LONGEVITY OF MINE DISCHARGES FROM ABOVE-DRAINAGE UNDERGROUND MINES

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ABSTRACT

The duration of acid mine drainage flowing out of underground mines is important to watershed restoration and abandoned mine land reclamation projects. Reclamationists usually employ remediation strategies once (land regrading, revegetating, and installing water treatment) with the hope that these methods will adequately improve the water for a long time. An understanding of the changing acid water conditions from these portals over time will help in designing treatment methods. Past studies have reported that acid water flows from underground mines for hundreds of years with little change, while others state that poor drainage quality may last only 20 to 40 years. Several factors are important in making a prediction of the drainage quality over time, such as coal seam characteristics (primarily sulfur content), time since mine closure, flooding, mining method and amount of coal remaining, collapse of roof and other disturbances within the mine, and subsequent nearby surface mining. Over 50 above-drainage (those not flooded after abandonment) underground mine discharges were located and sampled during 1968 in northern West Virginia, and we revisited those sites in 2000 and measured water flow, pH, acidity, alkalinity, Fe, Al, and sulfate. Most of the discharges were from mines in the Pittsburgh and Upper Freeport coal seams, both seams were extensively mined in this area during the past 70 years. There was no significant difference in flows between 1968 and 2000 from these discharges, so we felt that the water quality data could be compared. Across all sites, significant changes in water quality were found between 1968 and 2000 for all parameters: pH increased from 3.1 to 4.0, average acidity declined from 1,140 to 295 mg/L (as $CaCO_3$), Fe decreased from 352 to 61 mg/L, Al decreased from 143 to 38 mg/L, and sulfate declined from 2,918 to 1,037 mg/L. Pittsburgh seam discharge water was much worse in 1968 than Upper Freeport seam water and drainage water from both seams improved from 70 to 80% over 32 years (roughly 1800 and 750 mg/L as $CaCO_3$ in 1968 compared to 375 and 250 mg/L as $CaCO_3$ in 2000). The implications of this research provide a framework for estimating time periods when underground mine drainage will have less impact on nearby streams and rivers.

INTRODUCTION

Acid mine drainage (AMD) is a serious problem from both surface and underground coal mines. According to the U.S. Environmental Protection Agency (1995) approximately 10,000 km of streams have been affected by AMD in the four states of Pennsylvania, Maryland, Ohio, and West Virginia. Many mines currently discharging AMD were operated and abandoned before enactment of the Surface Mining Control and Reclamation Act (SMCRA) of 1977. The Act provided standards for environmental protection during mining operations and placed the responsibility of AMD control and treatment on the operator (SMCRA 1977). The Act also provided a means for reclaiming abandoned mines by taxing current coal operators, which generates funds for abandoned mine land reclamation programs. Even with millions of dollars spent in reclaiming abandoned mine lands, these abandoned mines still generate more than 90% of the AMD in streams and rivers in the region and most of this acidic drainage flows from underground mines (Faulkner, 1997; Zipper, 2000).

Because these sites were abandoned before 1977, no company or individual is responsible to treat the water and therefore the receiving streams are polluted and are essentially unusable. High flows and high levels of pollution (high acidity and metal concentrations) necessitates the use of chemicals for treatment, which tend to be expensive and labor intensive (Skousen et al., 2000). Costs for chemicals, dispensing equipment, electricity for pumps, and manpower all add up to significant public expense if the treatment entity is a government agency or utility. Perhaps the largest cost to the public is the unavailability of the waterbody for use and the accompanying impaired aesthetics and degraded water quality. Therefore, simple and inexpensive treatment approaches are being sought as well as a better understanding of the natural processes within mines that affect water quality over time.

An understanding of the behavior of acid-producing materials within abandoned mines would allow an estimate of the longevity of the acid discharge, which will aid in determining remediation strategies and the short and long-term costs of treatment. However, the changes in flow and water quality over time from surface and underground mines are not well documented. Surface mining generally removes 90% or more of the coal (which often contains the highest sulfide content and hence the acid-producing potential) thereby leaving little in the backfill for continued reaction and acid generation. The coal that does remain was broken apart by blasting and the acid products are leached fairly rapidly, typically within 16 to 20 years (Meek, 1996). Special handling of toxic materials may reduce the amount of pyrite oxidized, and the addition of alkaline material during mining may neutralize acid *in-situ*, both of which decrease the total acid load coming from the site (Brady et al., 1990; Perry and Brady, 1995; Rich and Hutchinson, 1990; Rose et al., 1995; Skousen and Larew, 1994). During the 20 years after reclamation, discharge water quality may reach pre-mining levels. Acid discharge from underground mines usually lasts much longer, sometimes 50 to 100 years (Wood et al., 1999).

The earliest model for the longevity of AMD from underground mines was the former British Coal Corporation's 'rule of thumb' for below-drainage mines. Iron concentrations in an abandoned mine were assumed to decrease by 50% during each subsequent pore volume flushing (the time period required for the mine pool to be filled with water). For example, if 10 years are required for a mine to fill with water, the iron concentration should decrease by half every 10 years. This suggests an exponential decay as described by Glover (1983).

Other researchers have observed that the most severe drainage occurs within the first few decades and even the largest systems settle to lower levels within 40 years. For mines in the UK, a neutral pH was reached within 30 years, and after 40 years the iron concentrations were less than 40 mg/L (Wood et al., 1999). Jones et al. (1994) also showed that underground mine water in Pennsylvania changed from acidic to neutral over a period of decades.

Lambert and Dzombak (2000), studied underground discharges in the Uniontown Syncline of Pennsylvania and found that the discharges could be divided into three distinct areas: 1) an unflooded, above-drainage area, which had been mined out by 1940; 2) a flooded, below-drainage area, which had been mined out by 1940; and 3) a flooded, below-drainage area, which had been mined out by 1970. Water quality measurements were taken in 1974 and 1999. The water quality from unflooded above-drainage mines after 40 to 60 years after closure showed water pH to be between 3 to 3.5 (slightly improved during the subsequent 25 years), Fe to be 10 mg/L in 1974 and <2 in 1999, and sulfate to be 800 mg/L in 1974 and declining to 600 mg/L in 1999 (water in all cases to be net acidic). The water quality from the older flooded, below-drainage mines was pH 6.0 to 6.4, Fe improving from 45 to 25 mg/L, and sulfate to be 1700 mg/L in 1974 to 1000 in 1999 (net alkaline water). In the younger, flooded, below-drainage mines, pH increased from 3.1 in 1974 to 5.9 in 1999, Fe decreased from 140 mg/L to 70 mg/L, while sulfate decreased from 2000 mg/L to 900 mg/L in 1999. Therefore, the researchers concluded that underground mine water quality changed from acidic to alkaline within 30 years after closure and flooding in their geologic setting. They also showed that above-drainage, unflooded areas improved in drainage, but still remained net acidic (but low metal concentrations) after 60 years since closure. Other researchers have found similar results in this region (Brady et al., 1998; Capo et al., 2001).

Donovan et al. (2000) monitored the water quality of the Montour mine, which had a section that had been flooded since the 1970s and also a section that became flooded in 1982. In 1984, the mines were interconnected and water quality changes from 1983 to 1998 were monitored at a pump and treat station. Water conditions were strongly acidic (pH ~3.0, acidity –2200 mg/L) for the first two years, after which acid began to decline exponentially. Seven years after flooding (five years after peak acidity), the water became net alkaline and has stabilized at a pH of 6.4, net alkalinity at 200 mg/L, and iron around 60 mg/L.

Younger (1997) divided the acid load flowing from underground mines into two categories. “Vestigial” acidity is associated with the first-time flushing of acid products from the mine during initial abandonment and flooding. “Juvenile” acidity is produced from ongoing pyrite oxidation due to fluctuations in the water table, and may persist for hundreds of years depending on the pyrite content and hydrology of the underground mine system. The longevity of AMD at a given site is dependent on the rate of depletion of both the vestigial and juvenile acidity.

In above-drainage underground mines, water continually flows out at the down-dip side of the mine and acid-generation may continue for decades until the pyrite is exhausted (Lambert and Dzombak, 2000; Younger et al., 1997). In these situations, the rate of dilution is greatest where the recharge rate of the mine is high, water flow out of the mine is high, and the mine volume is small (Younger, 1997). The fluctuating water level and pooling effect due to seasonal variations in precipitation also aid acid generation. During low water levels, pyrite oxidation forms iron hydroxysulfate solids, which settle on coal and rock surfaces due to evaporation. When the water level rises, these acid products are dissolved and released into the mine pool. Pyrite oxidation can continue to occur on the wet, oxidized mineral surfaces, producing a continuing cycle of acidity production (Younger, 1997). Therefore, these above-drainage underground mines can discharge poor water quality for longer periods than flooded mines.

Discharge chemistry is affected by several primary factors. One important factor is the coal seam, and more specifically the pyrite content of the mined coal. Each coal seam is unique with relatively predictable chemical and physical features, which may affect discharge water quality. However, it does not appear that pyrite must be exhausted in order for drainage quality to improve.

The mining method and degree of coal removal within a mine are other variables affecting discharge chemistry. Room and pillar underground mining (the most common method in this area) often left more than 50% of the coal as support for the roof. After abandonment, this coal continues to weather and crack away from the pillar, allowing more of the pyrite in the pillar to react. Remining old underground mines by surface mining has the potential to improve pre-existing acid discharges by removing coal pillars and then reclaiming the site to current reclamation standards, which often includes mitigating any acid mine drainage potential (Hawkins, 1994; Richardson and Doughterty, 1976).

Previously mined sites with acid discharges can be also affected by subsequent, adjacent surface mining. The flow may decrease because the surface overlying the recharge area has been reclaimed and vegetated, which could decrease infiltration into the underground mine. This effectively decreases the size of the mine pool and the subsequent flow rate out of the mine. Adjacent surface mining may also cause collapse of the roof in portions of the mine and reduce the void space, thereby changing flow paths or altering interconnection of certain areas. The collapse of pillars or roof rocks could create fresh pyrite surfaces for AMD reactions to take place and increase acid production. The degree of disturbance in a mine is difficult to measure and its ensuing impact on mine water chemistry is also difficult to predict over time.

A study in 1968 identified and sampled over 200 underground mine discharges in the northern West Virginia coal region. Most of these discharges were coming from above-drainage underground mines in the Upper Freeport and Pittsburgh coal seams. We revisited those sites in 1999 and 2000 and analyzed the water from the same discharge points. Several of the sites also had been sampled and analyzed in 1980, which provided an intermediate sampling time to assess acidity and iron concentrations from the mine. From this data set, we determined the change in water quality during this 30-year period and evaluated the factors that may have been responsible for their change. We tried to correlate these changes to disturbance effects and coal seam differences.

METHODS AND MATERIALS

Fifty underground mines and their associated discharges were sampled and used for water quality comparison. The sites were located in Preston and Monongalia Counties of West Virginia, and Fayette County in Pennsylvania. The sites were found according to marked locations on Valley Point, Cuzzart, Kingwood, Masontown, and Morgantown North USGS quadrangle maps. The discharges all drained underground drift mines to various streams within the Monongahela River Basin. Most mines operated in the Upper Freeport and Pittsburgh coal seams, but a few sites mined the Bakerstown, Upper Kittanning, and Lower Freeport seams. The drift mining method was generally used in hilly areas where coal seams outcrop along the contour and where the seam is nearly flat or slightly dipping.

The Pittsburgh coal seam is the lowest member of the Monongahela Series. The seam has a moderate sulfur content (1.5 to 2.0%) and a low ash content (6%). The Pittsburgh coal is composed of alternate layers of coal and slate or shale. A typical Pittsburgh coal cross-section shows a 3-m layer of good coal, a 0.7-m layer of bone coal or slate, and another 3-m layer of good coal. The Pittsburgh coal along the Monongahela and Cheat Rivers is located close to the surface (Hennen and Reger, 1914).

The Upper Freeport coal seam is the topmost strata of the Allegheny Formation of the Pennsylvanian System. Freeport coal is relatively low in sulfur (<1.5%) and has a moderately low ash content (8 to 12%). It is a multiple-bedded seam that is divided into a top coal and bottom coal, separated by a shale interlayer, all averaging a total of six feet in thickness (Hennen and Reger, 1914). The overlying strata in the Conemaugh Group contains several massive sandstones and some shales. Limestone or alkaline-bearing rock units are not generally found within 50 m above the Upper Freeport coal in this area, so very little overlying geologic material is available for acid neutralization (Hennen and Reger, 1914).

1968 Study

A previous study was conducted from 1968-1970 where field crews were sent out to identify all coal mines within the Monongahela River Basin and to sample their discharges. Each crew worked from 7.5-minute USGS topographic maps on which they outlined mine boundaries and indicated mine openings. Field sheets were also completed at each site with location and overburden information. Sites with a discharge were identified on the maps, flow rates were determined, and the water was sampled. The flow was measured when possible with a bucket and stopwatch. For larger flows, the crew installed a V-notch weir and measured flow rate. These values were recorded on the field sheet. In the field at the time of water collection, the pH of the discharge was measured using an electrometric pH meter, and temperature was checked with a lab grade thermometer. These values were recorded on the field sheet.

Two water samples were taken at each discharge in this early study: 1) a plastic quart bottle was filled, put on ice, and then analyzed in the laboratory for acidity, alkalinity, hardness, sulfate, and pH; and 2) a glass bottle was filled, treated with acid, and then analyzed in the laboratory for metals (total iron, manganese, aluminum). Water samples were delivered to the laboratory each Friday where they were analyzed using methodology from the latest edition of Standard Methods. Water analyses were monitored for accuracy and precision by running periodic samples of reference standards (Personal communication, Gary Bryant, U.S. EPA, 1999).

1999 Study

Mine sites and their associated point discharges were located on the USGS topographic map marked by the 1968 crew. Based on observations of the surrounding conditions, each site was categorized as disturbed or undisturbed. Undisturbed meant that the site appeared to have remained untouched since 1968 and that no obvious influence had occurred to the mine site or within the underground mine. Disturbed suggested that either surface mining had occurred in the area since 1968 or the area has been reclaimed or remined.

Discharges were sampled as close to the mine portal as possible. Flows were calculated using a measured cross-sectional area and flow velocity or an estimate was made. Two water samples were taken at each sample point: 1) a 250-mL unfiltered sample was taken for general water chemistry (pH, conductance, acidity, and alkalinity); and 2) a 25-mL, filtered sample was acidified to pH <2 with 0.5 mL concentrated nitric acid and used to determine metal concentrations.

Water pH, alkalinity, and acidity were determined by a Metrohm pH Stat Titrino System (Brinkman Instruments, Wesbury, NY). Conductivity was measured using an Orion Conductivity meter Model 115 (Orion Instruments, Beverly, MA). The metal analysis was preformed using an Inductively Coupled Spectrophotometer, Plasma 400 (Perkin Elmer, Norwalk, CT). Sulfate was measured turbidimetrically by flow injection analysis (Latchat Instruments, Milwaukee, WI).

Statistical Analysis

A subset of 28 sites for which we obtained a complete data set (pH, acidity, iron, aluminum and sulfate) was used for the statistical analysis. These 28 discharges emanated from 24 different mines. Analysis of variance was performed using a full model with main effects of Year, Disturbance, Coal Seam, and all possible interactions as class variables using PROC GLM (SAS Institute). Based on Type III sums of squares, the least significant term was dropped and a new analysis performed. This process was repeated until an optimal model for each parameter, the one that minimized the mean square error (MSE), was determined. Means for significant (alpha = 0.05) model terms were separated using Tukey's Honestly Significant Difference (alpha = 0.05).

RESULTS AND DISCUSSION

Generally, models were significant for all parameters (Table 1) even though R^2 values were somewhat low. A low R^2 is not entirely unexpected given the large, inherent variability of this data set and the relatively simple model used. Other variables likely to affect the variance in this data set include mine age and size (Table 2), mining practices and mine pool stratification (Ladwig et al., 1984). A slow mixing of water at various depths occurs between the dilute, newly-recharged waters at the top of the mine pool and the more dense, deeper waters containing high dissolved solids. Depending on the location of discharge (whether pumped from low levels in the mine pool, or discharged freely at the top of the pool), the water quality coming from the same mine pool may be quite variable.

None of the main effects or interactions was significant for the parameter Flow (Table 1). The fact that there was no Year effect for Flow suggests that these two sampling years (1968 and 2000) were similar and that water quality data can be compared directly. This is an important consideration because water quality parameters are sensitive to flow, and the within and between year variability can be large. Flow can affect water quality by diluting concentrations being released from the mine or can make the discharge appear more severe during low flow conditions.

The main effects of Year and Coal Seam were significant for the water quality parameters Acidity, Iron, Aluminum, and Sulfate; but only the Year effect was significant for pH (Table 1). Water quality was better in 2000 than in 1968 and worse if draining from the Pittsburgh coal seam (Table 3). There was a significant Year*Coal Seam interaction for Acidity and Sulfate. There were small but significant improvements in Acidity and Sulfate on the Upper Freeport sites, but the largest improvements occurred on the Pittsburgh sites (Figure 1). Significant differences were found in water quality between the Upper Freeport and Pittsburgh sites in 1968, but these differences vanished in 2000. That is, the main effect of Coal Seam on Acidity and pH is due principally to the water quality differences in 1968. The same general trends were also observed for Iron and Aluminum. There was a significant Disturbance main effect for only Flow and Aluminum, suggesting that it is time and not disturbance that has the largest effect on water quality discharging from a mine. These trends support the idea that natural attenuation occurs within underground mines.

This attenuation may be similar to what occurs on surface mines. As water infiltrates into the mines, acid products are leached from the rocks, and eventually water quality can reach pre-mining levels (Meek, 1996). This process may not be as straightforward in an underground mine, due to subsidence and ever changing flow paths. The attenuation can also be related to Younger's description of vestigial and juvenile acidity. The samples collected in 1968 may have been close enough to the time of mine closure to still be experiencing vestigial acidity. The samples collected in 2000 are examples of the juvenile acidity that continues to be released from the mines for up to 100s of years (Younger, 1997). Our data set also suggests that the models established by Jones et al. (1994) and Younger (1997) can be applied to above-drainage, shallow, drift mines.

It is important to consider the age of the mines in order to determine the break-off between vestigial and juvenile acidity (Table 2). For six of the twenty-eight discharges, 1980 data was found and used to analyze the trend of vestigial and juvenile acidity (Figure 2). The data at these six discharges show the overall trend of improving from 1968 to 1980, and then improving more between 1980 and 2000, except for Lake Lynn 3 and Martin Creek 2. Cheat River 5 began operation in 1935, meaning it would be 45 years old when sampled in 1980. The vestigial acidity should have been released by this time, but the mine should continue to release lower levels of juvenile acidity. In 1980, the youngest mine was Martin Creek 2. It shows dramatic decreases in both iron and acidity concentrations as compared to the 1968 sample, even though sulfate increased. This one mine shows that it has released its vestigial acidity in less than 25 years. It would be valuable to have large data sets over time to determine the exact break-off point when acidity comes primarily from vestigial to juvenile.

CONCLUSIONS

Our data indicate that the water coming from above-drainage underground mines shows significant improvement over time. A 65 to 80% reduction in acidity, iron, aluminum, and sulfate were found for these mines in northern West Virginia between 1968 and 2000. This suggests that remediation strategies for above-drainage underground mines may be augmented depending on the age of the mine and that passive treatment methods may be applicable for water treatment as acidity and metal concentrations decline with time.

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Table 1. Summary statistics for overall GLM model and significance level (Pr>F) for main effects and interactions.

	Parameters					
	Flow	pH	Acidity	Fe	Al	SO_4
	L/min	s.u.	---------------- mmol/L ---------------------			
Overall Model						
Mean	74.5	3.4	14.3	3.8	3.3	20.6
MSE	28345	1.60	161.70	10.09	10.34	260.51
R^2	0.09	0.21	0.48	0.52	0.42	0.48
Pr>F	0.0773	0.0068	<0.0001	<0.0001	0.0003	<0.0001
Individual Model Terms	----------------------------- Pr > F ----------------------------					
Year	0.1135	0.0248	<0.0001	<0.0001	<0.0001	<0.0001
Coal Seam	na	0.0604	0.0019	0.0113	0.0483	0.0022
Disturbance	0.1011	na	Na	na	0.2463	na
Year * Coal Seam	na	0.1731	0.0077	0.0613	0.1101	0.0016
Year * Disturbance	na	na	0.2541	na	Na	0.0723
CoalSeam*Disturbance	na	na	Na	na	0.2336	na
Year*CoalSeam*Disturbance	na	na	Na	0.3727	0.2740	na

na: not applicable; signifies a term dropped from the model because excluding it decreased MSE.

Table 2. Mine name, the year the mine opened, disturbance category, coal seam mined and mine area affected, for each discharge point sampled in 1999-2000.

Discharge Point	Mine Name	Year Opened	Category	Coal Seam	Mine Area (ha)
Bull Run 1	Kimberly	1962	Undisturbed	UF	21
Bull Run 2	Roxy Ann	1957	Undisturbed	UF	923
Bull Run 3	Roxy Ann	1957	Disturbed	UF	923
Bull Run 4	Sherrey	1955	Undisturbed	UF	282
Cheat River 1	Morgantown North E		Undisturbed	Pittsburgh	
Cheat River 2	Morgantown North D		Disturbed	Pittsburgh	
Cheat River 3	Frederick No. 1 Mine		Disturbed	Pittsburgh	
Cheat River 4	Morgantown North A		Undisturbed	Pittsburgh	
Cheat River 5	Canyon Mine	1935	Disturbed	Pittsburgh	448
Cheat River 6	Mountain Run	1952	Disturbed	UF	311
Cheat River PA1	Morgantown North B		Disturbed	Pittsburgh	
Cheat River PA2	Morgantown North C		Undisturbed	Pittsburgh	
Fickey Run 1	Valley Point C		Undisturbed	UF	
Fickey Run 8	Tri State	1952	Disturbed	UF	78
Glade Run 1	Liston	1955	Disturbed	UF	26
Glade Run 2	Valley Point F		Undisturbed	UF	
Lake Lynn 1	Hollow	1943	Undisturbed	Pittsburgh	34
Lake Lynn 2	Canyon Mine	1935	Disturbed	Pittsburgh	448
Lake Lynn 3	Canyon Mine	1935	Disturbed	Pittsburgh	448
Martin Ck 2	Me	1955	Disturbed	UF	11
Martin Ck 3	Me	1955	Disturbed	UF	11
Middle River 1	Mountain Run	1952	Disturbed	UF	311
Muddy Ck 11	Ruthbell #3	1943	Disturbed	UF	35
Muddy Ck 2	Cuzzart C		Undisturbed	UF	
Muddy Ck 3	Shermike		Disturbed	UF	
Muddy Ck 6	Cuzzart B		Undisturbed	UF	
Muddy Ck 8	Cuzzart F		Undisturbed	UF	
Muddy Ck 9	Tri State	1952	Disturbed	UF	78

Table 3. Mean water quality for the main effects of year and coal seam.

		Flow	pH	Acidity	Iron	Aluminum	Sulfate
		L/min	s.u.	-----------------mmol/L			--------------------
Year	1968	na	3.1	22.8	6.4	5.3	30.4
	2000	na	4.0	5.9	1.1	1.4	10.8
Coal Seam	Pittsburgh	na	na	21.7	5.2	4.6	29.8
	U. Freeport	na	na	10.3	3.0	2.6	15.5

na: not applicable; signifies a term dropped from the model because excluding it decreased MSE.

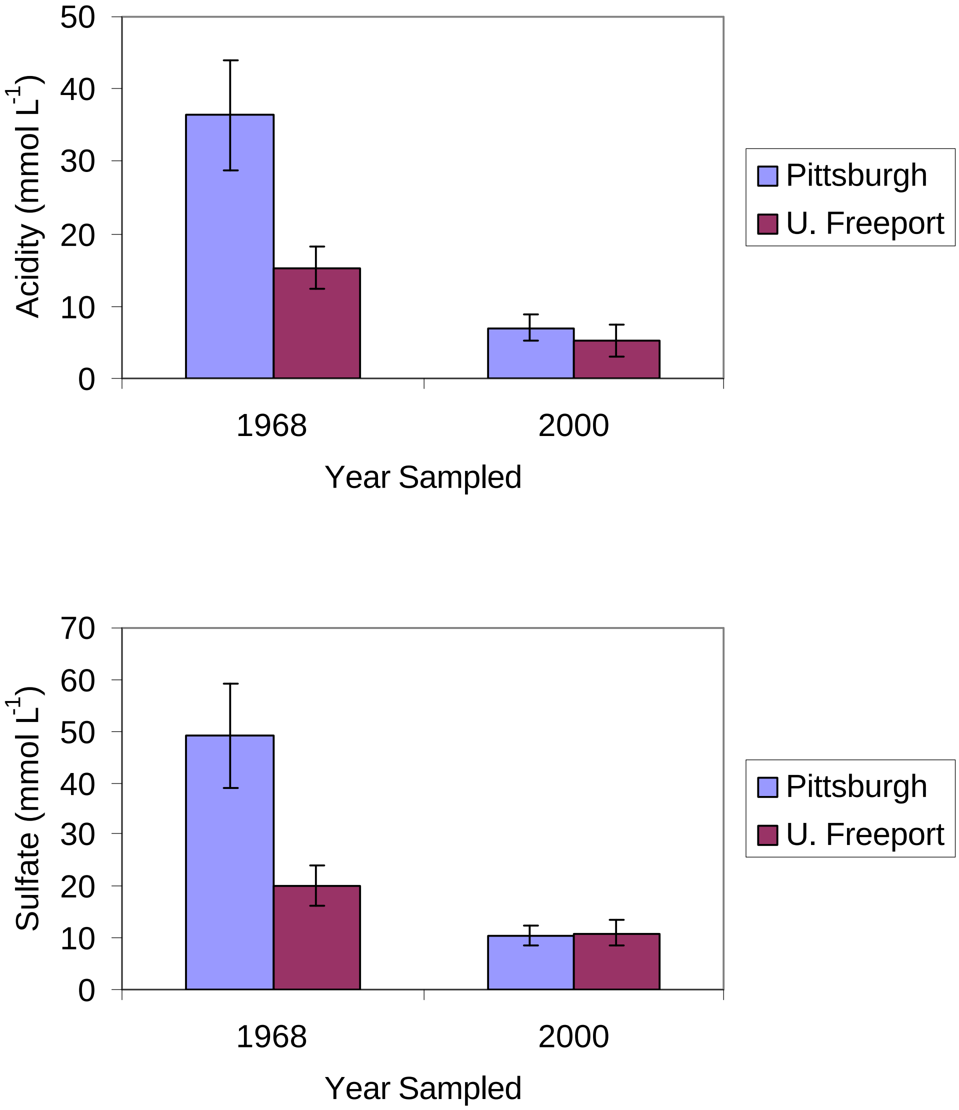

Figure 1. Year*Coal Seam interactions for sulfate and acidity. There is a significant difference between the Pittsburgh and Upper Freeport coal seam in 1968 for both acidity and sulfate, but not in 2000.

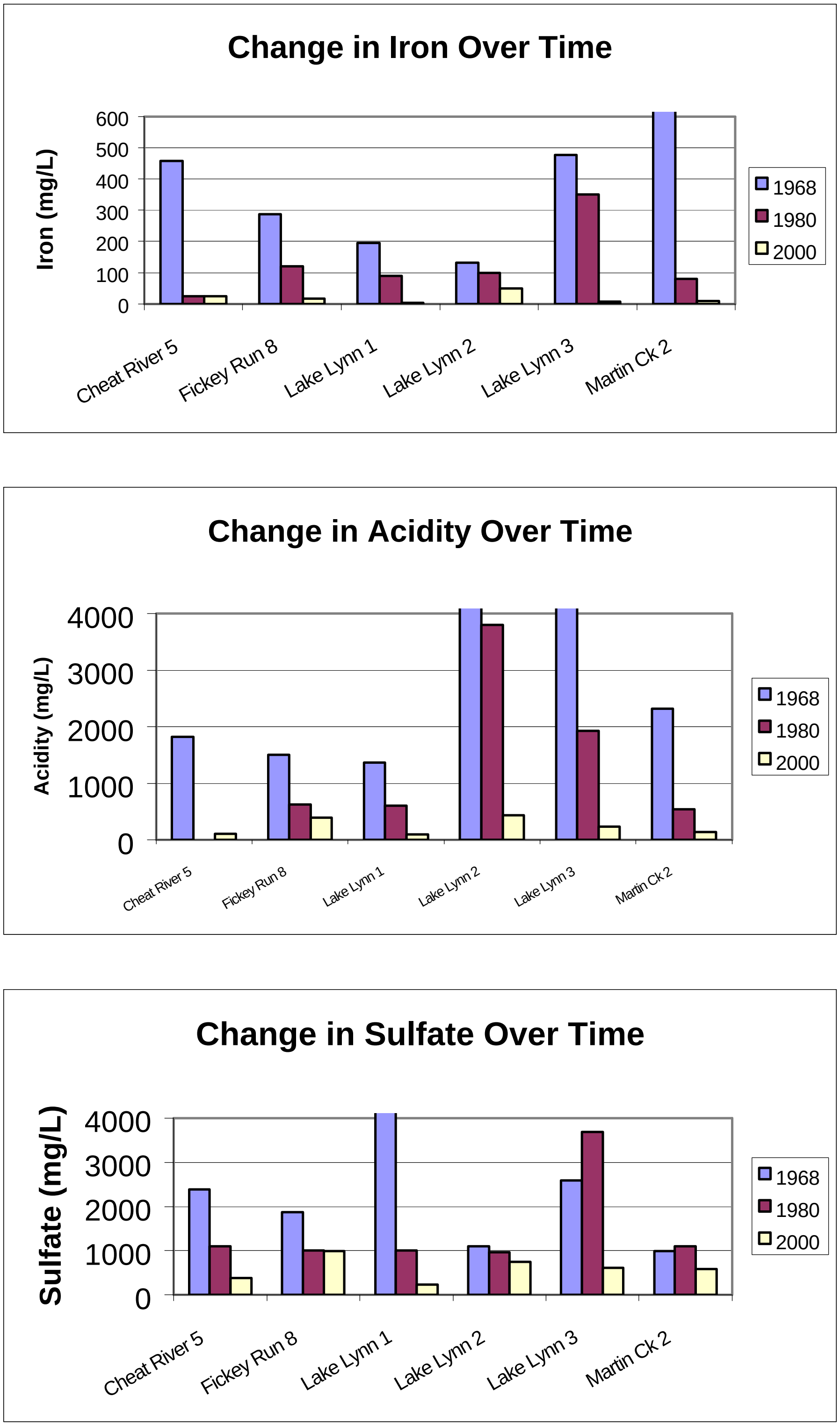

Figure 2: Water quality in 1968, 1980, and 2000 for six discharges.

Table 4: Water quality in 1968, 1980, and 2000 for six discharges.

Discharge	Year	pH	Flow	Acidity	Iron	Aluminum	Sulfate
		s.u.	L/min	-------------------	mmol/L	-------------------	
Cheat River 5							
	1968	2.6	19	1825	458	101	2392
	1980	2.6			25		1100
	2000	3.5	38	104	24	11	379
Fickey Run 8							
	1968	3	49	1505	288	84	1872
	1980	2.3	1	625	120		100
	2000	3.5	4	390	17	34	996
Lake Lynn 1							
	1968	2.8	38	1368	495	100	8861
	1980	2	1	605	90		1000
	2000	3.5	6	102	4	9	240
Lake Lynn 2							
	1968	3.2	38	4690	131	302	1105
	1980	2	1	3800	100		960
	2000	2.8	38	434	49	33	745
Lake Lynn 3							
	1968	3.1	480	4988	477	532	2593
	1980	2	1	1930	350		3690
	2000	2.9	6	237	7	33	619
Martin Ck 2							
	1968	2.7	57	2315	640	161	990
	1980	2.4	1	545	80		1100
	2000	4.2	38	135	10	4	587