Wolford Run Site Investigation and Reconstruction Design

Final Report

December 31, 2006

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Wolford Run passive treatment system. The settling ponds are undersized and full of sludge and do not provide good treatment

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Executive Summary

Acid mine drainage from an abandoned deep mine complex near Salina, PA (Westmoreland County) pollutes Wolford Run (tributary to the Kiskiminetas River). The flow is from a borehole that was relocated a decade ago into a passive treatment system. The system has failed because it is too small and because the ponds have filled with iron sludge. A Growing Greener grant was received whose purpose was to recommend improved treatment scenarios. The project included research into the borehole and the origins of the AMD. The borehole is a drain for a mining complex that included the Jamison and Truxall Mines. Both mines are in the Upper Freeport coal. The Jamison Mine is completely flooded while the Truxall Mine is largely above drainage and likely unflooded. The connection between the mines is near the borehole. It is likely that the discharge is a mixture of low pH water with elevated Al and Fe from the unflooded Truxall Mine and alkaline water with elevated Fe from the flooded Jamison Mine. The mixture would result in precipitation of Al solids within the mine and the discharge of water with elevated Fe.

The borehole was investigated with a video camera operated by the Greensburg District Mining Office. The hole was partially plugged with debris, which was cleaned out with the assistance of the Kiski Area Water Authority. The hole is now clear from the surface into the mine, a distance of 103 ft. The video indicated that the borehole consists of 8 ft of PVC pipe connected to steel casing that extends into the mine. The steel pipe is intact, although corrosion was visible its full length. There is a gap at the connection of the plastic and steel pipe that allows water to leak from the borehole. This observation explains the considerable leakage around the borehole that occurred when the ALD clogged and when the head on the hole was increased by raising the discharge elevation. In order to proceed with improved treatment, this problem must be corrected so that the flow can be relocated to treatment sites without leaking.

The water was sampled after the borehole was cleaned out. The flow in late 2006 was 200-300 gpm, had pH 5.7, and contained on average 135 mg/L Fe, 2 mg/L Mn, 0.7 mg/L Al, and 150 mg/L net acidity. The alkalinity generating capacity of the water was measured at ~275 mg/L. This is enough alkalinity to result in a final discharge with net alkalinity of about 50 mg/L. The original system design was correct (ALD followed by settling ponds) but the sizing was grossly inadequate. A passive system expected to discharge <1 mg/L Fe on a 250 gpm flow rate should contain a 4,400 ton ALD followed by 1.6 acres of settling ponds, and 0.9 acre of constructed wetlands. The system should be designed for iron oxide recovery, which will eliminate most of the long-term operational costs. Three sites near the discharge were identified for placement of a passive treatment system. The cost estimate to repair the borehole and build an adequately sized passive treatment system on these sites ranged from $533,000 to construct a system sized for average flow to $770,000 to construct a system sized for higher flows.

If the KWA proceeds with this project, the next step is to negotiate with property owners and secure long-term access to one of the sites.

Site Background

Wolford Run is polluted by an AMD discharge from a borehole located along the stream in Tinsmill, PA. The discharge flows through a passive treatment system installed in 1994 by the Westmoreland County Conservation District and the Soil Conservation Service using funding provided by the Rural Abandoned Mine Program (RAMP). Much has changed since then. The Soil Conservation Service was reorganized as the Natural Resources Conservation Service. Funding for the RAMP program declined to zero in the late 1990's and the recent reauthorization of Title IV of the Surface Mine Control and Reclamation Act of 1977 eliminated the program completely. The passive treatment system, which consists of an anoxic limestone drain (ALD) followed by three serially-connected settling ponds is still in place, but its performance is poor. Recent measurements indicate that the system is removing no more than 10% of the contamination.

The original digital mapping and plans for the RAMP project were not located. A paper copy of the as-built plans was obtained from a local landowner. Three sheets showing the current system and areas that should be considered for future treatment were copied and are included in the map folder of this report.

Data for the borehole discharge before this project indicated that the flow had pH 5-6, 200-250 mg/L acidity, 100-300 mg/L Fe, 2-3 mg/L Mn, and 2-3 mg/L Al. The aluminum concentrations were unexpected, because Al has a very low solubility at pH 5-6. The interest in Al was pertinent to treatment considerations because ALDs, the most reliable passive technique for generating alkalinity, are highly sensitive to Al concentrations. AMD with 3-5 mg/L Al has plugged ALDs, causing failure.

Disregarding the aluminum issue, it is obvious that the installed passive system is too small. The AMD flow rate is 200-400 gpm. Effective ALDs contain *at least* ten tons of limestone for each gpm of flow. At this ratio, at least 2,000-4,000 tons of limestone should be installed. The ALD originally contained 600 tons of limestone. Effective Fe-removal systems contain *at least* 0.75 acre of treatment for each 100 gpm of flow (alkaline water with 75-100 Fe). By this standard, the ponds should have been at least 1.5 – 3.0 acres. The installed ponds are 0.7 acres.

Given this background, the goal of the current project was to determine whether the system could be redesigned to be more effective. An understanding of the minepool hydrogeology was considered an important task because of the likelihood that the discharge would be moved from its current location to access sufficient treatment area. The opportunity for recovery of saleable iron sludge was considered because this feature would affect the long-term operational costs of a redesigned system. Lastly, several locations for placement of the redesigned system were evaluated.

Geology and Mining History

The Westmoreland County Coal Resource Report was reviewed. These reports are organized by USGS quad maps and show the location of various coal seams, the coal crop, and areas known to contain deep mines. The borehole and passive system are located on the USGS Avonmore 7.5 minute quad. The only mined coal seam shown for the area is the Upper Freeport and it does not crop anywhere in the Avonmore quad. The report does not show deep mines the area of the passive treatment system and borehole. This is contrary to what is shown on the mine maps from R&P Coal Company (see below). The R&P maps are considered more reliable with respect to mine details.

Indiana University maintains a mine map repository that includes maps produced by R&P Coal. Much of the mining in the Tinsmill area was done by R&P Coal and several deep mine maps were found that elucidated the local coal geology and coal mining history.

Figure A is taken from the R&P Coal Company Avonmore Field Map. The shaded areas are deep mines. The location of borehole discharge is marked. Two mines are apparent: the Jamison Mine and the Truxall Mine. Both mines were in the Upper Freeport coal seam. The map shows the structural contour elevations of the Upper Freeport coal seam at 50' contour intervals. The structural contours indicate that the Port Royal (Elders Ridge) Syncline is situated ~8,500 feet to the southeast of the site. The Roaring Spring (Murrysville) Anticline is situated ~ 16,000 feet to the northwest of the site. The dip of the Upper Freeport coal seam in this area is approximately 3% to the south and east. The elevation of the coal at the synclinal trough is ~450 ft while the elevation of the coal on the anticlinal ridge is at nearly 1100 ft. The coal elevation at the borehole is approximately 751 ft.

Figure B shows the location of the Jamison Mine entry, the borehole, and the tunnels that connects the Truxall and Jamison Mines. The borehole is located in an isolated eastern extension of the Jamison mine that is downdip from the Jamison Slope entry. The elevation of the ground surface at the top of the borehole is 854 ft and the hole extends 103 ft (according to mapping) to the coal. The R&P drilling (Figure A) found that the coal thickness ranged from 42 to 50 inches and averaged 48 inches. The borehole connects a downdip portion of the mine with the lowest surface elevation. This combination makes for good mine drainage because the water within the mine flows freely to the borehole which then discharges to the surface at the lowest elevation possible in this area. The operation of a pump located at the bottom of the borehole would have kept a large portion of the Jamison Mine dry and allowed access into the Jamison Mine Slope Entry.

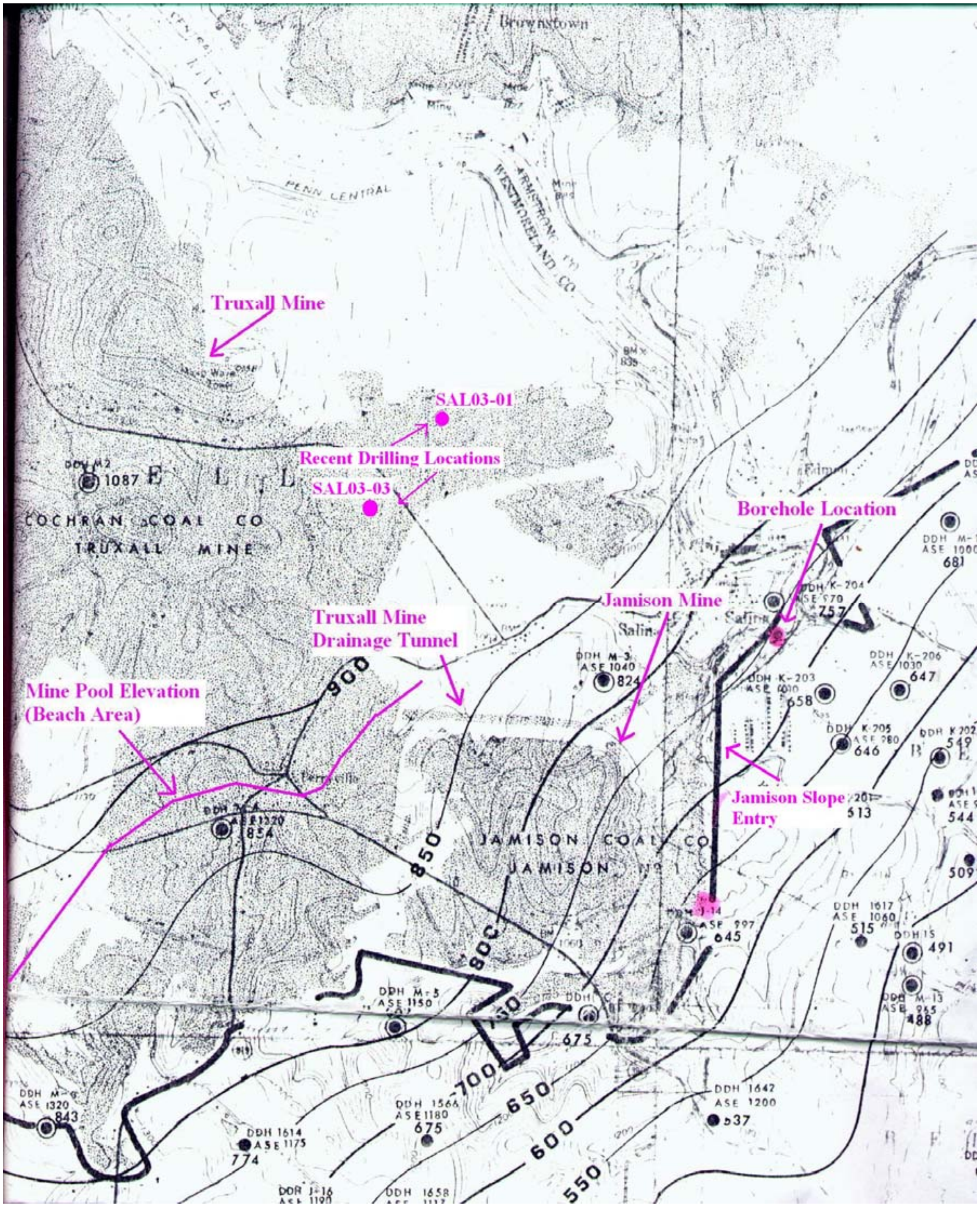


Figure A. Map showing structural contours of Upper Freeport Coal, deep mines, drill holes and the estimated current location of the mine pool beach within the mines (source: R&P Coal Co. Avonmore Field map)

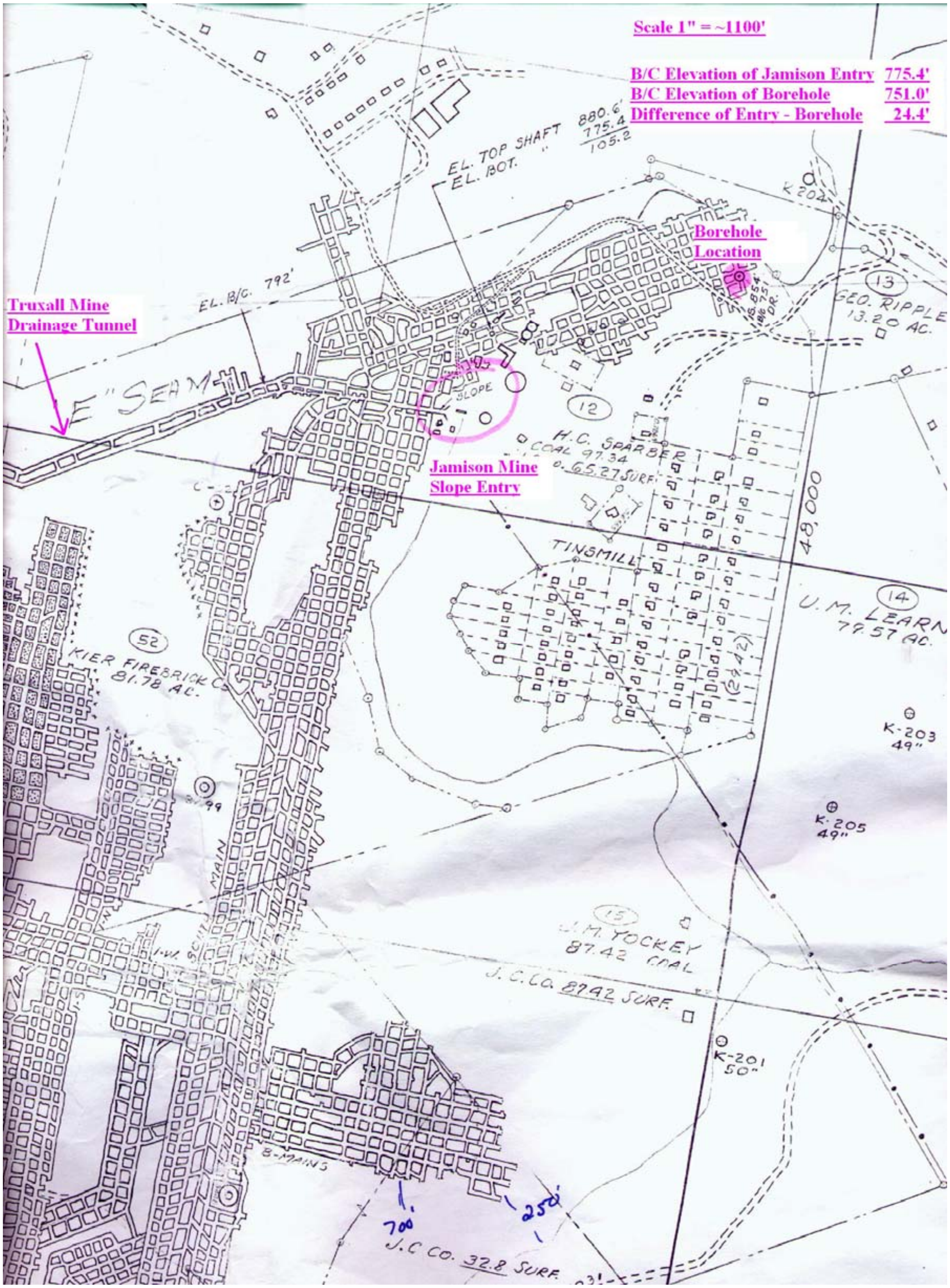


Figure B. Map showing location of Jamison Mine Entry, borehole location and the Truxall mine drainage tunnel. (source: Jamison Coal Co. Mine Map)

The Truxall Mine is located west and updip of the Jamison Mine. The mines are separated by coal barriers except for a single set of parallel tunnels that access the Jamison Mine extension approximately 2,000 ft west of the borehole location (Figures A and B). This tunnel appears to have been placed for drainage purposes. Water draining from the Truxall Mine would have flowed downgradient just north of the main Jamison Mine entry and to the borehole. The tunnels may also have been used for coal haulage as they line up with the Jamison Slope Entry shaft. The Truxall mine is substantially larger than the Jamison Mine (Figure A).

When mining ceased and the pumps were turned off, the mines filled up until a discharge developed at the borehole at 854 ft. This elevation is marked in red on Figure A and labeled as the "beach area" because it represents the shore of the mine pool within the mine. At this elevation, all of the Jamison Mine is flooded. Most of the Truxall Mine is higher than 854 and is not flooded.

Kier Clay Mine

The mining history of the site was discussed with Bill Bagonier, a former geologist from R&P Coal Co. Mr. Bagonier verified the information obtained from the maps and also pointed out the presence of the Kier Firebrick Company clay mine situated in the underclay of the Upper Kittanning coal seam. The Upper Kittanning coal is at least one hundred feet below the Upper Freeport coal seam. Clay mines are known to produce acidic water with high Al concentrations. If there was a connection between the mines, acidic water from the clay mine could flow upward into the Jamison Mine. This scenario is unlikely. The mines do not overlap in the area of the passive treatment system. The nearest overlap appears to be at least 2,000 feet to the southwest of the treatment site. No evidence was found that the mines were connected with a borehole.

Conclusions

The borehole is located approximately half way down the synclinal limb of the Port Royal Syncline. The synclinal limb trends in a southeast by northwest direction at approximately 3% dip**.** The borehole connects the mines with the lowest overlying surface point that is not in Wolford Run. All other points within the mine that are at a lower coal elevation are located higher in surface elevation by at least 50 feet in elevation. The borehole is an excellent mine drain.

The mine complex currently discharges through the borehole and an elevation of 854 feet. The Jamison mine has coal elevation of less than 850 feet, thus the entire mine is flooded. Coal elevations in the Truxall Mine are generally higher than 900 feet and most of the mine appears to be unflooded. The Truxall Mine is connected to the Jamison Mine by a tunnel that was likely used to discharge water from the Truxall Mine and may have been used for access through the Jamison Mine Slope Entry. Water discharged from the borehole is a mixture of flow from the unflooded Truxall Mine and the flooded Jamison Mine.

Borehole Cleanout and Investigation

The discharge flows from a PVC pipe that that was attached to the borehole by the RAMP project. The plastic pipe connects to a "Tee" and then to the original borehole casing. The Tee was intended to direct flow into the ALD. The top of the plastic pipe was originally capped, but the cap was removed to access the pipe and borehole. Before the cap was removed, water was discharging from the ALD and also from the opposite side of the borehole (and Tee) and flowing down the hillside to Wolford Run. After the cap was removed, most water flowed from the top of the pipe and in a channel to the first settling pond. A flume placed in this channel was used to measure flow. When water flowed freely from the plastic pipe, leakage flowing directly into the Wolford Run was minimized. After the borehole was cleaned out, an elbow was placed on the top of the pipe to lessen the chance that debris or rocks would fall inside the borehole. Photo 1 shows the discharge pipe and the flume were flow is measured.

Photo 1. Wolford Run borehole discharge and flume.

An important component of a redesigned treatment system is the relocation of the flow to an area with more acreage. The mapping suggests that it should be feasible to raise the discharge without a blowout occurring. This idea was tested by installing short lengths of solid PVC pipe onto the uncapped borehole so that water had to rise higher to discharge. The plan was to raise the discharge in increments. In February and March 2005, the elevation of the discharge was sequentially raised 2 ft, another 1 ft, and another 2 ft. In each case, the flow ceased with installation of the new pipe, but the flow returned within 48 hours. This experiment indicated that the discharge could be raise and moved. However, the addition of head caused leakage from the borehole to increase substantially. This leakage complicates any plans to relocate the discharge by piping it from the borehole. The leakage suggested that either the PVC pipe installed by the RAMP project was broken, or that the ground around the borehole was incompetent down to the mine.

During the April watershed meeting it was suggested that the borehole should be investigated to determine its integrity and the cause of the leakage. DEP agreed to supply and operate a borehole camera that would be lowered into the borehole and allow its observation and inspection. The camera was operated by Michael Gardner of the Greensburg District Mining Office.

On May 30th, DMO and HE personnel met on site to investigate the borehole. The equipment was set up and the camera was lowered into the hole. The borehole was found to be blocked off with large aggregate at about 7 feet of depth, the approximate location of the Tee. The investigation was stopped and plans were made to re-visit the hole after the blockage was removed.

Removal of the blockage required several efforts. Initially the plan was to use the hooks attached to steel pipe to grab and retrieve the rocks. The hooks proved ineffective for rock retrieval. However, the pipe was used as a ramrod and the rocks were dislodged to a depth of 13 ft. After several attempts to remove the blockage at 13' a steel pipe fitting broke, ending the effort.

Several weeks later, 42 ft of 3/8" steel pipe (7 ft long sections) was brought to the site to help remove the blockage. The pipe was used as a ramrod and after several attempts the blockage appeared to have been removed. A rope was tied to the end of the pipe and lowered down the borehole. The pipe stopped on what appeared to be a soft mucky bottom at 100' from the top of pipe.

Mr. Gardner returned on July 18 to photograph the hole. The investigation discovered that blockage remained in the hole at 60 feet. Apparently the steel pipe was able to slide past the blockage and continue to the bottom of the hole. The video inspection showed sediment along with large rocks blocking the borehole.

A copy of the video was sent to Bob Kossak of the Kiski Valley Water Authority. On August 30, a crew from water authority removed the remaining blockage using a heavy 2 feet long piece bar of steel at the end of a 3/8 " rope and a truck-mounted high-pressure sewer cleaner (Photo 2). The piece of steel was repeatedly dropped on the blockage to break it up. The high pressure pump pushed water through a fire hose and a high pressure nozzle to dislodge the blockage. The combination of raising and dropping the steel weight and the high pressure nozzle finally dislodged the blockage completely. The hole was cleared to the bottom, a depth of 107'. The flow from the borehole increased substantially immediately following removal of the obstruction (Photo 3).

Photo 2. Kiski Water Authority crew feeding plastic tubing into the borehole for purpose of removing blockage.

Photo 3. The large flow of water immediately after removal of the borehole obstruction.

On September 16, 2006, Ron Horansky and Mike Gardner returned and found the hole open to the bottom. The hole was inspected by lowering the camera down to the mine void. The video showed steel casing that extended 103.5 feet into the mine void. There was an 8 foot open void from the end of the pipe to the mine floor.

The steel casing had many very small (< 1/4 inch diameter) chunks of scale encrusted onto the inside of the casing. The scale was not large and does not present a problem for clogging. There was sufficient scale developed that it was impossible to visually determine where sections of the steel pipe met one another. The video did not expose holes in the pipe, but the scale could have hid decaying pipe. The water has a high CO_2 content and over time carbonic acid could corrode the steel pipe.

The video showed the condition of the PVC pipe at the top of the borehole. The connection between the plastic pipe and the steel casing occurs just beneath the PVC Tee. The pipes were not fit well and a space was visible between these two pieces. This space was providing a conduit for leakage out of the borehole before it rose up to the T or to the top of the pipe. The addition of pressure, through the plugging of the ALD with solids or by raising the end of the borehole with additional pipe, would have increased pressure on the joint and increased the amount of water leaking out.

Conceptual Mine Water Geochemistry Model

The borehole provides a single discharge from a large mine complex that varies in elevation and the presence of flooded conditions. These conditions can have important influences on mine drainage chemistry. In western PA, flooded Upper Freeport mines generally produce alkaline water with moderate Fe concentrations and negligible Al. Unflooded Upper Freeport mines can produce low pH water with high concentrations of Fe and Al. If these geochemical conditions are being realized in the mines, then the water flowing from the unflooded Truxall Mine is likely highly acidic with high concentrations of Al and Fe. The water in the flooded Jamison is likely alkaline with moderate Fe concentrations. Upon mixing, the alkaline Jamison water should partially neutralize the Truxall water, causing the pH to rise and Al to form a solid. If there is enough retention time and storage space, the Al solids would be retained in the Jamison Mine. If retention time is too short or if storage is not present, the Al solids would likely be carried to the borehole. The Fe content of the waters is less affected by the mixing and changes in pH, and the Fe largely stays in solution and is discharged from the mine through the borehole.

Improved Treatment of the Wolford Borehole Discharge

Flows and chemistry were measured at the influent to the first settling pond before the borehole was cleaned and at the borehole afterwards. The table below shows chemistry and flows. The pH and concentrations of alkalinity, Fe, Mn, and sulfate were similar in both periods. Acidity and Al appear to have decreased somewhat. Aluminum is barely soluble in waters with pH 5.5-6.0, so its presence in 2002/03 was geochemically problematic. The recent low Al concentrations (<1 mg/L) are more typical of mine discharges with pH >5.5.

Several events could explain why Al concentrations have decreased. It is possible that the borehole cleanout eliminated the source of particulate aluminum. The mid-pipe obstruction was observed to contain sediment which if washed up the pipe, would result in measurable Al. During the cleanout, the high pressure hose was extended all the way into the mine. The high pressure water produced when the hose was in the mine could have dislodged Al hydroxide solids lying in the mine. When the obstruction was fully removed, a high flow of water occurred. The increased velocity may have mobilized and washed out Al solids in the vicinity of the bottom of the borehole. Lastly, it is possible that the lessened Al may indicate a slight amelioration of water chemistry. Over time, the acidity of the Truxall drainage will decrease and the alkalinity of the flooded Jamison mine will increase, causing complete removal and retention of Al within the mines. It is possible that the sampling activities during this project captured this modest (but important) change in chemistry.

Table 1. Flow and chemistry of discharges from the Wolford borehole.

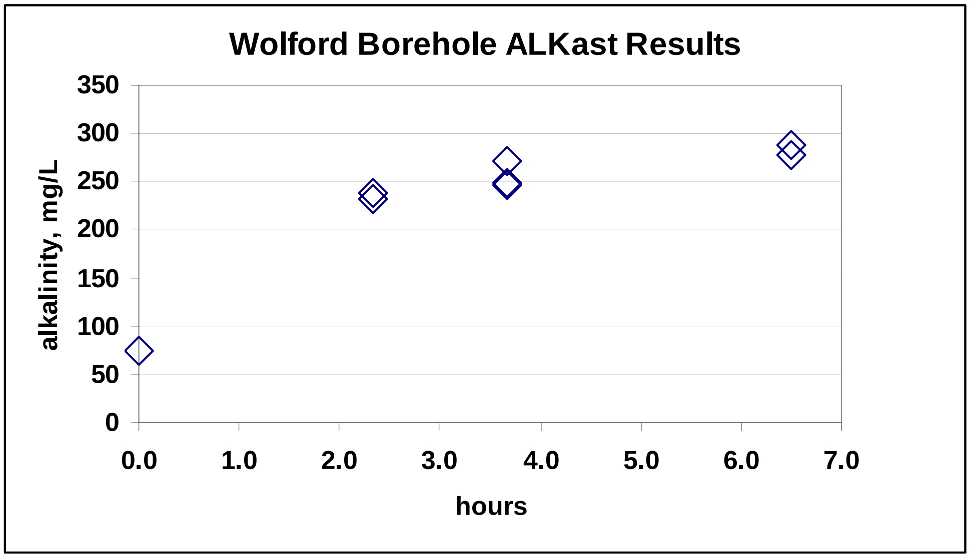
Point	Date	Flow	pH	Alk	Acid	Fe	Mn	Al	SO4	Fe
		gpm		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	kg/d
Pond In	11/04/02		5.6	22	232	127	2.5	3.4	1,058	
Pond In	04/23/03	430	5.5	87	209	122	2.5	3.3	1,046	285
Pond In	06/11/03	350								
Pond In	06/18/03	400	5.3							
Pond In	07/10/03	350	5.1							
Pond In	08/14/03	300	5.2							
Pond In	09/17/03	300	4.8							
Pond In	10/14/03	345	5.1							
Borehole	06/30/06	250	5.6	63	165	104	2.4	1.1	976	142
Borehole	09/15/06	275		43	249	145	2.4	0.8	897	217
Borehole	10/23/06		5.6	62	140	127	2.2	0.8	1,150	
Borehole	10/25/06	188	5.9	67	149	115	2.2	0.9	934	118
Borehole	12/29/06	250		58	160	138	2.5	0.5	850	188
Borehole	average	241	5.7	59	173	126	2.4	0.8	961	166

A common passive technology of acidic discharges with < 1 mg/L Al is the anoxic limestone drain (ALD). The water is directed into a buried bed of limestone aggregate that is designed to maintain anoxic conditions. Under these conditions calcite dissolution is favored and alkalinity is released. Fe and Mn do not precipitate under these conditions, so the limestone aggregate is not fouled with metal solids. When the alkaline discharge from the ALD is aerated, the Fe (and to a lesser degree Mn) oxidize and precipitate as oxide solids. Properly designed and constructed ALDs can function for more than a decade with no O&M.

The Wolford discharge is suitable for treatment with an ALD. The amount of alkalinity that would be generated from an ALD was estimated by conducting limestone incubation tests with Hedin Environmental's proprietary Alkast (alkalinity forecasting device). The Alkast is a 60cc plastic syringe modified to contain limestone chips and mine water in an anoxic environment. After a period of time the contents are dispelled and the concentration of alkalinity is measured. The amount of alkalinity generated after 3-6 hours of incubation is a good predictor of the alkalinity that will be produced by a full scale ALD

Figure C shows the results of the testing. The maximum alkalinity was 288 mg/L. A properly sized ALD should generate about 275 mg/L alkalinity.

Figure C. Results of alkalinity generating measurements made on the Wolford borehole discharge.



For effective passive treatment, the ALD must produce enough alkalinity to neutralize the acidity released when the ferrous iron oxidizes and hydrolyzes. The precipitation of each mg/L Fe consumes 1.8 mg/L alkalinity. The average iron content of the Wolford discharge, 126 mg/L, will consume 225 mg/L alkalinity. A properly sized ALD will produce a discharge with about 50 mg/L net alkalinity.

Passive Treatment System Redesign

The recommended passive treatment is an ALD followed by ponds that settle most of the iron and a constructed wetland to remove residual Fe. This design is conceptually similar to the one implemented by the NRCS ten years ago, but the treatment elements are sized larger. The renovations also require improvements to the borehole so that water can be moved around the site without leakage or loss of head.

Borehole Improvement

The borehole must be improved so that the mine drainage can be moved to a preferred treatment location with additional head pressure but without leakage. Two ways to assure the borehole's integrity are proposed.

1. A plastic sleeve could be installed within the existing steel casing from the surface into the deep mine. The 12 inch steel casing would be left in place and a 8 inch PVC pipe would be inserted inside the casing and sealed with cement grout pumped in between the steel and the PVC pipe the full length. The cement would be held in place at the bottom of the pipe (just above the mine void) with shale traps. The estimated cost to install the plastic pipe is $16,000 (Table 2). The estimate assumes four days of work by a driller and six days of project planning and construction oversight by an engineer or professional scientist.

2. The steel casing could be removed and replaced with 10 inch plastic casing. Shale traps would be set at the bottom of the pipe and the void between the borehole and pipe would be grouted shut with cement. The cost is estimated at $21,000 (Table 3). The estimate includes 6 days of work by a driller and 8 days of project planning and oversight by an engineer or professional scientist. The extra cost (compared to option #1) is due to the extra time spent removing the steel pipe. If there are difficulties in removing the steel pipe, the cost would be higher.

Either method of plumbing would then allow for the collection the minewater without producing leakage in the area around the ALD. This would also provide for an opportunity to valve the flow of water off for a period of time to observe the mine pool to see how high the water can be raised before it breaks out elsewhere.

Table 2. Cost estimate for insertion of PVC sleeve into current 12 inch steel pipe.

Equipment	Total	Units	Unit Cost	Total Costs
Equipment Mob and demob	2	mobs	$1,000	$2,000
Dozer (to assist access)	24	Hours	$50	$1,200
Drill (daily rate to insert sleeve)	4	Days	$1,300	$5,200
Labor	30	Hours	$25	$750
Pump (pump down mine pool)	1	Week	$500	$500
Equipment Cost (total)				$9,650
Materials				
Pipe (8" pipe for insert)	110	Feet	$10	$1,100
Valve (regulate flow)	1	Each	$500	$500
Couplers	1	Each	$100	$100
Packers (around sleeve into borehole)	2	Each	$40	$80
Grout (around packers)	1	Each	$500	$500
Fuel (Pump)	1	Each	$100	$100
Material Cost (total)				$2,380
Project Planning and Oversight	48	Horus	$80	$3,840
Total Cost				**$15,870**

Table 3. Cost estimate for removal of 12 inch steel casing and replacement with 10 inch PVC pipe.

Equipment	Total	Units	Unit Cost	Total Costs
Equipment Mob and demob	2	mobs	$1,000	$2,000
Dozer (to assist access)	24	Hours	$50	$1,200
Drill (daily rate to remove pipe)	6	Days	$1,300	$7,800
Labor	60	Hours	$25	$1,500
Pump (pump down mine pool)	1	Week	$500	$500
Equipment Cost (total)				$13,000
Materials				
Pipe (10" pipe in place of 12 inch steel)	110	Feet	$12	$1,320
Valve (regulate flow)	1	Each	$600	$600
Couplers	5	Each	$100	$500
Packers (around sleeve into borehole)	2	Each	$40	$80
Grout (around packers)	1	Each	$500	$500
Fuel (Pump)	1	Each	$100	$100
Material Cost (total)				$3,100
Project Planning and Oversight	64	Hours	$80	$5,120
Total Cost				**$21,220**

Anoxic Limestone Drain The ALD should be designed for maximum alkalinity generation and sustainability. In order to produce 275 mg/L alkalinity, the mine will need 10-12 hours of retention time within the ALD. This is achieved with 10-12 tons of limestone aggregate for each gpm of design flow. The ALD will continually loose limestone through dissolution. Assuming that the ALD increases the alkalinity concentration from 75 mg/L to 275 mg/L and that the limestone is 90% $CaCO_3$, then the ALD will loose 5 tons of limestone every ten years for each gpm of average flow. Generally, passive systems are designed with 25 year life expectancy for the design flow. An ALD designed to treat the Wolford borehole for 25 years should contain about 25 tons of limestone for each gpm of flow.

The ALD should contain at least 4,400 tons of limestone. This quantity of limestone will produce ~275 mg/L alkalinity for all flow conditions observed during the last four years. The loss of limestone through dissolution will cause the alkalinity produced under high flows to gradually decline. Assuming a 250 gpm average flow rate, then after ten years the ALD will have lost about 1,300 tons of limestone and will contain about 3,100 tons. The ALD will still produce ~275 gpm for a 300 gpm flow rate, but it will likely produce 225-250 mg/L alkalinity for a 400 gpm flow. After 20 years, the loss of limestone may result in alkalinity concentration under higher flow conditions of 150-200 mg/L. If this alkalinity generation is not adequate, then limestone will need to be added to the ALD. It is possible that the acidity of mine discharge will decrease over this period, offsetting the ALD's alkalinity generation losses.

Settling Ponds Water discharging from the ALD should be directed into a series of settling ponds where the iron will oxidize and precipitate as iron oxide sludge. The ponds should be constructed to eliminate preferential flows, ideally be distributing and collecting the flow in troughs that extend the full pond width at the influent and effluent ends. The rate of Fe removal in the ponds is partially dependent on Fe concentration. Empirical evidence from successful, well designed passive systems shows that iron precipitates at concentrations between 50-150 mg/L at a rate of ~30 g Fe per m^2 per day. At Fe concentrations between 15-50 mg/L, the rate is ~15 g Fe/m^2/day. Settling ponds are generally not effective at further reductions in Fe concentration. Constructed wetlands are a preferred passive polishing technology and remove iron at a rate of ~5 gFe/m^2/day.

The parameters discussed above were used to develop the designs of the passive system alternatives. The loading, which is a strong function of flow, is used to size the system. Table 4 shows the size of the various passive elements at several design flow rates.

Table 4. Wolford Run Passive Treatment System Calculations

	Design Flow Rate			
	200 gpm	250 gpm	300 gpm	350 gpm
ALD	4,400 tons 0.3 acres	5,500 0.3	6,650 0.4	7,800 0.5
Primary settling	0.7 acres	0.8	1.0	1.2
Secondary settling	0.6 acres	0.8	0.9	1.1
Wetland polish	0.8 acres	0.9	1.1	1.3
Total ALD, ponds and wetlands	2.3 acres	2.9	3.5	4.0
Total footprint*	3.2 acres	4.0	4.9	5.7

* 1.4 times the summed acreages of the ALD, ponds, and wetland

The flows have recently averaged about 250 gpm. All the flow rates measured average 313 gpm. The highest flow rate measured was 430 gpm.

There is limited acreage available for construction of the passive system. The current system consists of a small ALD and three ponds. The existing treatment totals 0.7 acres and the footprint of the area is about 1.0 acres. Three areas for system expansion are considered (Table 5). The location of these areas is shown in Figures D and E.

- <u>Area I.</u> There is undeveloped reclaimed AML located immediately to the southwest of the current system. This area is about 2.8 acres, borders Wolford Run, and has a drainage ditch flowing through it. The total amount of usable acreage is estimated as 2.1 acres. Full use of the site would require raising the discharge about ten feet and piping it 1,700 ft to the head of the hollow.
- <u>Area II</u> Immediately across the stream from the treatment system there are about 2.8 acres of abandoned mine land. The site contains coal wastes and there is an abandoned elevated railroad bed that ends at a bridge abutment. Making use of this site would require removal of the coal wastes and fill contained in the railroad bed. If the material was removed, there would be approximately 2.1 acres of usable treatment area. The site is lower than the borehole. A 400 ft pipeline, that crosses Wolford Run, would be necessary to move the discharge from the borehole to Area II.
- <u>Area III</u> A third potential treatment site is located south of SR 981 along Wolford Run. The site is referred to as the Novosel Site on the RAMP drawings and is about 4.6 acres. The area is reclaimed mine land, similar in characteristics to Area I. The site is 25-35 ft higher than the borehole. A 3,600 ft long pipeline, that crosses under SR 981, would be necessary to move the discharge from the borehole to the head of this site.

Four treatment scenarios are considered. The first scenario assumes that *none* of the Areas are available and treatment must occur within the existing system footprint. The second scenario assumes the *either* Area I or II is available and treatment must occur within the existing system footprint and the new area. The third scenario assumes that *both* Areas I and II are available and that treatment occurs in the existing system footprint and in the both areas. The fourth scenario considers providing all treatment in Area III. Table 6 shows treatment components of each scenario and predicted effluent water quality under various flow conditions.

Table 5. Wolford Run Treatment Areas: Acreage

Current ALD Area	0.06 acre
Current Pond A	0.16 acre
Current Pond B	0.26 acre
Current Pond C	0.26 acre
Total Current	*0.74 acre*
Expansion Area I: total	2.8 acre
Usable Area (75%)	*2.1 acre*
Expansion Area II: total	2.8 acre
Usable area (75%)	*2.1 acre*
Expansion Area III: total	4.6 acre
Usable area (75%)	*3.4 acre*

<u>Scenario A: Stay within the existing System Footprint</u> Treatment is limited to approximately 1 acre. A 4,400 ton ALD is installed over the borehole that is 8 ft deep and requires 15,000 ft^2. This size ALD will produce a net alkaline discharge for all flow conditions for about ten years. After 10-15 years, the replacement of the lost limestone may be necessary. The existing ponds are cleaned out and reshaped as two serially-connected 12,000 ft^2 settling ponds designed. Two ponds are recommended so that during maintenance that requires one pond to be shut down, the second pond can still provide treatment. The ponds should be designed to facilitate sludge removal, which would be necessary every 5-7 years.

Table 6 shows the expected discharge chemistry of the renovated system under a variety of flow rates during the first five years. Because the ponds are much smaller than needed, considerable iron is discharged from the system. The discharge would always be alkaline with pH 6-7. At the average flow of ~250 gpm, the system would neutralize all of the acidity, but only retain about 40% of the Fe. Under high flow events, the system would only retain about 20-25% of the Fe.

<u>Scenario B: Either Area I or Area II is available</u> If *either* Area I or II can be obtained, then a substantially larger system can be constructed. Combined with the current treatment area, about 2.8-3.0 acres of treatment system could be constructed. The recommended treatment system should consist of a 4,400 ton ALD whose flow is split between a single pond constructed at the current system site, and two ponds and a wetland constructed at the second site. The single pond at the existing site should be constructed as large as possible. With the elimination of existing berms, a pond with about 30,000 ft^2 is possible.

The balance of the flow should be directed into a separate treatment system consisting of two serially connected settling ponds, each ~30,000 ft^2, and a single wetland constructed as large as possible. It appears that this polishing wetland would be about 25,000 ft^2 at both sites.

The amount of water directed to either system would be controlled with a flow control structure connected to the effluent of the ALD. Initially, the structure would be set to allow only 50 gpm to go to the single pond, and the remaining flow would be directed to the larger system.

Scenario B is expected to provide a very good effluent for a 250 gpm flow (the recent average). At higher flows Fe would be discharged from the system (Table 6). At 400 gpm the system should still remove 80-85% of the iron.

<u>Scenario C: Both Areas I and II are available</u> If both areas I and II are available, a system can be installed that is sized large enough to treat all flow conditions to a very good quality. The ALD should be constructed larger to accommodate higher flow for a longer period of time. The discharge of the ALD would be split between two separate systems on each side of the stream. Each system would have two 30,000 ft^2 settling ponds followed by a 30,000 ft^2 constructed wetland. These two systems are large enough to effectively treat the highest flow rates observed.

<u>Scenario D: Relocate discharge to Area III</u> Area III is located along Wolford Run 3,000 ft upstream of the current system (see Figure E or the RAMP Plans). Using the site will require raising the discharge about 35 ft to approximately 800 ft elevation. If Scenario D is considered, the discharge should be experimentally raised by 35-40 feet for several months while the chemistry and flow are monitored and the local area is searched for new mine discharges. Particular attention should be paid to the backfilled Jamison Mine entry and ventilation tubes located in Area II.

The success of attempts to facilitate mine drainage treatment by raising discharges is mixed. The Lowber (Westmoreland County) and Wingfield Pines (Allegheny County) both involved raising a large deep mine discharge 5-7 feet, without ill effect. However, at the Brinkerton site (Westmoreland County) soon after the discharge was raised 5-10 feet it blew out at a lower location. This failure was due to the sites close proximity to the coal crop. This situation does not exist at the Wolford Run site.

Area III is about 4.6 acres. The discharge should be piped to an ALD constructed at the southern end of the site that discharges to three serially connected settling ponds, each about 30,000 ft^2. The last pond should discharge into a single 40,000 ft^2 constructed wetland that produces the final discharge. The recommended passive system will produce a very good discharge at flows up to 300 gpm. At flows as high as 400 gpm, the system would still remove 90% of the iron.

Table 6. Recommended sizes of passive treatment units and predicted final effluent chemistry under different flows. The influent is acidic with 135 mg/L Fe.

	A. Current site only	B. Current & Either I or II	C. Current & I & II	D. Area III Only
ALD	4,400 tons (12,000 ft^2)	4,400 tons (12,000 ft^2)	6,650 tons (18,000 ft^2)	6,650 tons (18,000 ft^2)
Ponds	2 X 12,000 ft^2	3 X 30,000 ft^2	4 X 30,000 ft^2	3 X 30,000 ft^2
Wetland	None	1 X 25,000 ft^2	2 X 30,000 ft^2	1 X 40,000 ft^2
Flow (gpm)	***Predicted effluent***	***Predicted effluent***	***Predicted effluent***	***Predicted effluent***
200 gpm	Alk, Fe 60-70	Alk, Fe <2	Alk, Fe <2	Alk, Fe <2
250 gpm	Alk, Fe 70-80	Alk, Fe <2	Alk, Fe <2	Alk, Fe <2
300 gpm	Alk, Fe 80-90	Alk, Fe 5-10	Alk, Fe <2	Alk, Fe <2
350 gpm	Alk, Fe 90-95	Alk, Fe 10-15	Alk, Fe <2	Alk, Fe 5-10
400 gpm	Alk, Fe 95-100	Alk, Fe 20-25	Alk, Fe 1-3	Alk, Fe 10-15

Predicted effluents: “Alk” indicates net alkaline discharge (pH >6); Fe values are mg/L

Iron Oxide Recovery

The DEP is increasingly concerned about long-term maintenance requirements of mine water treatment systems. While effective passive systems have much lower operation and maintenance requirements than chemical systems, the systems still require routine monitoring, maintenance and sludge management. The recovery of saleable products from mine water treatment systems is one way to lessen long-term costs. The only income-producing product of mine water demonstrated to date is the recovery of crude pigment-quality iron oxide sludge. Hedin Environmental is the leader in this field, having recovered and sold 2,600 tons of iron sludge from mine water sites during the last five years. Research has determined that the best sludge is obtained from passive systems where iron precipitates in an alkaline environment. The proposed treatment systems would function in this manner and should produce pigment-quality iron sludge.

Samples of the existing sludge were collected from the existing ponds, analyzed for elemental composition, and evaluated as pigment. Table 7 shows the chemical composition of the sludge compared to material from a system that produces good pigment-quality sludge. The sludge in the current ponds has a higher silica and aluminum content than the SRX sludge. This is probably due to sediment carried into the ponds during rainstorms and from the Al content of the water several years ago. The treatment system would be designed to divert surface water around the ponds and would not have inputs of Al from the mine water. Good quality iron sludge is expected from the proposed passive treatment system. An evaluation of long-term care for the treatment systems should include the consideration that sludge could be removed periodically at no cost to the Association. It is possible that a company interested in recovering the sludge would also agree to provide the system’s routine O&M in return for ownership of the iron.

Table 7. Characteristics of iron sludge from the Wolford passive treatment system and another system that produces pigment-quality iron oxide.

	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Total
	%	%	%	%	%	%	%	%	%	%	%
WOLFORD	12.3	4.8	62.8	0.0	0.2	0.1	0.2	0.4	0.0	18.6	99.6
SRX	6.1	0.1	77.2	0.0	0.0	0.5	0.1	< 0.01	0.5	14.3	98.8

LOI, loss on ignition

Despite the elevated Si and Al content, the existing material has pigmentary characteristics and could be usable in a pigment blending operation. If plans proceed to install an improved treatment system, the recovery of the sludge from the ponds should be explored. Hedin Environmental would be interested in further evaluating the existing sludge and, if the results continue to be promising, propose including sludge removal and recovery as part of the construction project.

Project Phasing

The installation of the passive systems should occur in two phases. Phase I would include a site survey, modifications to the borehole, and the experimental raising of the discharge. If the plan is to build the system in Area I, then the discharge should be raised 5-10 ft (final elevation determined from the site survey). If the plan is to build the system in Area III, then the discharge should be raised 35-40 feet. After the discharge is raised, its flow and chemistry should be monitored for at least six months. The area along Wolford Run should be regularly inspected and searched for mine discharges. The quality of the discharge should be monitored to assure that the final treatment system design is appropriate. It is anticipated that raising the discharge should improve the water quality because more of the deep mines would be flooded. This suspicion should be verified through sampling.

Phase II is the permitting and construction of the treatment system. This phase will require ecological studies of the proposed construction sites, with particular attention to the need to encroach on Wolford Run in order to maximize treatment area. Once permits are approved, the construction can proceed.

Estimated Costs

The estimated costs are shown in Table 8. The costs were developed from the quantities in Table 6 and the following assumptions:

- Site mapping: based on site size;
- Borehole repairs: Table 3;
- Monitor discharge after borehole repairs and elevation changes: estimate based on the complexity of the elevation modifications;

- Permitting: Scenario A only requires E&S and Construction NPDES; Other Scenarios involve DEP Bureau of Water Quality and cost depends on size of project
- Relocate Discharge: the cost to pipe the discharge to a new location was assumed at $10 per linear foot of installed pipe. For Area II, the cost to cross the stream was estimated at $10,000. For Area III, the cost to bore under SR 981 was estimated at $10,000.
- ALD: $30 per ton of limestone installed;
- Ponds: $2 per ft^2 of pond, including features to facilitate sludge removal;
- Wetlands: $1 per ft^2;
- Special Earthwork: Area I assumed to require importing of clay or use of synthetic liners; Area II assume to require removal of refuse and fill that is disposed of locally at no cost; Area III assumed to involve importing of clay or use of synthetic liners;
- Mobilization and demobilization: estimate based on size of project
- Erosion and Sediment control: estimate based on size of project
- Engineering: cost for system design, construction oversight, and management of technical aspects of project: approximately 10% of construction costs.

Table 8. Estimated Costs for the borehole repairs and passive treatment installation.

	Scenario A	**Scenario B**	**Scenario C**	**Scenario D**
Phase I				
Site mapping	$3,000	$5,000	$7,000	$7,000
Borehole repairs	$21,000	$21,000	$21,000	$21,000
Monitor	$5,000	$10,000	$10,000	$15,000
Phase II	0	0	0	0
Permitting	$7,500	$15,000	$25,000	$25,000
Relocate Discharge	$0	$27,000	$40,000	$46,000
ALD	$132,000	$132,000	$199,500	$199,500
Settling Ponds	$48,000	$180,000	$240,000	$180,000
Wetland	$0	$25,000	$60,000	$40,000
Special earthwork	$0	$50,000	$75,000	$75,000
Mob/demob	$5,000	$10,000	$10,000	$10,000
E&S controls	$5,000	$15,000	$25,000	$20,000
Engineering	$20,000	$45,000	$60,000	$60,000
Total	**$246,500**	**$535,000**	**$772,500**	**$698,500**

Property Acquisition or Easement

The costs presented above do not include property acquisition. Discussions were held with the owner of Area I to explore his willingness to donate the property or provide perpetual easement. While very supportive of the project (this owner already provided the area of the current treatment system), he was unwilling to donate permanent easement to Area I.

The Association needs to either purchase or obtain permanent access to one of the Areas. This action is necessary before the Association proceeds with a treatment system funding proposal because the DEP will not fund proposals that do not have property issues settled.

Conclusions and Recommendations

AMD flowing from the Wolford Run borehole is produced in the abandoned Jamison and Truxall Mines. The borehole was likely installed and used as a drain during mining operations and is currently the lowest discharge point from the mine complex. The borehole was partially clogged. The obstructions were removed and the integrity of the borehole and its steel casing were found to be good. A faulty connection between the steel casing and a PVC pipe installed when the current passive treatment system was constructed is causing leakage and complicates future efforts to relocate the flow. The leakage should be corrected by reinstalling a plastic pipe within the borehole.

The chemistry of the water flowing from the cleaned-out borehole is suitable for reliable passive treatment with an anoxic limestone drain, settling ponds, and constructed wetland. This is the same design used a decade ago in the RAMP project, but the system units were undersized. Based on recent flows and chemistry, a passive system that will treat the average flow to a net alkaline condition and <1 mg/L Fe should include an ALD with at least 4,400 tons of limestone, approximately 1.6 acres of settling ponds, and 0.9 acres of wetland. This system will treat high flows to a net alkaline condition and remove 80-90% of the iron.

The current treatment area is not large enough to accommodate a properly sized treatment system. Three alternative treatment areas were identified. There are reclaimed and unreclaimed abandoned mine lands in the immediate vicinity of the borehole that could be utilized. If one of these areas is obtained a system adequate to treat average conditions can be constructed. If both of the areas are obtained, a system capable of treating all flow conditions can be constructed. Upstream 3,500 feet there is a reclaimed mine land site that is large enough to support a full size system. Relocation of the discharge to this site would require an investigation to assure that new discharges do not develop around Wolford Run as a result of increased mine pool elevations.

Iron sludge samples were collected from the existing ponds. The material has pigmentary characteristics and might be recovered and sold as crude pigment in the future. Any new construction should consider iron sludge removal because it is likely that management of a new passive system for iron oxide production could offset most long-term O&M costs.

Costs were estimated to design and construct passive treatment systems on the identified areas. The costs range from $535,000 for an average-flow system constructed on one of the sites adjacent to the borehole, to $772,000 for a system designed to treat all anticipated flow conditions to a high quality condition.

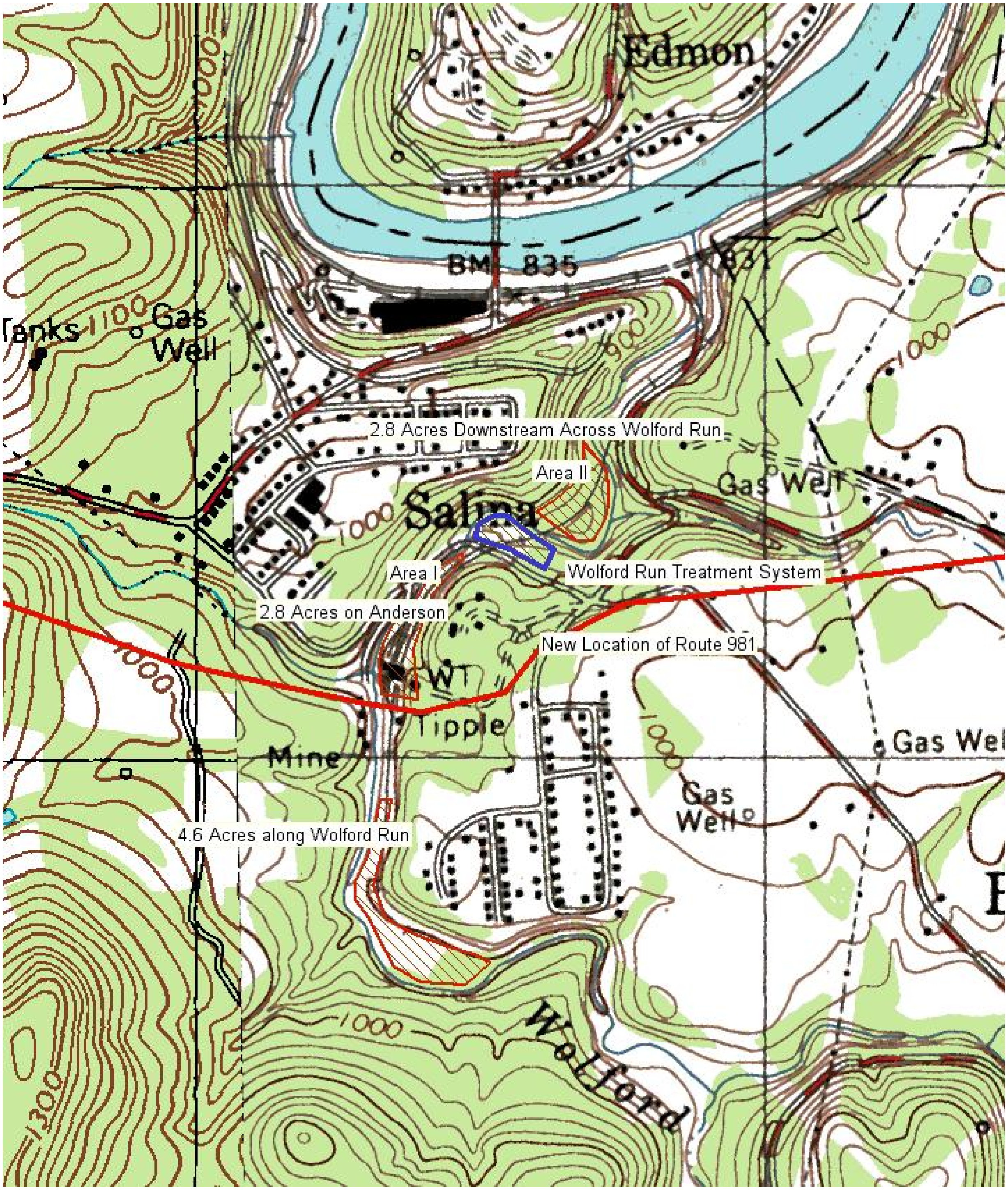


Figure D. USGS Map showing the location of the current treatment system and the lociations of three areas that should be considered for construction of a new system. The new location of SR 981 is shown.

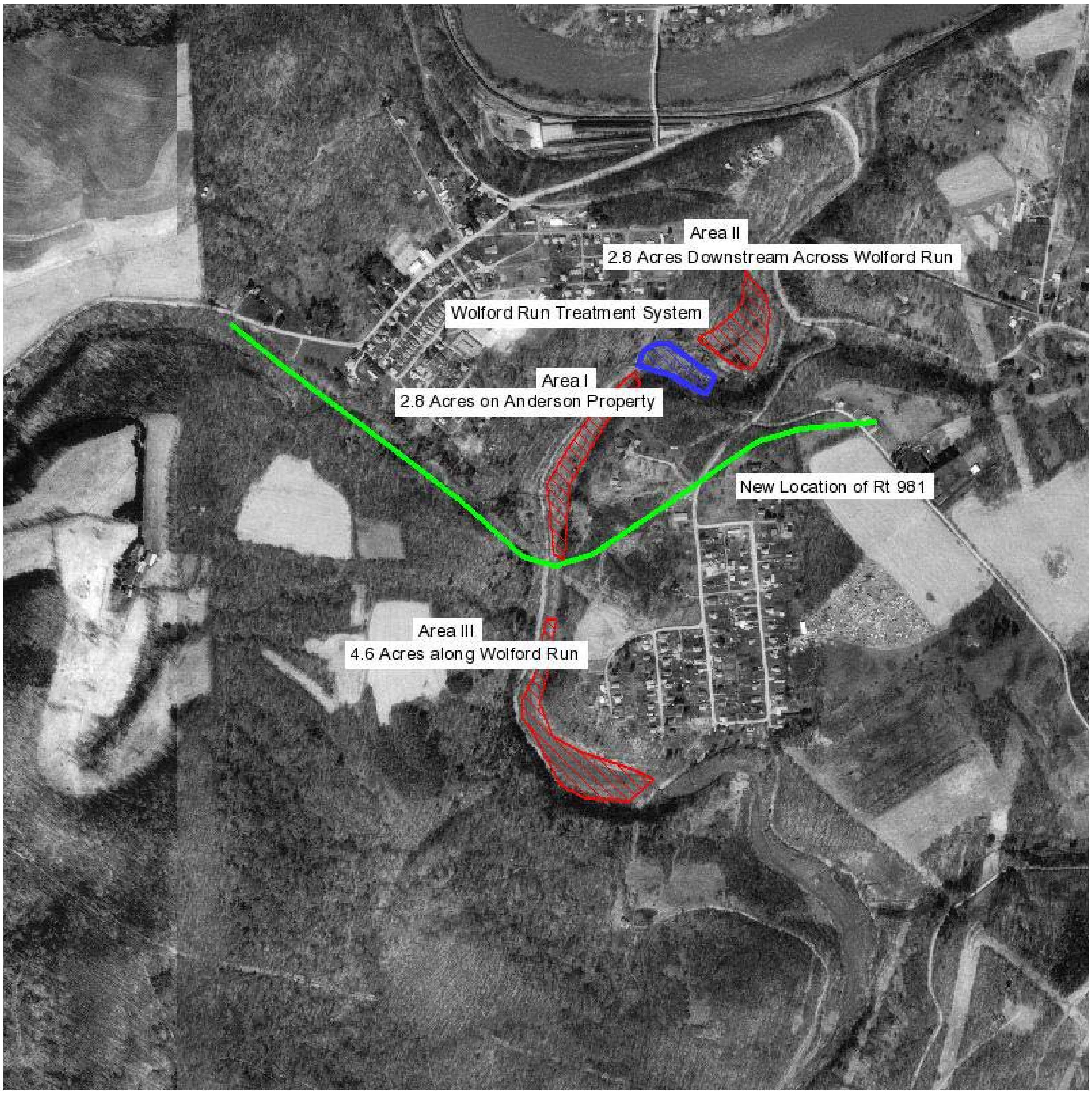


Figure E. Location of the Wolford Run passive treatment system and three potential treatment areas.