

# WHERE DID ALL THE WATER GO<sup>1</sup>

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**Abstract:** The Friends of the Cheat (FOC) is a 501 (c) 3 watershed organization in northern West Virginia. FOC formed in 1994 to respond to the impact of acid mine drainage on tributary streams and the mainstem of the Cheat River. Since then, millions of dollars in water monitoring, assessment and treatment has been invested within the watershed.

In 2006, FOC received an EPA Targeted Watershed Grant to address 27 miles of impaired water on Muddy Creek, a major contributor of acid mine drainage to the Cheat River. Over the past eighteen months, monitoring has taken place on Muddy Creek and the data collected has brought to light some interesting results that otherwise would have went unnoticed without continual sampling. Water monitoring consisted of walking streams with GPS unit to determine locations of all acid mine drainage sources. Data collected while monitoring also included the pH, conductivity, and flow rates, which were then mapped using ArcGIS to produce a spatial picture of water quality in the Muddy Creek drainage area.

With this database and the GIS map, FOC consulted with WVU geologist Dr. Joe Donovan, who has conducted research on mine pools in the Freeport coal seam. After reviewing the data we had collected, Donovan realized that several surrounding mines were not discharging where they should be according to existing mine maps. In addition, he noticed an unusually high flow coming from an abandoned deep mine, which contributes about twenty percent of the acid load on Muddy Creek.

This proposed presentation will show field research and technical analysis that is currently ongoing and is expected to be completed by the spring of 2008. Research will involve geo-spatial assessment of mine maps, continued monitoring, investigation into mining permits as well as the local history. In addition, drilling may occur to help in determining mine pool locations. The utilization of water monitoring, GIS mapping, and assessment will have a direct influence on the level of restoration this project achieves for the Cheat watershed. The determination of the source of this discharge from the abandoned deep mine could determine how hundreds of thousands of dollars in reclamation expense will be funded.

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## **Introduction**

The organization which currently houses an OSM/VISTA (Volunteers In Service To America), is Friends of the Cheat (FOC). In 2005, Friends of the Cheat received a Targeted Watershed Grant (TWG) to use for monitoring and reclamation costs within the lower Cheat watershed. The Targeted Watershed area consisted of Fickey Run, Glade Run, Martin Creek, and Muddy Creek. Additionally FOC had other secured funds that allowed them to continue monitoring in areas outside the TWG area. Working jointly with faculty from West Virginia University (WVU) has given FOC leverage to accomplish more monitoring and restoration projects throughout the lower Cheat watershed. Late in August of 2007 WVU hydrologist Dr. Joe Donovan and Annie Morris, also a hydrologist who works under Donovan, requested to see some of the Friends of Cheat data. After reviewing the FOC database, Donovan noted the discharge coming out of the Ruthbell #3 mine seemed unusually high. This mine discharge alone accounts for 20 percent of the total acid load to Muddy Creek. Upon further investigation by Donovan we noted that there were five mines in the vicinity that mines maps illustrated as being very close in relation to the underground extremities of the mine chambers. The five mines include: Ruthbell #3 which closed in 1943, Coal Lick Mines which closed in 1971, Mineral Development No 1 which closed in 1975, Sunshine Mine which closed in 1991, and the JCB No 2 which closed in 1998. There are two creeks that run through this area and seem to be unaffected by the typical acid pollution that should be discharging from these mines into the streams. Crab Orchard Run runs through the middle of the five mines and shows some evidence that acid mine drainage from the Bakerstown coal seam has entered the stream which produces a net alkaline drainage. Bakerstown coal would have been mined by surface mining. However the mines in question were all part of the Upper Freeport Coal seam which produces acidic drainage and would have been deep mined (Fig. 1 and Fig. 2). Roaring Creek runs to the east of all the mines and shows no sign of the acid mine drainage pollutants. It is actually home to native brook trout, which require pristine water habitat to survive.

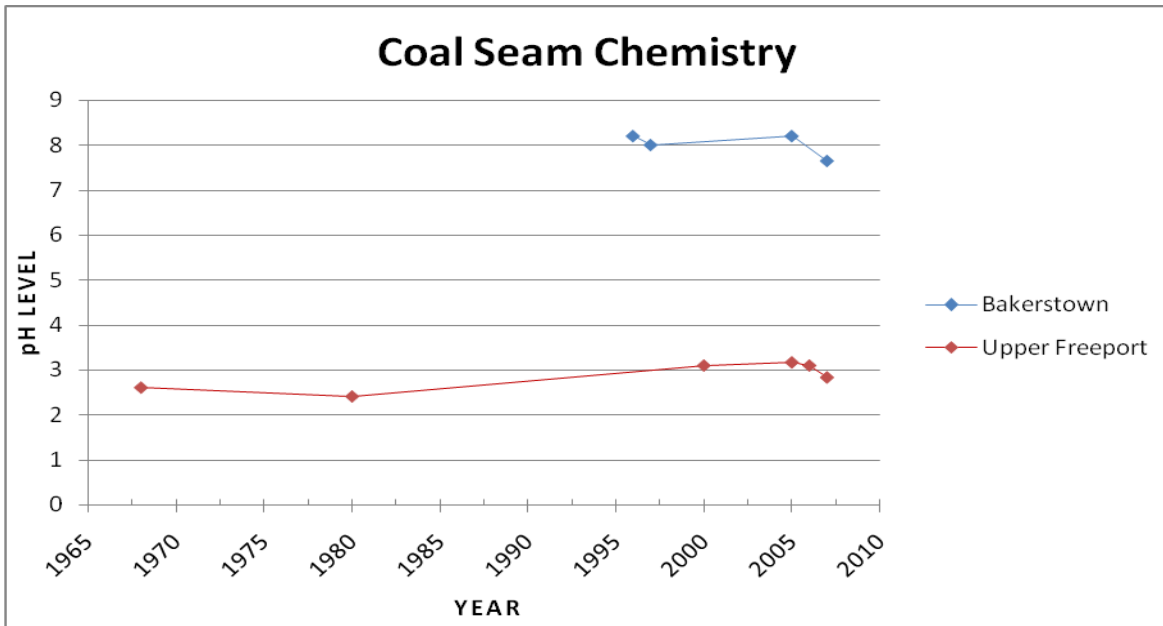


Figure 1. Compares the differences in pH levels from discharges over a period of time in the Bakerstown and Upper Freeport coal seams.

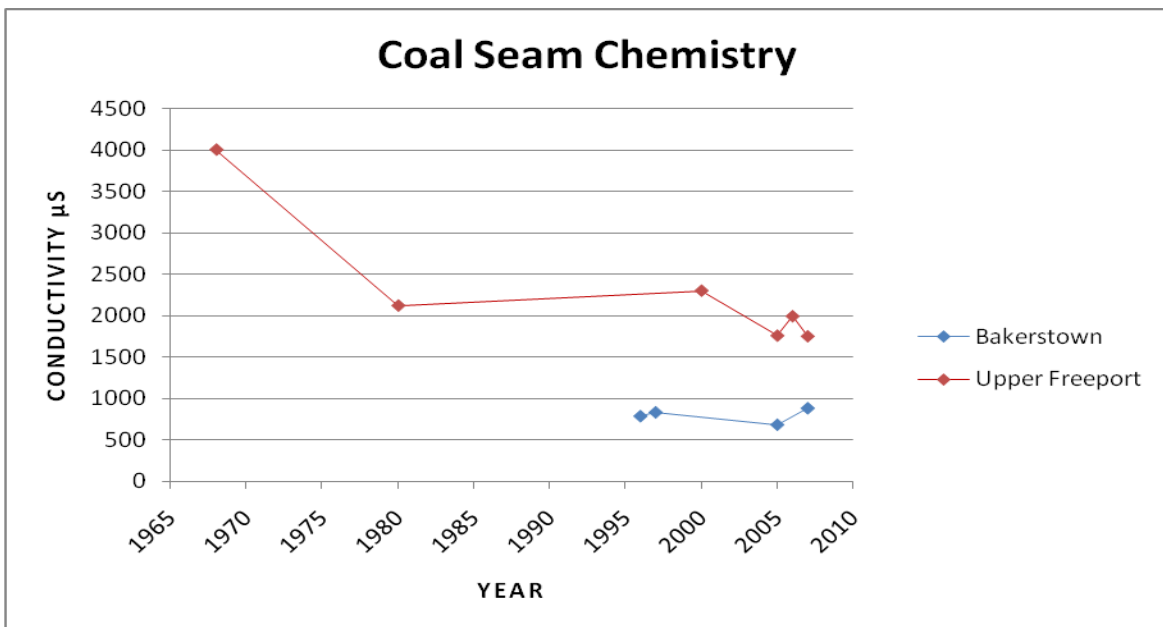


Figure 2. Compares the differences in conductivity levels from discharges over a period of time in the Bakerstown and Upper Freeport coal seams.

Based upon what we can see above ground, we now have an abandoned mine discharging seemingly too much water based on the rule of thumb for this area and coal seam, which is 1.89

liters per minute per 0.4 hectares (½ gallon per minute per acre) of underground mining. However some mines in the Upper Freeport coal seams have been known to discharge 3.79-7.57 liters per minute per 0.4 hectares (1-2 gallons per minute per acre). Looking at the Ruthbell #3 mine which is mapped at 78.5 hectares (194 acres), an estimated discharge would likely be around 380 liters per minute (100 gallons per minute) discharge. However FOC data concludes that flow rates from the Ruthbell #3 mine range from 750-2660 liters per minute (200-700 gallons per minute) depending on the time of the year (Table 1). Therefore even at 7.57 liters per minute per 0.4 hectares (2 GPM/ac) the Ruthbell #3 mine would logically only discharge about 1514 LPM (400 GPM), which seems to be unrealistic for the capacity of the mine. A figure that does fall closer within the range of flow rates comes by applying 1.89 liters per minute per 0.4 hectares (½ gallons per minute per acre) rule to the total number of mined acres in all five mines combined. The total area for all five mines equals 453 ha (1120 ac). This area would be expected to discharge roughly 2120 LPM (560 GPM). Now there is a bond forfeiture site that may be draining into and discharging from an abandoned mine land site, which brings up the question of who is responsible for reclamation expenses. The problem is that the bond forfeiture program and the abandon mine land program are funded by different allotted monies.

Table 1. Comparisons between size of the mine above the discharge point to the average flow rates of three different mines in the Upper Freeport coal seam.

<b>Mine Name</b>	<b>Total Up-Dip Hectares (Acres)</b>	<b>Average Flow Liters per Minute (GPM)</b>	<b>Average Discharge Liter per Minute per Hectare (GPM/Ac)</b>
Ruthbell #3	78.5 (194)	3837.42 (1013.74)	48.9 (5.23)
Lucky Jack Mining Co	56.7 (140.14)	374 (98.8)	6.6 (1.43)
Omega Mine	68.0 (168)	319.1 (84.3)	4.7 (0.5)

## Methods

### Responsibilities

Based upon the information that is known at the present time, Donovan prepared a proposal and presented it to the Friends of the Cheat. This delegated to the Friends of the Cheat who would be working on the project and the responsibilities each person or organization has. Donovan, director of the WVU Hydrogeology Research Center will be the primary investigator. Annie Morris (M.S. 2003, WVU) will be one of the research hydrogeologists that will be responsible for coordinating and completing fieldwork, and GIS spatial analysis. Eb Werner (M.S. 1971, Rutgers) will be in charge of mine mapping and georeferencing. FOC with the help provided by the OSM/VISTA will be responsible for data collection from the field, corresponding with landowner and agencies and contracting the drilling process.

### Hypothesis

Based on the observations of the current data available, Donovan has developed four separate hypotheses:

- a) The Ruthbell #3, Mineral Development No. 2, the Sunshine Mine, JCB No. 2, and the Coal Lick mines are hydraulically interconnected and discharge from only one location, the Ruthbell #3 portal.
- b) Crab Orchard Run is losing water into the Ruthbell #3 mine.
- c) The Sunshine Mine is discharging into Crab Orchard Run.
- d) The Sunshine Mine, JCB #2, and Coal Lick mines are not hydrologically interconnected to the Ruthbell #3 and are filling but have not discharged to Roaring Creek yet.

### Proposed Solutions

The Ruthbell #3 mine accounts for 20 % of the acid load on Muddy Creek and is situated in an area where passive treatment is not feasible. Therefore Donovan has suggested that if indeed the mines are interconnected and discharge solely from the Ruthbell #3 portal or Crab Orchard is draining into Ruthbell #3 mine void, then an in situ treatment method should be investigated for the site. In situ treatment is defined as, “introducing alkaline coal combustion by-products (CCBs) into a mine void to impart alkalinity, increase pH, and precipitate metals; thus, improving the quality of acid mine drainage.” (Canty and Everett, Spring 2004). In this case, rather than using CCBs in a slurry mixture, a second option will be tried. Water from Crab Orchard Run will be treated by diverting part of Crab Orchard Run through a steel slag bed and

then inject treated water into the mine. Steel slag will further increase pH and alkalinity of the water and provide acid reduction within the mine void, rather than sacrificing stream miles of Muddy Creek for treatment. On a previous treatment put in place within the Cheat Watershed, steel slag produced the following results. The freshwater tributary the fed into the steel slag bed had an average pH of 6.55 and upon leaving the steel slag bed; the pH had risen to 11.54. This has mixed with the mine water to precipitate out the metals. The theory is that we should be able to produce similar results on this site with the exception that this process will occur within the existing mine void since there is no room for above ground treatment systems at the discharge point.

If the mines are not interconnected then the Sunshine Mine, JCB No 2, and Coal Lick Mines are filling, but have not filled to the point of the outcrop and have not begun to discharge into Roaring Creek at this time. If this is the case Donovan stresses the importance of monitoring the mine pool levels and proactively plan for water treatment. This may enable us to prevent impairment of Roaring Creek which is currently home to native brook trout.

### Research

Friends of the Cheat had previously collected data from the Ruthbell #3 discharge and Crab Orchard Run mouth, however above the mouth of Crab Orchard Run is all privately owned land. Friends of Cheat has contacted landowners and obtained permission to cross private land to collect water samples. So far Friends of the Cheat and the OSM/VISTA has obtained two sweeps through three in stream sample points along Crab Orchard Run and the Ruthbell #3 discharge on the same day for comparative purposes. The data preliminarily eliminates hypothesis “b” because as samples are taken moving downstream flows continued to increase, which should decrease if Crab Orchard Run had been losing water into the Ruthbell #3 mine (Fig. 3).

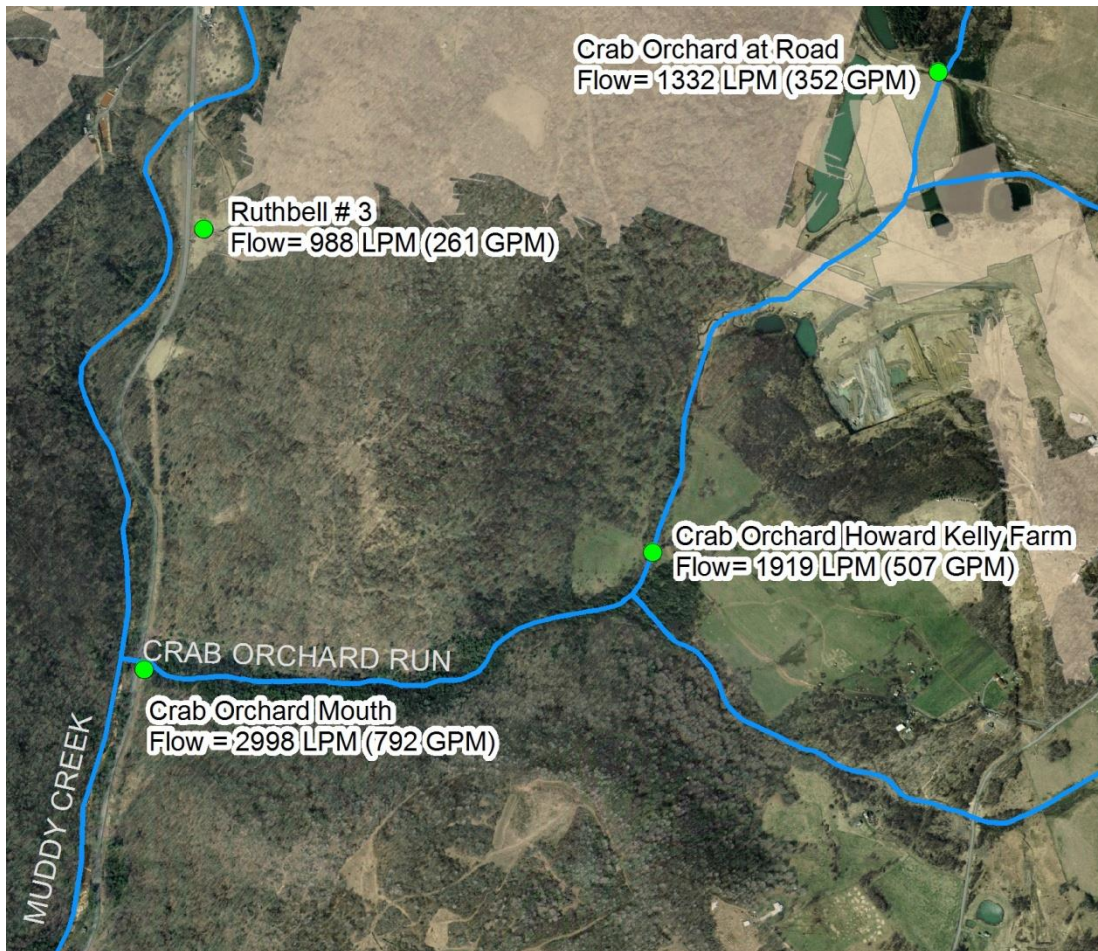


Figure 3. Shows the flow rates gathered in the field on October 29, 2007 when FOC and the OSM/VISTA made a complete sweep of Crab Orchard Run sample points and the Ruthbell #3 discharge.

Data collected from Crab Orchard Run mouth would eliminate hypothesis “c” based upon the water chemistry found on site. The data shows that the water chemistry at Crab Orchard Mouth reflects the expected water chemistry found with the Bakerstown coal seam. Bakerstown coal drainage generally consists of pH levels between 7 and 8 along with high conductivity (Table 2). This chemistry is very different than what would be expected if the Sunshine mine was discharging into Crab Orchard Run. If the Sunshine mine had been discharging into Crab Orchard Run the expected water chemistry would be even higher in conductivity and pH levels would be significantly lower.

Table 2. Water chemistry data available for the Crab Orchard Run mouth sample location.

Site Description	Date	pH	Conductivity
Crab Orchard Mouth	6/17/1996	8.30	881
Crab Orchard Mouth	11/19/1996	8.10	697
Crab Orchard Mouth	7/16/1997	8.00	835
Crab Orchard Mouth	7/28/2005	8.20	686
Crab Orchard Mouth	9/6/2007	7.60	1060
Crab Orchard Mouth	10/29/2007	8.30	622

After walking Roaring Creek, hypothesis “d” can be preliminarily be disproved based upon a visual field analysis. Results indicate that there are no signs of acidic mine drainage entering into Roaring Creek at this time. However further testing must be done to ensure that the mines that range in age from 10 to 37 years since their closing simply have not filled up to the outcrop elevation at this time.

Research will continue through a four step process which will include compiling field data and mapping results, then exploring for flooded mine pools, then testing for feasibility of in situ treatment, and finally reporting the findings to all those involved. Funding for FOC on this project will be funded using the TWG monies, which now covers Crab Orchard Run and Roaring Creek as part of the TWG area through an amendment to the grant between EPA and FOC.

### Methodology

Field data will include walking Crab Orchard Run and Roaring Creek to inventory all existing mine discharges. Crab Orchard will also be tested for seepage. Donovan has proposed that a stream walk on Crab Orchard run have stream flow measurements in 91.4 m (100 yd) intervals in places where Crab Orchard Run is undermined. Flows will be measured using a Marsh-McBirney Flow-Mate 2000 portable flow meter. Crab Orchard Run will also be tested for pH and conductivity to assess the degradation caused by mining impacts. Field test instruments include pH and conductivity pens by Oakton Instruments, which are calibrated daily. Two water samples will also be collected at each sample location, which will be sent to the



National Research Center for Coal and Energy (NRCCE) analytical lab at West Virginia University (WVU) for analysis. One sample is filtered and acidified with  $\text{HNO}_3$ , which is tested as the NRCCE analytical lab for dissolved metal concentration. The other sample is tested for pH, conductivity, and acidity. Roaring Creek will be walked and surveyed for evidence of any existing mine drainage or signs of previous discharges that would likely be seen in the form of iron staining. This would lead us to believe that the JCB No 2, Sunshine Mine, or Coal Lick mines are discharging when the water table is high such as winter and spring, but mines are not fully flooded during drier seasons such as summer and fall. All discharges and sample point locations will be mapped from GPS coordinates gathered by using a Garmin eTrex Vista C handheld GPS unit. Very detailed underground mine maps and generating structure contours will work in conjunction with the field data to give a better understanding of the area. Mine maps and structure contours have been generated as part of the Hydrogeology of Underground Mines in the Upper Freeport Coal Seam, Northern Appalachian Basin, WV-PA-MD project completed by the Hydrogeology Research Center for EPA Region III. In addition to these maps it will be necessary to work with local surveyors to enhance the quality of the existing maps to obtain a better understanding of the true land and mine working structure. Testing for the viability of using in situ treatment on the site will involve installing instruments to collect stream flow, conductivity, and temperature at both the Ruthbell #3 discharge and on Crab Orchard Run (Fig. 4).

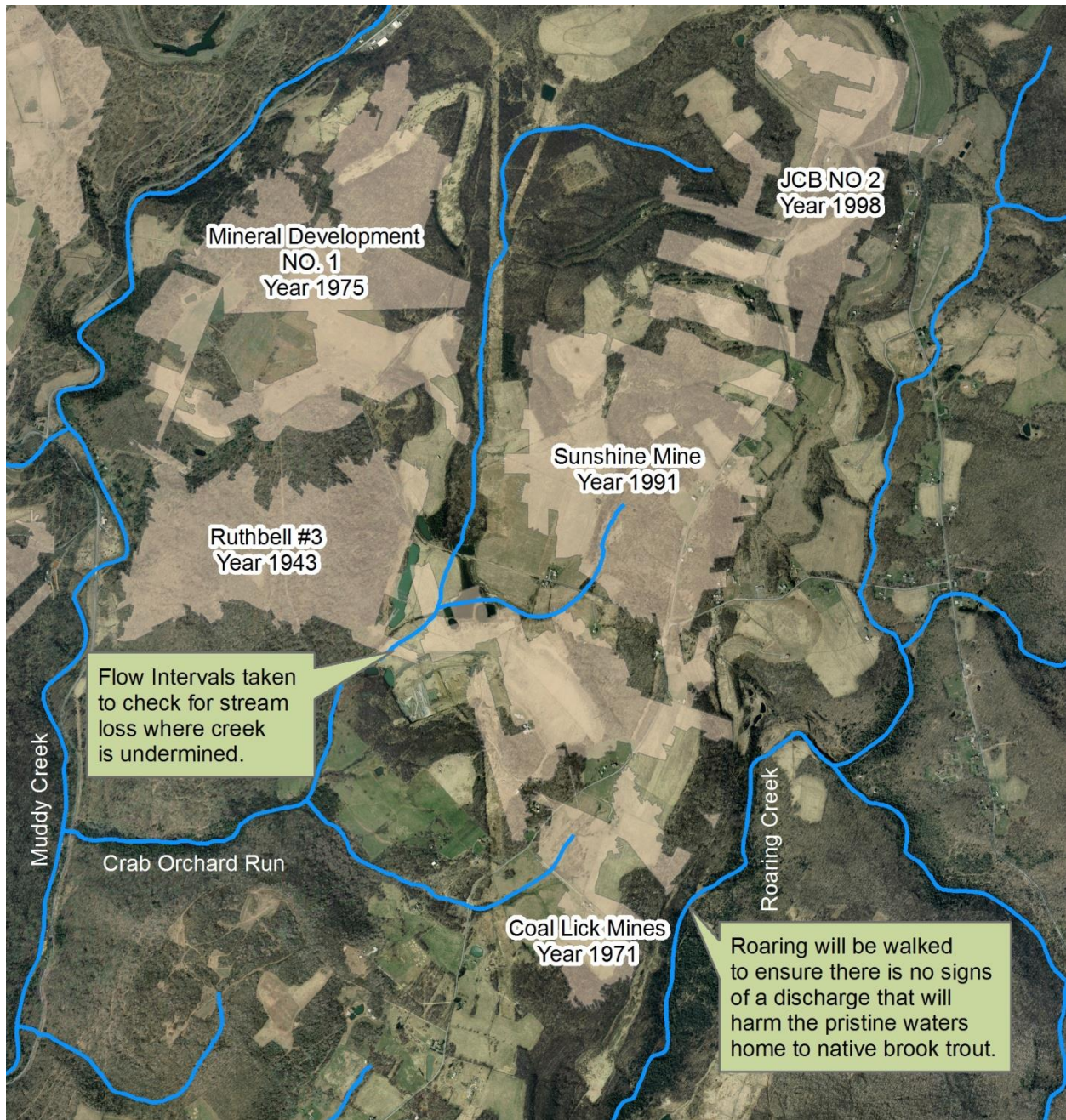


Figure 4. Shows all five mines in the area and the year that they closed. It also labels the creeks in the area that will be walked and the area where Crab Orchard Run is undermined and flow intervals will be taken to check for seepage.

Exploring for flooded mine pools will include drilling monitoring wells to determine hydrologic connections between mines in question. According to Donovan the first well to be

drilled will be located in the down dip section of the Sunshine Mine. Based upon the elevation of the mine pool or lack thereof will conclude one of four possible conclusions:

- a) The Sunshine Mine is fully flooded.
- b) The Sunshine Mine is flooded to an elevation of 549 m (1800 ft) and is spilling into the eastern portion of the mine that is hydrologically connected to the Ruthbell #3 mine.
- c) The Sunshine Mine is flooding but is not fully flooded.
- d) The Sunshine Mine has a down dip discharge somewhere.

If conclusion “d” is true then more field investigation must be conducted to locate the down dip discharge from the Sunshine Mine. If conclusions a, b, or c are true then a second well will be drilled into the down dip section of the JCB No 2 mine. The second well will indicate whether JCB No 2 mine is fully flooded, partially flooded, or draining into the Sunshine Mine. A third well will also be drilled into the Coal Lick mine which will indicate whether the mine is fully flooded, partially flooded, or draining into the Sunshine mine. Based upon the results from the first three monitoring wells, if they show good reason that the mines are indeed interconnected, then a fourth well will be drilled. The fourth well will be drilled into the Sunshine Mine where there should only be a small mine pool if the mines are interconnected. Therefore according to mine pool elevations, if the first well drilled into the Sunshine Mine reported a pool elevation of 549 m (1800 ft) and the second well indicated the pool elevation at 494 m (1620 ft), then the mines are definitely interconnected.

Testing for feasibility of the in situ treatment on this site will involve drilling three additional monitoring wells to determine the exact corridor which water is flowing between mines. The first well will be drilled into the connector between the Sunshine Mine and the Ruthbell #3, the second well drilled between the Sunshine Mine and the JCB No 2 mine, the third well drilled between the Coal Lick mine and the Sunshine mine. Note that all three additional wells will be dependent upon the results of the first four monitoring wells. This will involve drilling between one and seven monitoring wells depending on the results of previously drilled wells.

### **Results**

We expect to use the results from the field data collection, mine maps, and drilling of monitoring wells to prove that the Ruthbell #3, Mineral Development No 1, Sunshine Mine, JCB

No 2, and the Coal Lick mines are hydrologically interconnected. We also intend to use the additional drilling of monitoring wells to pinpoint the connections between mines and show feasibility of the in situ treatment on this site.

Preliminary data has showed up to this point that the Sunshine mine is not discharging into Crab Orchard Run based upon water chemistry results from the NRCCE analytical lab. Two sweeps of Crab Orchard Run have been conducted where samples were taken and sent to the analytical lab. Both sample sets have come back with no surprises or outliers in the data. Both sample sets have showed that Crab Orchard Run is being affected by the Bakerstown strip mining sites that have occurred in the past. Preliminary data has also ruled out that Crab Orchard Run is draining into the Sunshine or Ruthbell #3 mine voids because the flows of Crab Orchard Run continue to increase as samples are taken moving downstream. The seepage test in 91.44 m (100 yd) intervals has been conducted where Crab Orchard Run was undermined and showed that there appears to be no seepage in this area. Further testing will be conducted to prove indeed, that neither of the above situations are occurring on site.

Roaring Creek has been walked and visually assessed while field measurements were taken for conductivity and pH. The stream walk revealed no signs of acidic mine drainage entering the stream such as iron staining or highly acidic water entering the stream itself. This does not prove or disprove any interconnectivity hypothesis; however it does lean towards the mines being connected due to the amount of time that has passed since the mines have been inactive. The drilling process and mine pool elevation studies will need to be conducted in order to further back and prove the hypothesis that the mines are interconnected and discharging from one location.

### **Acknowledgements**

Department of Environmental Protection Agency West Virginia University Water Research Institute West Virginia University Hydrogeology Research Center Office of Surface Mining National Research Center for Coal and Energy Analytical Water Lab

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Canty, Geoffery A., and Jess W. Everett, 2004. *Ashlines, Spring 2004, Volume 5, Number 1*. Use of CCBs for In-Situ Treatment of Acid Mine Drainage.