilization of Al as the acidic water flows over bare clay soils. If this interpretation is correct, it may be possible to maintain lower Al concentrations by collecting and isolating the AMD from clay substrates.

Table 8. Chemistry of samples collected in Robbins Hollow at BAMR Weir 10 (See Map 3). Results for two additional samples collected in December 1999 are shown but not included in the data summaries.

BAMR Site	Date	pH	Acid mg/L	Fe mg/L	Fe^{2+} mg/L	Al mg/L	Mn mg/L	SO4 mg/L
10	8/30/99	3.4	516	274	264	4	25	1600
10	9/29/99	3.4	470	26	11	6	28	1560
10	10/18/99	3.3	408	191	158	16	25	487
10	11/22/99	3.2	436	155	116	1	28	1110
10	12/20/99	3.4	276	64	52	22	17	740
10B	*12/20/99*	*3.1*	*254*	*5*	*1*	*33*	*19*	*609*
10C	*12/20/99*	*3.1*	*324*	*10*	*2*	*42*	*12*	*550*
10	3/15/00	3.4	172	1	<1	23	11	294
10	5/6/00	3.2	314	96	75	13.9	18.0	821
10	average	3.3	370	115	97	15	22	945

Table 9. Summary of Data for Robbins Hollow BAMR Weir 5 (Map #84)

	Flow gpm	Lab pH	Acid mg/L	Fe mg/L	Al mg/L	Mn mg/L	SO4 mg/L	Acid lb/d	Fe lb/d	Al lb/d
average	167	3.9	79	1.8	9.3	7.9	219	97.5	2.3	9.8
median	107	3.8	60	1.1	5.9	4.3	147	56.9	0.8	5.9
75%	278	4.0	123	2.1	14.9	12.5	323	162.6	2.8	16.2
90%	427	4.5	169	3.4	20.3	20.3	536	241.4	5.6	25.2
max	533	4.6	196	13.7	28.6	29.3	744	383.8	21.5	33.3
count	42	46	46	46	46	46	46	42	42	42

The total loading of AMD to Robbins Hollow is estimated from data collected at BAMR weir 5 (Map #84). The weir captures all of the flow of Robbins Hollow below most of the AMD inflows. Statistical summaries for this discharge are shown in Table 9. All the data collected at BAMR weir 5 follow in Table 10..

The flow rate of the AMD discharges can be estimated from the loadings measured at BAMR weir 5 (Map #84) and the chemical concentrations measured at BAMR weir 10 (See Map 3). The calculated average flow is 22 gpm. Flow calculations using DEP TMDL data range as high as 56 gpm. It is recommended that remediation plans assume that the flow rate of all AMD discharges to Robbins Hollow will average 25 gpm and range to 50-60 gpm.

Recommendations: The discharges are highly acidic. Treatment requires the addition of alkalinity and the precipitation of Fe and Al. The presence of Al and ferric iron (Fe^{2+})

caution against treatment with an anoxic limestone drain. Waters with similar chemistry are currently being treated passively with vertical flow ponds (VFP). Water flows vertically in a pond down through a layer of organic substrate into a bed of limestone aggregate that is plumbed to collect and discharge the flow. The purpose of the organic matter is to remove dissolved oxygen and reduce ferric iron to ferrous iron. This will limit armoring of the limestone with ferric hydroxide. The purpose of the limestone aggregate is to neutralize acidity and generate alkalinity through calcite dissolution. Aluminum will also precipitate within the limestone aggregate, eventually resulting in permeability problems. To counter this condition, pipes are placed in the limestone aggregate that facilitate periodic flushing of aluminum solids out of the aggregate.

The recommended passive treatment system should consist of a mine water collection system, a vertical flow pond (for alkalinity generation and metal retention), a sedimentation pond (for solids collection), and a wetland (for polishing of remaining iron). Because of the high acidity, a second alkalinity-generating unit should be considered. Possible options include a second VFP pond, an oxic limestone bed, or a limestone-amended constructed wetland.

Predicted Performance of the Passive System The VFP will raise the pH to ~6.5 and discharge water containing 40-80 mg/L Fe and 80-120 mg/L alkalinity. All the Al will be retained in the VFP. The sedimentation pond and wetland will eliminate biochemical oxygen demand (BOD) and retain iron. The discharge from the wetland is predicted to contain 1-5 mg/L Fe and 0-30 mg/L alkalinity. A second alkalinity-generating unit should discharge water with pH 6.5-7.0 that contains <2 mg/L Fe, <1 mg/L Al, and 40-80 mg/L alkalinity.

Predicted Effect of System on Receiving Streams The treatment system will eliminate all known AMD inputs to Robbins Hollow. Approximately 2,420 feet of Robbins Hollow will be restored.

Table 10. Flow, Chemistry and Loading at the Robbins Hollow BAMR Weir 5 (Map #84)

Date	Flow gpm	Lab pH	Acid mg/L	Fe mg/L	Mn mg/L	Al mg/L	SO4 mg/L	Acid lb/d	Fe lb/d	Al lb/d
8/16/95	3	3.3	172	4.6	17.4	19.3	368	5.2	0.1	0.6
9/13/95	1	3.5	154	6.9	23.9	18.5	530	1.8	0.1	0.2
10/25/95	50	3.4	106	1.5	8.4	11.5	170	63.6	0.9	6.9
11/13/95	284	3.6	60	1.0	4.4	6.4	144	204.5	3.3	21.9
12/18/95	70	3.7	74	0.8	5.3	8.2	177	62.2	0.7	6.9
1/18/96	123	3.7	92	1.9	6.7	9.1	92	135.8	2.8	13.4
2/13/96		3.9	64	0.9	4.4	7.3	162			
3/12/96	123	3.8	52	0.9	3.2	5.3	203	76.8	1.3	7.8
4/9/96	236	3.9	74	0.8	3.0	5.3	160	209.8	2.1	15.1
5/15/96	533	4.0	34	0.6	2.0	3.6	107	217.5	3.6	23.1
6/18/96	131	3.8	68	13.7	4.9	12.6	121	106.6	21.5	19.7
7/16/96	22	3.4	140	1.9	11.4	13.8	291	36.4	0.5	3.6
8/12/96	3	3.4	174	2.2	16.9	17.2	339	6.1	0.1	0.6
9/16/96	405	3.5	74	1.5	4.2	5.9	115	359.6	7.1	28.5
10/29/96	204	3.9	52	0.8	3.2	4.7	209	127.1	1.9	11.5
11/20/96	55	4.5	20	0.1	1.4	1.1	82	12.9	0.1	0.7
12/17/96	291	4.4	15	0.2	1.2	1.4	59	51.7	0.5	4.9
1/13/97	25	4.6	28	0.1	1.5	1.8	150	7.8	0.0	0.5
2/24/97	260	4.4	13	0.1	1.0	1.2	46	40.6	0.4	3.6
3/24/97	130	4.5	19	0.1	1.1	1.3	59	30.3	0.1	2.0
4/14/97	34	4.6	18	0.2	1.3	1.7	101	7.2	0.1	0.7
5/12/97	65	4.5	22	0.2	1.7	1.8	100	17.1	0.1	1.4
6/16/97	14	4.3	28	0.3	2.2	2.1	90	4.8	0.0	0.4
7/28/97	12	4.6	66	6.7	14.9	11.8	333	9.8	1.0	1.8
8/18/97	533	3.7	60	1.4	3.6	5.2	92	383.8	9.1	33.3
9/24/97	7	3.5	128	2.5	11.6	15.3	307	10.3	0.2	1.2
10/21/97	20	3.5	154	3.1	13.5	16.3	338	37.5	0.7	4.0
11/17/97	397	4.0	56	1.0	3.4	5.2	96	266.9	5.0	24.8
12/15/97	104	3.9	56	1.3	4.5	6.6	101	69.9	1.6	8.2
1/8/98	397	4.0	42	0.8	2.8	4.4	89	200.1	3.9	20.8
2/17/98	533	4.0	40	1.2	2.6	4.3	81	255.8	7.5	27.8
3/17/98	429	4.0	44	1.1	3.1	5.4	104	226.5	5.7	27.7
4/14/98	397	4.0	36	0.6	2.0	3.5	15	171.5	2.8	16.5
5/18/98	533	3.9	38	0.6	2.6	4.0	91	243.1	3.7	25.3
6/8/98	32	3.7	106	1.4	8.3	10.9	188	41.2	0.6	4.2
7/13/98	12	3.5	150	2.3	12.8	15.3	328	22.3	0.3	2.3
8/11/98	13	3.5	178	2.9	19.2	19.0	544	28.6	0.5	3.1
11/18/98	12	3.5	22	3.8	21.3	24.9	540	3.3	0.6	3.7
3/30/99		4.1	24	0.5	1.6	2.6	55			
8/30/99		3.7	150	1.6	29.3	25.2	676			
9/29/99		3.7	196	1.5	25.6	28.6	646			
10/18/99	11	3.5	166	2.3	17.7	21.2	744	21.5	0.3	2.7
11/22/99	15	3.4	196	2.7	21.7	22.6	531	34.8	0.5	4.0
12/20/99	111	3.6	66	1.4	4.7	6.0	168	87.6	1.9	7.9
3/15/00	220	3.8	44	0.7	2.9	4.2	107	115.9	1.8	11.1
5/6/00	160	3.8	42	0.5	3.2	4.2	45	80.4	1.0	8.0

Table 10, Continued: Flow, Chemistry and Loading at the Robbins Hollow BAMR Weir 5 (Map #84)

	Flow gpm	Lab pH	Acid mg/L	Fe mg/L	Mn mg/L	Al mg/L	SO4 mg/L	Acid lb/d	Fe lb/d	Al lb/d
average	167	3.9	79	1.8	7.9	9.3	219	97.5	2.3	9.8
median	107	3.8	60	1.1	4.3	5.9	147	56.9	0.8	5.9
75%*	278	4.0	123	2.1	12.5	14.9	323	162.6	2.8	16.2
90%	427	4.5	169	3.4	20.3	20.3	536	241.4	5.6	25.2
max	533	4.6	196	13.7	29.3	28.6	744	383.8	21.5	33.3
count	42	46	46	46	46	46	46	42	42	42

** 75% of the measurements for the parameter are expected to be less than this value*

AMD Source: "Swamp" Discharges from Robbins Hollow Surface Mine
Receiving Stream: Twomile Run
Map Point # (See Map 2): 85, 146, 147, 148

Site Description Acid mine drainage flows from an abandoned surface mine that encompasses portions of the Robbins Hollow, Twomile Run and Shintown Run watersheds. The total surface area of the surface mine is approximately 120 acres. Contaminated drainage flows to the west to Twomile Run through an area referred to as the "Swamp" and to the south to Robbins Hollow. Discharges to Robbins Hollow are considered in a separate remediation recommendation. The Swamp is a 5-10 acre zone located below the toe-of-spoils where numerous AMD seeps have killed most of the vegetation. The surface mine above the Swamp is poorly vegetated and is not graded in a manner that would direct surface water off the site. As a result, high infiltration is likely contributing to the high AMD loadings that exist in the Swamp area.

BAMR weir 6 (Map #85) is located on a pipeline right-of-way below the Swamp. Flows and chemistry have been determined for BAMR weir 6 since 1995. Three seeps within the Swamp were sampled in December 1999 (Map #145, 146, and 147). Average data for BAMR weir 6 and seep analyses are shown below. All samples collected from the Swamp area were highly acidic and contaminated with elevated concentrations of Fe and Al. See Table 12 for the complete data set for this point.

Table 11. Water quality in the Twomile Run swamp kill zone area

	Period	N	Flow gpm	pH	Acid mg/L	Fe mg/L	Al mg/L	Mn mg/L	Sulfate mg/L
BAMR weir 6, (below Swamp)	Aug 95 – May 00	45	72	3.1	526	77	41	31	888
Swamp seep B	Dec 1999	1	na	2.8	228	1	32	10	432
Swamp seep C	Dec 1999	1	na	2.7	1166	30	161	33	1390
Swamp seep D	Dec 1999	1	na	2.7	384	5	58	11	671

na indicates that the data are not available, "N" is the number of samples

Recommendations Remediation of the Swamp AMD requires neutralization of acidity and removal of toxic metals. Because of the very high Al concentrations, passive treatment of water will be a challenge. Anoxic limestone drains are not recommended because of the high Al. The current passive approach most generally used for AMD similar to the BAMR weir 6 is treatment with vertical flow ponds, sedimentation ponds, and constructed wetlands. Water flows vertically in a pond down through a layer of organic substrate into a bed of limestone aggregate that is plumbed to collect and discharge the flow. The purpose of the organic matter is to remove dissolved oxygen and reduce ferric iron to ferrous iron. This will limit armoring of the limestone with ferric hydroxide. The purpose of the limestone aggregate is to neutralize acidity and generate alkalinity through calcite dissolution. Aluminum will also precipitate within the limestone aggregate, eventually resulting in permeability problems. To counter this condition, pipes are placed in the limestone aggregate that facilitate periodic flushing of aluminum solids out of the aggregate. Water flows from the vertical flow pond to a sedimentation pond intended to collect and store solids flushed from the vertical flow pond and to promote the oxidation and precipitation of iron. If the resulting water is still acidic, a second alkalinity-generating unit must be installed. Options include another vertical flow pond, an oxic limestone bed, and a limestone-amended constricted wetland.

Based on the data provided at BAMR weir 6 (Map #85), the recommended passive treatment system would consist of 2-3 acres of vertical flow ponds and 2-3 acres of ponds and wetlands. Sufficient flat land exists within the Swamp area and adjacent hollow to fit a 6-10 acre passive treatment system. However, the high Al concentrations make the long-term performance of the passive system uncertain. The recommended system will require regular maintenance and there is a possibility that the system could fail prematurely.

An alternative to constructing a treatment system (at this time) is to decrease contaminant loadings by reclaiming the surface mine that feeds the Swamp discharges. The spoils should be regraded to promote off-site drainage of surface water and revegetated so that evapotranspiration is increased. Both actions will decrease infiltration, which should decrease flow rates in the Swamp. Because flow rate is typically the major contributor to variability in contaminant loading at AMD sites, the decreased flows should result in decreased contaminant loadings. During reclamation the spoils should be amended with alkaline materials. The interaction of the alkaline amendments with infiltrating water should neutralize, somewhat, the AMD. This would also result in lower contaminant loadings in the Swamp.

Reclamation of the surface mine is unlikely to eliminate the Swamp discharges. Therefore, monitoring of the BAMR weir 6 (Map #85) should continue. After completion of the reclamation project and a period of time to allow groundwater recovery (probably one year), AMD production by the Swamp should be reassessed and a treatment plan should be developed. Decisions regarding how to best treat the swamp discharges should be based, in part, on experiences gained with passive treatment in the Middle Branch watershed.

Table 12. Flow, Chemistry and Loading at the Texas Pipeline ("Swamp") BAMR Weir 6 (Map #85)

Date	Flow gpm	Lab pH	Acid mg/L	Fe mg/L	Fe^{2+} mg/L	Al mg/L	Mn mg/L	SO4 mg/L	Acid lb/d	Fe lb/d	Al lb/d
8/16/95	1	2.9	764	144	114	25	37	1523	9.2	1.7	0.3
9/13/95	5	2.9	782	204	112	34	57	1758	46.9	12.2	2.1
10/25/95	44	2.9	712	32	21	91	30	1043	375.9	16.6	47.8
11/13/95	50	3.1	320	28	19	29	16	572	192.0	16.5	17.6
12/18/95	22	3.0	656	61	45	55	27	1060	173.2	16.1	14.6
1/18/96	34	3.2	436	62	38	29	29	424	177.9	25.1	11.8
2/13/96		3.1	560	54	31	67	28	1076			
3/12/96	36	3.0	502	40	29	56	21	869	216.9	17.2	24.2
4/9/96	36	3.1	484	36	31	14	22	814	209.1	15.6	5.9
5/15/96	174	3.1	446	22	15	55	20	716	930.7	46.3	114.1
6/18/96	214	3.0	340	37	12	26	19	499	873.9	94.3	65.5
7/16/96	14	2.9	648	151	91	32	45	1300	112.3	26.2	5.5
8/12/96	7	2.9	806	180	145	29	48	1600	64.8	14.5	2.3
9/16/96	139	2.9	692	25	13	84	27	1030	1150.1	40.9	139.1
10/29/96	65	3.1	526	36	11	55	23	786	409.3	27.6	42.9
11/20/96	156	3.1	556	31	21	54	23	755	1038.2	57.3	99.9
12/17/96	284	3.1	468	20	11	58	20	466	1594.9	67.5	197.3
1/13/97	70	3.4	494	55	34	47	36	659	416.1	46.3	39.2
2/24/97	184	3.3	218	19	13	22	11	278	481.3	42.6	47.9
3/24/97	101	3.2	414	32	19	42	67	508	501.8	38.2	51.1
4/14/97	70	3.2	416	43	25	44	24	491	350.4	36.3	37.2
5/12/97	22	3.2	422	67	43	28	27	800	109.9	17.3	7.3
6/16/97	13	3.0	544	92	65	21	29	908	87.5	14.7	3.3
7/28/97	11	2.9	728	148	84	25	45	1200	92.6	18.8	3.1
8/18/97	193		300	24		12	12		696.2	55.2	28.5
9/24/97	28	3.0	656	141	84	44	46	1100	216.5	46.5	14.5
10/21/97	9	3.1	690	152	67	33	43	1100	73.7	16.2	3.5
11/17/97	204	3.2	498	34	16	52	24	524	1217.3	83.8	125.9
12/15/97	31	3.2	494	50	28	45	23	817	183.8	18.4	16.8
1/8/98	70	3.3	270	30	14	22	15	409	227.4	25.3	18.7
2/17/98	123	3.2	292	30	17	26	17	465	429.6	44.0	37.8
3/17/98	88	3.2	500	36	22	57	22	690	526.8	38.2	60.2
4/14/98	97	3.1	442	25	14	49	21	777	516.6	29.7	57.5
5/18/98	76	3.1	430	36	1	47	21	601	391.1	32.5	42.9
6/8/98	10	3.1	642	116	71	49	37	1000	74.7	13.5	5.7
7/13/98	12	2.9	678	158	79	26	41	998	93.6	21.8	3.6
8/11/98	13	3.0	636	131	88	26	37	1200	102.3	21.1	4.2
11/18/98	4	3.0	354	162	15	31	51	649	16.1	7.4	1.4
3/30/99	178	3.1	430	23	9	61	19	705	920.0	49.2	129.7
8/30/99		2.8	632	204	108	27	47	1250			
9/29/99		2.9	596	158	14	25	45	1510			
10/18/99	3	2.9	574	161	56	31	47	1380	20.7	5.8	1.1
11/22/99	9	2.9	636	153	12	33	54	1120	69.5	16.7	3.6
12/20/99		3.1	508	51	16	70	30	781			
3/15/00		3.1	420	28	15	51	20	744			
5/6/00		2.9	580	43	14	69	27	1020			

Table 12, Continued: Flow, Chemistry and Loading at the Texas Pipeline ("Swamp") BAMR Weir 6 (Map #85)

	Flow gpm	Lab pH	Acid mg/L	Fe mg/L	Fe^{2+} mg/L	Al mg/L	Mn mg/L	SO4 mg/L	Acid lb/d	Fe lb/d	Al lb/d
average	72	3	526	77	40	41	31	888	385	31	38
median	40	3	505	46	22	38	27	814	217	25	18
75%	106	3	641	143	65	54	42	1100	505	43	49
90%	185	3	702	160	90	64	48	1348	941	55	115
max	284	3	806	204	145	91	67	1758	1595	94	197
count	40	45	46	46	45	46	46	45	40	40	40

AMD Source: Middle Branch Discharges
Receiving Stream: Middle Branch
Map Point # (See Map 2): 82, 86, 87, 88

Site Description Middle Branch enters Twomile Run 1½ miles upstream of the inflow of Huling Branch. Middle Branch is polluted by AMD associated with abandoned deep mines and surface mines. Flows and chemistry have been measured near the mouth of Middle Branch at BAMR weir 2 (Map #81), and at individual points near discharges (BAMR weirs 3, 7, 8, and 9; Map #82, 86, 87, and 88 respectively). Summary data are shown below. Middle Branch near its mouth is acidic and contaminated with moderate concentrations of acidity and Al. The flow at this station is, however, heavily influenced by dilution of the AMD by clean water. At weirs 3, 7, 8, and 9, the characteristics of the AMD sources are evident. The actual discharges are highly acidic and contain high concentrations of Al.

Table 13. Summary Data for Middle Branch Flows (Map #81, 82, 86, 87, and 88)

BAMR Site		Flow gpm	Lab pH	Acid mg/L	Fe mg/L	Al mg/L	Mn mg/L	SO4 mg/L	Acid lb/d	Fe lb/d	Al lb/d
2	average	556	4.2	42	0.2	4.7	1.6	58	245	1	24
3	average	27	3.5	489	4.3	68.0	19.7	555	150	1	21
7	average	9	2.9	614	14.4	73.0	19.3	545	66	1	8
8	average	7	3.2	318	7.5	51.0	19.6	616	18	<1	2
9	average	3	2.9	598	9.7	78.1	19.2	598	54	1	7

Recommendations BAMR has recently constructed a passive treatment system in the Middle Branch watershed (See Map 3). The system, which was completed in autumn 2000, treats discharges measured at BAMR weirs 3, 7, 8 and 9. The passive system consists of two vertical flow ponds (in parallel) followed by sedimentation ponds, wetlands and oxic limestone beds. One of the oxic limestone beds will be inoculated with Pyrolusite microbes (a patented microbial treatment process marketed by Allegheny Mineral Abatement of Midland MD). Because the treatment system is designed to allow side-by-side comparison of the effectiveness of the Pyrolusite system, the performance of the passive treatment systems will be closely monitored by BAMR.

The vertical flow ponds will receive AMD with very high Al concentrations. The success of these ponds in providing effective treatment with reasonable maintenance requirements will influence the implementation of similar passive treatment systems in the Swamp area and above the Huling Branch tipple.

Table 14. Flow, chemistry and loading at the Middle Branch BAMR Weir 2 (Map #81)

Date	Flow gpm	Lab pH	Acid mg/L	Fe mg/L	Al mg/L	Mn mg/L	SO4 mg/L	Acid lb/d	Fe lb/d	Al lb/d
4/26/95	400	4.3	46	0.1	3.3	1.2	54	221	0.4	16
5/24/95	1050	4.2	70	0.1	2.7	1.0	39	882	1.0	34
6/29/95	332	4.1	48	0.1	4.2	1.6	49	191	0.4	17
7/17/95		4.0	46	0.1	4.8	2.0	104			
8/16/95		4.0	50	0.1	5.5	2.4	101			
9/13/95		4.0	40	0.4	5.7	2.6	68			
10/25/95	265	4.1	38	0.1	4.9	2.0	48	121	0.3	16
11/13/95	1135	4.1	30	0.1	4.0	1.4	41	409	1.4	54
12/18/95	232	4.1	62	0.1	7.5	2.1	74	173	0.4	21
1/18/96	367	4.2	48	0.5	5.2	1.8	204	211	2.0	23
2/13/96		4.2	52	0.3	5.7	1.7	86			
3/12/96		4.1	38	0.5	4.4	1.3	40			
4/9/96		4.1	62	0.2	4.8	1.3	50			
5/15/96	777	4.1	30	0.2	2.8	0.9	40	280	1.9	26
6/18/96		4.1	60	1.1	7.8	2.3	115			
7/16/96		4.2	46	0.6	6.3	2.3	80			
8/12/96	33	4.1	48	0.1	4.7	2.2	65	19	0.0	2
9/16/96	438	4.0	48	0.3	5.8	0.1	61	252	1.8	30
10/29/96	496	4.3	42	0.1	3.8	1.3	10	250	0.8	22
11/20/96	419	4.3	46	0.1	4.6	1.5	46	231	0.7	23
12/17/96	1503	4.3	32	0.3	3.1	0.9	58	577	4.7	56
1/13/97	600	4.4	62	0.2	6.3	1.7	64	446	1.8	45
2/24/97	2105	4.2	26	0.4	2.6	0.8	21	657	10.1	67
3/24/97	477	4.3	42	0.2	3.7	1.1	25	240	1.0	21
4/14/97	419	4.4	40	0.4	4.1	1.2	31	201	2.1	20
5/12/97	260	4.4	24	0.2	3.4	1.1	38	75	0.7	11
6/16/97	142	4.3	40	0.1	3.1	1.2	34	68	0.1	5
7/28/97	18	4.2	38	0.0	3.3	1.8	39	8	0.0	1
8/18/97	1163		30	0.1	1.4	0.6		419	1.7	19
9/24/97	70	4.2	66	0.4	10.9	3.6	66	56	0.3	9
10/21/97	60	4.2	42	0.3	6.0	2.4	80	30	0.2	4
11/17/97	477	4.4	36	0.1	3.5	1.3	46	206	0.7	20
12/15/97	260	4.2	42	0.3	5.8	1.7	48	131	1.0	18
1/8/98	1121	4.3	28	0.1	3.3	1.1	26	377	2.0	45
2/17/98	920	4.3	32	0.2	4.6	1.3	33	353	2.2	51
3/17/98	643	4.2	32	0.2	4.7	1.3	30	247	1.8	36
4/14/98	1147	4.3	24	0.2	3.0	0.9	33	330	2.8	41
5/18/98	777	4.2	30	0.2	3.4	1.1	10	280	1.8	31
6/8/98	116	4.2	64	0.1	8.9	2.4	67	89	0.2	12
7/13/98	92	4.2	50	0.0	6.1	2.1	64	55	0.1	7
8/11/98	33	4.2	32	0.1	4.2	2.0	77	13	0.0	2
11/18/98		4.5	22	0.4	3.1	1.8	84			
3/30/99		4.2	28	0.4	3.6	1.0	42			
10/18/99		4.4	32	0.4	4.9	2.4	70			
11/22/99		4.3	36	0.0	5.8	3.0	114			
1/5/00		4.3	32	0.1	4.4	1.4	45			
3/15/00		4.2	38	0.2	4.8	1.3	63			
5/6/00		4.1	44	0.2	5.3	1.4	61			

Table 14, Continued: Flow, chemistry and loading at the Middle Branch BAMR Weir 2 (Map #81)

	Flow gpm	Lab pH	Acid mg/L	Fe mg/L	Al mg/L	Mn mg/L	SO4 mg/L	Acid lb/d	Fe lb/d	Al lb/d
average	556	4.2	42	0.2	4.7	1.6	58	245	1	24
median	419	4.2	40	0.2	4.6	1.4	50	221	1	21
75%	777	4.3	48	0.3	5.7	2.1	69	330	2	34
90%	1145	4.4	62	0.4	6.3	2.4	92	441	2	50
max	2105	4.5	70	1.1	10.9	3.6	204	882	10	67
count	33	47	48	48	48	48	47	33	33	33

AMD Source: Huling Branch Tipple Area
Receiving Stream: Huling Branch
Map Point # (See Map 2): 83

Site Description Huling Branch is severely degraded by inflows of highly acidic acid mine drainage. The discharges emanate from Lower Kittanning deep mines and surface mines on both sides of Huling Branch. Surface mines and refuse piles on the western side of Huling Branch are sparsely vegetated, but do not currently produce large quantities of AMD. The majority of AMD is associated with mines and a tipple site on the eastern side of Huling Branch. The tipple area contains refuse and a sediment pond that appears to be full of coal fines. North of the tipple is a large horseshoe-shaped kill zone that is a major producer of AMD. Northeast of the tipple AMD flows from a separate set of spoils, deep mines, and kill zones.

Upstream of mining, Huling Branch is unpolluted and supports native wild trout. The first discharge to degrade Huling Branch flows from the western side of the stream from a spring located mid-slope, approximately 100 ft below the coal seam. In March 2000 the discharge flowed 5 gpm, had a pH of 3.4, and contained 146 mg/L acidity, 16 mg/L Al and <1 mg/L Fe. Further downslope on the western side are a few small flows of acidic water that degrade Huling Branch, but do not appear to severely impact it. At the tipple site, large flows from the eastern side of the stream enter Huling Branch and kill it. BAMR weir 4 (Map #83) measures most of the flow from the tipple site and the mines above it. Summary data are shown in Table 15. All the collected data are attached. The drainage at this point, well down-flow of its sources in the kill zones and surface mines above the tipple, has pH less than 3 and contains 500-1,000 mg/L acidity, 50-120 mg/L Fe, 40-70 mg/L Al, and 15-40 mg/L Mn. Flows generally range between 25 and 250 gpm. Acidity loadings range between 250 and 2000 lb/day ($CaCO_3$).

Table 15. Summary of Data at the Huling Branch BAMR Weir 4 (Map #83)

Date	Flow (gpm)	Lab pH	Acid mg/l	Fe mg/l	Fe2 mg/L	Mn mg/L	Al mg/L	SO4 mg/L	Acid lb/d	Fe lb/d	Al lb/d
average	110	2.7	692	72	4	23	54	845	751	68	62
median	73	2.8	647	69	4	22	55	855	536	56	40
75%	137	2.9	862	88	5	29	59	1000	971	87	80
90%	228	2.9	967	116	6	36	70	1327	1327	118	126
max	571	3.1	1142	139	11	40	75	1756	3823	303	325
count	38	46	46	46	46	46	46	46	38	38	38

In December 1999 samples of mine water were collected from discharge points above the tipple site. Data are shown in Table 16. The chemistry of the seep discharges was similar to that obtained at the BAMR weir 4 (Map #83). The results of the seep sampling indicate that the AMD is contaminated with high concentrations of Al before it flows over bare clay soils.

Table 16. Chemistry of AMD seeps above the Huling Branch BAMR weir 4 (Map #83)

	Period	pH	Acid mg/L	Fe mg/L	Al mg/L	Mn mg/L	SO4 mg/L
Kill zone seep	Dec 1999	2.9	554	47	69	17	747
seep above tipple	Dec 1999	3.1	222	16	26	6	379
seep above tipple	Dec 1999	2.7	718	102	63	30	1100
Seep on west side (first discharge to HB)	Mar 2000	3.4	146	<1	16	5	169

Recommendations AMD at the Huling Branch tipple site is highly acidic and contaminated with very high concentrations of Al. Acidity loadings exceed one ton per day during high flow periods. These conditions are too extreme for reliable passive technologies that are currently available. The high concentrations of Al are of particular concern. Many passive systems constructed to treat AMD with elevated Al concentrations have experienced permeability problems within several years of construction. Passive systems being constructed in the Middle Branch watershed will treat similar Al concentrations, but much lower flows. A system proposed for the Robbins Hollow watershed will treat water with lesser concentrations of Al. The performance of these systems should be assessed and used as a basis for making decisions about pursuing passive treatment in the Huling Branch watershed.

Chemical treatment of the Huling Branch AMD discharges should be considered because restoration of lower Kettle Creek depends greatly upon the remediation of Huling Branch. The remote nature of the discharges makes the chemical option challenging. The preferred treatment location is the tipple site because it is located immediately below most of the AMD and flat land is available for system construction. Difficulties of the tipple site include the absence of electricity and winter access. Downstream of the tipple site the stream valley is quite steep and no good sties for construction of a treatment system exist.

Several levels of chemical treatment are possible. The simplest and least costly treatment is to install a lime doser either at the tipple site or directly on the stream. The doser could be operated by a waterwheel, without any electricity. The waterwheel, doser, and lime hopper would cost approximately $200,000. Based on data collected at BAMR weir 4, the doser should add approximately 120 tons $Ca(OH)_2$ per year. At $80/ton delivered, the lime cost is approximately $10,000 per year. Operation of the system and maintenance of the access road would cost approximately $20,000 per year. Lime dosers placed on AMD polluted streams have proved very effective in the restoration of downstream lakes (East Branch of the Clarion River Lake) and rivers (Potomac River). Dosers do not result in any net reduction of metal solids. The treatment would likely turn Huling Branch orange. (The stream is currently clear because the pH is so low that metals do not precipitate until they reach Kettle Creek.) Most of the metal solids that precipitate in Huling Branch would likely be washed into Kettle Creek during high flows. However, the input of alkaline water from Huling Branch, and subsequently from Twomile Run to Kettle Creek, would substantially improve the chemical condition of lower Kettle Creek.

At the other end of the treatment spectrum is a chemical plant that treats the AMD and collects and manages the metal sludge. Chemicals are added to the AMD in treatment ponds followed by sedimentation ponds where metal-rich sludge settles. The discharge to Huling Branch would be alkaline with low metal concentrations. Sludge would be periodically (several times a year) pumped from the ponds to a disposal site – probably an abandoned strip pit above the tipple site. If electricity was present, the most cost-effective treatment would be a lime plant equipped with mixers and aerators. In most remote locations like the tipple site, treatment is done with liquid sodium hydroxide. Sodium hydroxide is much more expensive than lime, and would cost approximately $60,000/yr to purchase. The complete operation of the NaOH treatment plant and management of sludge, would likely cost about $150,000/year. Start-up capital investments in equipment and pond construction would likely cost about $250,000.

Before a treatment plant is designed for Huling Branch, the principle AMD discharges should be collected and separated from surface water. The BAMR weir 4 flow measurements are a combination of AMD seepage and surface water. The AMD should be collected either by installing an underground collection system in AMD-producing areas, or by installing a surface ditch system that collects the AMD and diverts surface water away from treatment areas.

Surface reclamation of the Huling Branch area may also be considered in the future. However, because of the importance of the existing ATV trail, any surface reclamation must consider the needs of ATV users.

Predicted Effects of Treatment on Receiving Streams If a stream doser is installed on Huling Branch, the stream will become contaminated with metal solids. Little restoration of Huling Branch or lower Twomile Run would be expected. Lower Kettle Creek will be positively affected by the reduction of acidity and addition of alkalinity. While staining of lower Kettle Creek in the vicinity of the Twomile Run inflow will likely persist, the chemical changes should promote restoration of ~5,000 ft of lower Kettle Creek.

If an AMD treatment plant is installed at the tipple site, most of the 10,200 ft of Huling Branch below the tipple will be restored. Assuming that remediation projects occur and are successful in the Middle Branch and upper Twomile Run watersheds, then the Huling AMD treatment plant would also result in the recovery of 1,500 ft of lower Twomile Run and 5,690 ft of lower Kettle Creek.

Table 17. Flow, Chemistry and Loading at the Huling Branch BAMR Weir 4 (Map #83; immediately below the tipple site).

Date	Flow (gpm)	Lab pH	Acid mg/l	Fe mg/l	Fe^{2+} mg/L	Mn mg/L	Al mg/L	SO4 mg/L	Acid lb/d	Fe lb/d	Al lb/d
8/16/95	9	2.5	964	88	5	33	75	1333	104	9	8
9/13/95	17	2.5	1142	130	4	37	69	1756	233	27	14
10/25/95	38	2.6	820	89	6	27	57	906	374	40	26
11/13/95	131	2.7	632	75	4	22	48	950	994	118	75
12/18/95	50	2.8	772	76	5	23	55	1010	463	45	33
1/18/96	50	2.8	770	94	3	28	56	1049	462	56	33
2/13/96		2.9	638	72	11	22	61	915			
3/12/96	193	2.8	527	47	8	12	50	727	1221	110	116
4/9/96	123	2.8	594	46	6	17	49	820	874	67	72
5/15/96	284	2.9	462	31	3	12	42	539	1577	104	143
6/18/96	76	2.7	752	70	4	26	55	672	684	63	50
7/16/96	46	2.6	844	82	3	30	60	1150	465	45	33
8/12/96	22	2.5	1006	105	4	34	64	1320	262	27	17
9/16/96	130	2.6	728	69	6	22	52	904	1139	108	81
10/29/96	571	2.8	558	44	4	17	47	424	3823	303	325
11/20/96	311	2.9	588	40	6	14	44	574	2191	148	164
12/17/96	284	2.9	462	35	5	12	46	323	1574	118	156
1/13/97	76	3.1	656	70	9	22	57	748	597	64	52
2/24/97	204	3	398	37	5	13	36	436	974	91	87
3/24/97	139	2.9	576	49	5	17	46	525	961	82	77
4/14/97	70	2.9	550	55	4	19	52	558	463	46	44
5/12/97	48	2.9	678	65	2	25	56	904	391	37	32
6/16/97	70	2.6	726	60	2	23	45	896	612	50	38
7/28/97	22	2.5	920	92	3	33	57	1000	240	24	15
8/18/97	88	2.7	522	53	5	19	33	325	550	56	34
9/24/97	23	2.6	868	112	3	35	62	927	241	31	17
10/21/97	22	2.6	950	116	3	30	61	1000	247	30	16
11/17/97	70	2.9	620	69	5	21	46	393	522	58	38
12/15/97	50	2.9	618	85	4	22	55	483	373	51	33
1/8/98	82	3	484	51	2	18	42	496	475	50	41
2/17/98	108	3	440	57	5	18	37	480	570	73	48
3/17/98	188	2.9	524	60	6	16	52	589	1185	136	118
4/14/98	193	2.9	448	38	3	14	41	426	1040	88	94
5/18/98	119	2.8	498	40	2	16	43	561	710	57	61
6/8/98	38	2.7	770	79	3	24	58	1000	350	36	26
7/13/98	25	2.5	874	83	2	27	58	896	257	24	17
8/11/98	32	2.6	908	10	3	3	57	1200	353	4	22
11/18/98	17	2.7	466	123	3	39	72	652	93	25	14
3/30/99	160	2.9	476	41	3	15	50	509	911	79	95
8/30/99		2.4	970	116	2	40	72	1650			
9/29/99		2.5	994	109	3	36	65	1580			
10/18/99		2.5	912	126	3	37	72	1460			
11/22/99		2.6	1022	139	2	39	71	1320			
12/20/99		2.7	668	88	3	27	57	863			
3/15/00		2.8	528	49	2	18	47	756			
5/6/00		2.7	496	37	1	19	53	847			

Table 17, Continued: Flow, Chemistry and Loading at the Huling Branch BAMR Weir 4 (Map #83; immediately below the tipple site).

	Flow (gpm)	Lab pH	Acid mg/l	Fe mg/l	Fe^{2+} mg/L	Mn mg/L	Al mg/L	SO4 mg/L	Acid lb/d	Fe lb/d	Al lb/d
average	110	2.7	692	72	4	23	54	845	751	68	62
median	73	2.8	647	69	4	22	55	855	536	56	40
75%	137	2.9	862	88	5	29	59	1000	971	87	80
90%	228	2.9	967	116	6	36	70	1327	1327	118	126
max	571	3.1	1142	139	11	40	75	1756	3823	303	325
count	38	46	46	46	46	46	46	46	38	38	38

C. Flow Management

The flow rate of the main branch of lower Kettle Creek is controlled at the Alvin R. Bush Dam. The reservoir is currently managed for recreational uses and for flood control. The discharge from this reservoir could also be managed to minimize the impacts of Twomile Run on the main branch of Kettle Creek. This could be accomplished by monitoring the flow rate of the mouth of Twomile Run and releasing additional water from the reservoir as needed to offset the effects of Twomile Run.

Table 18 was developed using the average chemistry of Kettle Creek at the USGS Gauging Station upstream of Westport and of the mouth of Twomile Run. The resulting chemistry of Kettle Creek at Westport was predicted for various flow ratios. For example, when Kettle Creek is flowing at least ten times greater than Twomile Run, the stream mixtures are calculated to be net alkaline. These calculations do not consider inputs of AMD from the western side of Kettle Creek. These inputs have not been quantified, but are thought to be less significant than the impact of Twomile Run.

Table 18: Predicted Chemistry of Kettle Creek at Westport

Flow Ratio	**Predicted Chemistry of Kettle Creek at Westport**		
Twomile Run : Kettle Creek at Gauge	Net Acidity (mg/L)	Iron (mg/L)	Aluminum (mg/L)
0 (no flow at Twomile)	-13	0.3	0
1 : 1,000 (0.1 %)	-13	0.3	0.01
1 : 200 (0.5 %)	-12	0.3	0.04
1 : 100 (1 %)	**-12**	**0.3**	**0.09**
1 : 40 (2.5 %)	**-10**	**0.4**	**0.21**
1 : 20 (5 %)	**-8**	**0.5**	**0.41**
1 : 13 (7.5 %)	-6	0.6	0.60
1 : 10 (10 %)	-4	0.7	0.78
1 : 5 (20 %)	4	1.0	1.43
1 : 3 (33 %)	11	1.3	1.98
1 : 2.5 (40 %)	17	1.6	2.46
1 : 2 (50 %)	22	1.8	2.87

The bolded region indicates the range of flow ratios that were measured during the TMDL study (See Table 4).

Using Table 18 or similar calculations, downstream quality targets for Kettle Creek could be established and the flow of Kettle Creek through the Alvin R. Bush dam could be managed to meet these targets. For example, if the target for lower Kettle Creek is a net alkaline condition of at least 10 mg/L, the flow of Kettle Creek should be at least 40 times greater than the flow of Twomile Run. The discharge from the reservoir could be managed to release at least this amount of water in response to flow monitoring data from the mouth of Twomile Run.

Due to the limited amount of data for Kettle Creek at the mouth and for the western discharges, future monitoring data should be incorporated into the above model in order to determine the proper ratio of flow necessary to maintain the fishery in lower Kettle Creek.

The above model predicts a higher quality than will actually exist because it ignores inputs of AMD from the western discharges and from Butler Hollow.

While this management strategy does not remediate the AMD problems in Lower Kettle Creek or Twomile Run, it will help to mitigate the effects of pollution. A management plan such as this could be implemented quickly in order to protect the Kettle Creek fishery while permanent AMD remediation efforts are taking place.

In order to develop a Flow Management plan, the following steps should be taken:

- Develop in-stream quality targets for Kettle Creek below Twomile Run
- Install a continuous flow monitoring station at the mouth of Twomile Run
- Continue to sample Twomile Run, Kettle Creek at the USGS gauge, and Kettle Creek at Westport
- Use the data to refine the model (Table 18)
- Develop a plan to meet the quality targets
- Implement the plan by managing the flow release at Alvin R. Bush dam.

This plan will require the cooperation of the Army Corps of Engineers (managers of the dam) and the US Geological Survey (stream flow monitoring).

VI. Recommended Plan

Several projects in the Twomile Run watershed are already in progress and others are in advanced planning stages. The following recommended plan incorporates these projects as well as recommendations for the western drainage of Kettle Creek.

1. Monitor the performance of the recently completed Middle Branch Treatment System (Map #82, 86, 87, 89)
   - System construction began in Fall 1999 and was completed is Fall 2000.
2. Develop a program to further characterize the western discharges
   - BAMR began a monitoring program in 2000. Continued monitoring is recommended.
3. Continue sampling of Twomile Run (at discharge locations and mouths)
4. Develop a Flow Management Plan for the Alvin R. Bush Dam
5. Pursue BAMR-sponsored reclamation of area above the Swamp (Map #85) (Growing Greener submission, August 2000)
   - Include in the Project a sub-surface collection drain for the Swamp Area
   - Continue to monitor BAMR weir 6 for at least one year after reclamation is complete
6. Collect Robbins Hollow discharges and construct a passive treatment system in the headwaters of Robbins Hollow (Growing Greener August 2000)
7. Collect and monitor the Huling Branch tipple site discharges (Map #83) (Growing Greener submission, August 2000)
8. Construct a passive treatment system at the Swamp Area as needed according to post-reclamation monitoring
9. Using data and experiences gained at the Middle Branch system, continually reevaluate the feasibility of passive treatment options for Huling Branch.
10. If passive treatment is not feasible, design and construct of an appropriate chemical treatment system on Huling Branch

VII. Plan Implementation

Recommendations necessary to implement the Plan are shown below in a chronological

1. Reclaim surface mines above “Swamp” and monitor discharges.
2. Construct a treatment system at Robbins Hollow.
3. Collect and monitor the tipple discharges on Huling Branch.
4. Develop a Flow Management Plan for the Alvin R. Bush Dam.
5. Design and construct a treatment system for remaining Swamp discharges, if necessary.
6. Perform surface reclamation in Huling Branch (considering ATV users).
7. Design and construct a treatment system for Huling Branch discharges.

The first three projects listed above have been submitted to Pennsylvania’s Growing Greener Program during the second round of funding. Decisions on these projects are due as this plan is being finalized. If awarded Growing Greener funding, the first three projects will be completed within two years.

VIII. Assessing Plan Effectiveness

The effectiveness of remediation projects should be assessed by measuring changes in chemical and biological conditions in the Twomile Run watershed and lower Kettle Creek. Amelioration of chemical conditions in the Twomile Run watershed can be measured through continued monitoring of stream chemistry and flows at points below significant inflows of AMD. Baseline data are available from the BAMR monitoring stations and the DEP's TMDL stations. The TMDL study should be completed by the end of 2000 and should provide good baseline conditions for Upper Twomile Run, Robbins Hollow, Middle Branch, Huling Branch, and lower Twomile Run. When the TMDL study is completed, the feasibility of combining BAMR weir data into the TMDL database should be investigated. At this point, permanent long-term sampling stations should be established and sampled on a quarterly basis. Once chemical changes have been documented, biological studies will be necessary to determine the extent of stream restoration.

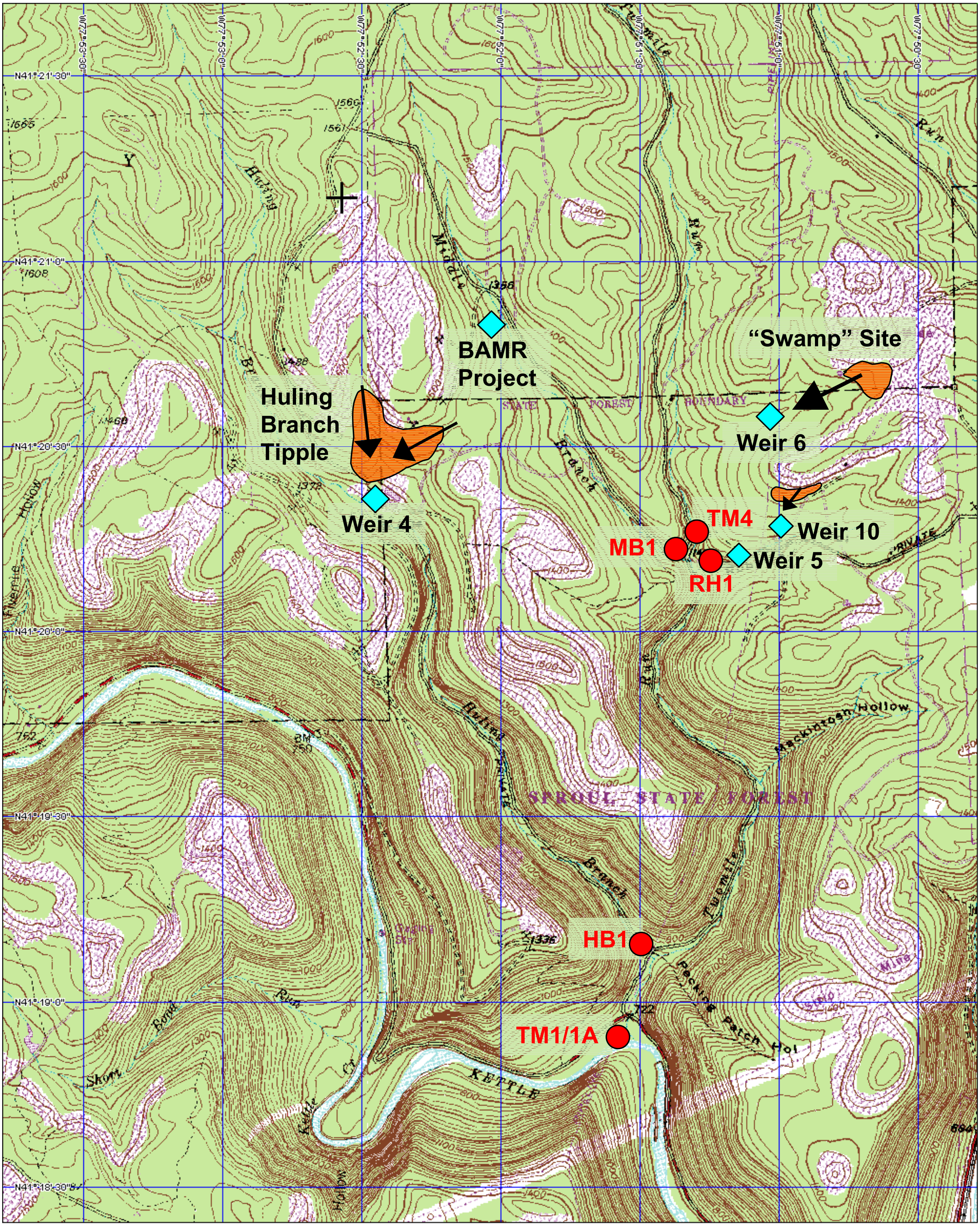
Lower Kettle Creek is not currently being monitored on a regular basis. Monitoring stations should be established above Twomile Run, below Twomile Run, above Butler Hollow, and at the mouth. Water samples should be collected on a quarterly basis and during extreme climatic conditions such as severe drought. Flows cannot be easily and accurately measured at the sampling stations. Incorporation of flow rates from the USGS gauging station is recommended. If the chemical database collected for the mouth of Twomile Run and lower Kettle Creek indicates an amelioration of AMD conditions, a biological survey of lower Kettle Creek should be conducted.

IX. References

Mine Drainage Pollution Abatement, Kettle Creek, Clinton County, Pennsylvania. Operation Scarlift Project SL-115. Performed by Neilan Engineers, Inc. Somerset, PA. June 1973.

Hyrdologic Unit Plan, Twomile Run and Shintown Run. Pennsylvania DEP, BAMR, Pamela J. Milavec and Richard L. Beam. November 30, 199

Map 3: Twomile Run Sampling Locations



 750 ft Scale: 1 : 25,000 Detail: 13-0 Datum: WGS84

TMDL Point ● BAMR Weir ◆ Seep Zone