Disposal of Fluidized Bed Combustion Ash in an Underground Mine to Control Acid Mine Drainage and Subsidence

**Quarterly Report
March 1 - May 31, 1995**

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Progress Report

for the Quarter of

March 1, 1995 to May 31, 1995

Project - ETD05 "Disposal of Fluidized Bed Combustion Ash in an Underground Mine to Control Acid Mine Drainage and Subsidence"

DE-FC21-94MC29244

During Phase I (first 18 months) the project is segregated into four areas of reporting: A) Grout Formulation, B) Grout Characterization, C) Water Quality Monitoring, D) Subsidence Control & Contaminant Transport. The first component involves formulating a grout mixture with appropriate flowability and strength (flow and strength requirements will be set by other components) to be used in filling complex mine voids. The Grout Characterization component will determine the flowability characteristics of the formulated grout and model the flow of the grout filling the mine void. The Water Quality component involves background monitoring of water quality and precipitation at the Phase III (Longridge) mine site. The last component involves evaluating the strength requirements and the migration of contaminants through the candidate grouts.

This report separately discusses progress on all components of the program in order of project subtask. The subtasks are arranged according to the Network Diagram on the following pages. Progress for each subtask can be seen in the Gantt Chart following the Network Diagram.

Executive Summary

During this reporting period the results from several test showed favorable results. Of interest is the relationship between strength of the various batches of ash that have been delivered from the MEA Power Plant. Strength continues to increase with age for all samples made from each of the five batches of ash. The minimum strength requirement (500 psi) is exceeded by all mixes in about 20 days. Also to be noted is that acidic mine water can be used for mixing the grout. A reduced strength is exhibited but the minimum strength requirement of 500 psi is again exceeded in 20 days. Another encouraging result is that cylinders that were allowed to harden while submerged in mine water showed no significant loss in unconfined compressive strength. All data to date is encouraging to the success of the field demonstrations schedule for Phases II and III.

Other significant advances during this period include the fabrication of the bench-scale flow testing apparatus, and the delivery of the Brookfield rotational viscometer. The viscometer will allow the measurement of yield stress and when used along with known machine constants, can find the relationship between shear stress and rate of strain.

Water quality data continued to be sampled weekly from the Longridge mine. Flow averaged 58 gallons per minute during the quarter while pH continued to be 2.5 to 2.8. Other values of interest are 848 mg/l of acidity and 138 mg/l of iron.

Project Name: ETD05

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A. Grout Formulation

1.0 TASK DESCRIPTION:

GROUT DEVELOPMENT

The purpose of this task is to develop a grout formulation that will be capable of filling complex mine voids while displaying strength great enough to prevent subsidence. This task involves the physical mixing and testing of grouts while keeping in close communication with Dr. Siriwardane's and Dr. Gray's research teams. Dr. Siriwardane's team will evaluate the strength requirements needed for subsidence control while Dr. Gray's team will be responsible for grout rheology or flowability.

2.0 SUMMARY OF ACCOMPLISHMENTS AND SIGNIFICANT EVENTS

- 2.1 Mr. Michael Main joined the project as a graduate research assistant in mid-May replacing Martin Dougherty who left the University to seek full-time employment. Mr. Main has adequate laboratory experience and considerable construction experience. He will be an asset to the project.
- 2.2 Long term strength testing of samples continued to aid in assessments of strength development of various grout mixtures.
- 2.3 Tests were initiated to determine the extent to which mixture consistency, measured by slump, changed with time. Such information has use in field applications where grout pumpability may be affected by time delays encountered in placement operations.
- 2.4 Tests were initiated to assess the utility of mine water as grout mixing water. Of interest was the effects, if any, of acidic mine water on strength development.
- 2.5 Determinations were made of the influence of ash variability on mixture strength and strength development.

3.0 TO-DATE ACCOMPLISHMENTS:

As noted above.

4.0 TECHNICAL PROGRESS REPORT:

Results of laboratory testing of grout mixtures appear in Figures 1 - 4 attached to this report. Figure 1 plots compressive strength versus age for specimens made from five different lots of ash; i.e., batches of ash that were obtained from the power plants at five widely separated times. As indicated in the plot, strength continues to increase with age for all batches.

Moreover, significantly variability to strength exists between batches with samples from batch four exhibiting the highest strength levels. These results confirm the opinion expressed early in this project concerning the probability of significant variability between ash lots.

Figure 2 displays slump as a function of time for mixes made with tap water or acidic mine water. Slump increases with time, as anticipated. The plot further indicates that for given proportions, the relationship between slump change and time is essentially independent of type of mixing water.

On Figure 3 is plotted compressive strength as a function of time for samples of identical composition save type of mixing water. As indicated in the plot, mixtures can be made successfully with mine water as well as tap water.

Figure 4 plots compressive strength versus age for samples made with tap water. After nine days, however, one set of samples was submerged in mine water to assess the effects of an acidic environment on strength gain. No differences in strength gain were observed between submerged samples and samples which were not submerged in acid mine water.

5.0 PLANS FOR THE NEXT QUARTER

- 5.1 Continue strength testing to assess long-term strength development.
- 5.2 Initiate strength tests of mixtures containing admixtures and combinations of admixtures in attempts to enhance the flowability and cohesiveness of grout mixtures. Admixtures of interest are bentonite, a commercially available clay material used in drilling applications, a concrete air entraining agent, and a concrete plasticizing agent. Mixtures will be made using these admixtures both singly and in combination.
- 5.3 Continue swell testing to assess tendencies of mixtures to change in volume with time.

Fig. 1

31% Tap Water
50/50 Blend
Various Lots of Ash

Fig. 2 Slump vs. Time
31% water content
50/50 Mix of Solids

Strength vs Age

Tap Water and Acid Mine Water
31% moisture, 50/50 solids mixture

Fig. 4
31% Tap vs. 31% Tap Submerged in Mine Water

B. Grout Characterization

1.0 TASK DESCRIPTIONS

1.1 Literature Search: This task will involve both manual and computer searches of the literature on several topics. This task will insure that the latest advances in grout technology are incorporated into this project and that no effort is wasted in the duplication of results.

1.2 Grout Characterization: In this task, appropriate viscometric tests will be conducted to determine the relationship between stress and rate of strain, as a function of time and composition of the grout mixture.

1.3 Analytical Modeling: This task is the development of an analytical model to describe the rheology of the grout. This task will provide a constitutive relation that describes the behavior of the grout in agreement with the laboratory results.

1.4 Numerical Modeling: This task includes the adaption of commercially available fluid modeling software to incorporate the rheological model developed in task 1.3. This task will enable the placement of grout to be modeled numerically.

2. SUMMARY OF ACCOMPLISHMENTS & SIGNIFICANT EVENTS

Literature Search: 100% complete

Grout Characterization: 75% complete

Analytical Model: 10% complete

Numerical Model: 60% complete

3. TO DATE ACCOMPLISHMENTS

The literature search may be considered complete, but new information relevant to the project is continually being revealed. No other tasks are complete to date.

4. TECHNICAL PROGRESS REPORT

4.1 GROUT RHEOLOGY

After trying unsuccessfully to characterize the unstable grout using the squeeze plate rheometer, a Brookfield LVDV-III rotational viscometer with T-bar spindle attachments was purchased to perform rheological tests on the grout. With this machine the spindle is turned at varying rotational speeds and the torque needed to maintain this speed is recorded. From the viscometer data, plots of torque versus rotational speed are plotted. This data is then analyzed using the method described by Metzner and Tattersall. In this method the slope and intercept

of the plot (either on linear-linear or log-log paper) along with an independent measure of the yield stress are used along with known machine constants to find the relationship between shear stress and rate of strain (known as the constitutive law for the fluid.

The independent test that is planned for the yield stress is the vane method. This test is done by immersing a four-bladed vane in to the material and recording the torque that is needed to start the rotation of the vane. This torque value can then be converted to a value of stress which will be the yield stress of the fluid.

Another project that has been worked on this quarter is the preparation of an apparatus for use in bench-scale mine filling simulations. The apparatus consists of a 2.6 gallon pressurized container connected to a plywood box (4' X 4' X 3.5") by 0.5 inch plastic piping. To maintain similarity between the lab tests and field work, the Froude number of the flows will be matched. For this to hold, a volumetric flow rate of 4.2 L/min was used which matches with a field flow rate of 150 cubic meters per hour. Axi-symmetric filling tests will be done with the grout in an effort to validate the numerical simulation being done using PHOENICS. Further tests will be done were mine pillars are added to the model to again check the computer results.

To keep the ash in suspension so that these tests can be done, bentonite must be added to the grout. Bleeding tests were conducted to determine what percentage of bentonite is needed to make the grout stable. From the tests that have been conducted thus far, it seems that the amount of bentonite must be greater than 5% by weight of solid material in the grout. With the addition of other additives (plasticizers and/or air entraining agents) this number may change.

C. Water Quality Monitoring

1.0 TASK DESCRIPTION

BASELINE WATER QUALITY MONITORING

This task is to monitor baseline water quality of the acid mine drainage (AMD) from the Longridge and Fairfax Mines prior to grouting. A flow monitoring and sampling station has been set up at the Longridge Mine and a precipitation gauge has been established between the two mines.

2.0 SUMMARY OF QUARTER'S ACCOMPLISHMENTS & SIGNIFICANT EVENTS

Water quality monitoring and sampling continued as planned. Data is presented and discussed in some detail below. Flow from the Longridge Mine varied significantly during the quarter from a weekly low of 27.5 gpm to a high of 106.8 gpm and averaged 58.8 gpm. The average flow increased slightly over last quarter when the flow averaged 52.2 gpm. The higher flows in this quarter resulted in a reduced concentration of pollutants due to dilution of the acid water leaving the mine. For example, the iron concentration fell to an average value of 174 mg/l this quarter as compared to 194.9 mg/l last quarter. However, the actual average pounds of pollutants leaving the mine was higher this quarter due to the higher flows.

3.0 TO DATE ACCOMPLISHMENTS

Accomplishments to date include choice of parameters to sample, design of the sampling station, procurement of equipment, site preparation, installation and shake down of equipment, initiation of sampling and preliminary analysis of data to date.

4.0 TECHNICAL PROGRESS REPORT

Results of monitoring flow, precipitation and water quality are discussed below. In addition, issues related to monitoring activities at the site are described.

4.1 Flow and Precipitation Monitoring

Average weekly flow (gpm) from the Longridge Mine is shown in Table 1 and Figure 5. No flow data is available for the last three weeks of the quarter (weeks 40 to 42) due to flowmeter malfunction. It was necessary to ship the meter back to the manufacturer for repair and it has now been re-installed. Flow from the Longridge Mine varied significantly during the quarter from a weekly low of 27.5 gpm to a high of 106.8 gpm and averaged 58.8 gpm. The average flow increased slightly over last quarter when the flow averaged 52.2 gpm. Weekly precipitation varied from none to 1.59 inches per week for an average of 0.51 inches. This was slightly less than the average

precipitation last quarter of 0.69 inches per week. It should be noted that four of the rainfall values from last quarter were obtained from a gauging station at the Morgantown Lock and Dam rather than at the site because of freezing problems with our unheated gage at the site. As a result the average value from last quarter may have been somewhat high reflecting rainfall in the Morgantown area rather than at the site.

Figure 6a shows daily variation in flow and a trace for each sample taken during week # 33 (March 18 to 25). Figures 6b and 6c show plots of the rainfall intensity and rainfall cumulative total as a function of time respectively. It may be seen that 0.64 inches of rain fell beginning late on the 20th (Monday) and continuing through the 21st (Tuesday). Examination of Figure 6a shows that there is about a 24 hour time lag till the flow from the mine reflects the rainfall event.

4.2 WATER QUALITY ANALYSIS

Analysis of the weekly composite AMD samples is presented in Table 1 for the quarter. In addition to the weekly values, the average value for weeks 30 through 39 is presented for each of the 15 parameters measured. As noted earlier, the flowmeter malfunctioned during week 40. As a result, sample 40 was only composited over the first two days of the week. Sample 41 was a grab sample taken on 5/21/95. The sampler was set to take samples every 1 1/2 hours for week 42. However, since no flow values are available for these three weeks, the water quality values for weeks 40 to 42 have not been used in computing the average shown in the last column.

Examination of Table 1 shows that the AMD from the Longridge Mine is relatively strong with pH ranging from 2.5 to 2.8 and an average acidity of 848 mg/L. Other parameters are correspondingly high with sulfate and iron averaging 1,429 and 138 mg/L respectively. The mine effluent also contains substantial levels of trace elements with arsenic, selenium and lead averaging respectively 0.645, 0.503 and 0.215 mg/L respectively.

Figure 5 shows acidity (mg/L) as a function of flow. It may be noted that as flow increases, the concentration of acid falls due to dilution. This phenomena is shown clearly in Figure 7 where the concentration of acidity and iron are both seen to fall as flow increases. However, when the mass of acid leaving the mine per day is compared to flow as in Figure 8, it is seen that the total mass of acid increase as flow increases due to the increased flow flushing the acid out of the mine. Although not shown, the same trend would be expected to hold for other pollutants such as sulfate and metals.

The average concentration of As, Se, and Pb are presented in Figure 9 for each week. In some weeks, these metals seems to rise and fall together, while in other weeks they do not. The three metals are plotted as a function of flow in Figure 10. It may be noted that As and Pb (to a lesser extent) seem to fall as flow increase, while Se does not.

In Table 2, selected water quality parameters are compared for this quarter and the two previous quarters. It may be noted that as flow increased from quarter to quarter, the concentration of pollutants generally decreased due to dilution. However, the actual lbs of acid increased due to the higher amount of water flushing acid from the mine.

End Qtr	Flow (gpm)	Fe (mg/L)	Al (mg/L)	SO ₄ (mg/L)	As mg/L)	Pb (mg/L)	Acidity (mg/L)	Acidity (lbs/d)
11/30/94	24.6	195	80	1776	0.83	0.29	1134	336
2/28/95	52.2	174	47	1421	0.66	0.23	980	564
5/31/95	58.8	138	57	1429	0.65	0.22	848	567

4.3 Miscellaneous Issues Related to Monitoring Activities

The only significant problem this quarter was the failure during week 40 of the flow meter. However, as noted above, the instrument was shipped back to the manufacturer for repair and is now re-installed.

5.0 PLANS FOR NEXT QUARTER

- 5.1 The site will be visited weekly to pickup samples and collect data from the flow sampling station and rain gage. Data analysis and evaluation will be carried out as appropriate.
- 5.2 Unresolved Issues: There were no unresolved issues during this reporting period.
- 5.3 Schedule: The Water Quality Monitoring Task is on schedule.
- 5.4 Budget: This task is "on budget".

TABLE 1		LONGRIDGE MINE															Average
Date		3/4/95	3/11/95	3/18/95	3/25/95	4/1/95	4/8/95	4/15/95	4/22/95	4/29/95	5/6/95	5/14/95	5/21/95	5/27/95			
Week #		30	31	32	33	34	35	36	37	38	39	40 (1)	41 (1)	42 (1)			
Flow (gpm)		106.8	95.53	89.97	55.49	43.76	31.82	27.5	29.74	35.95	70.94	*na	*na	*na	58.75		
Temp (C)		10	10	10	10	10	10	10	10	10	10	10	10	10	10		
Precip. (Inch)		0.54	0.84	0	0.64	0.15	0.2	0.67	0.23	0.77	1.03	1.59	1.46	0.16	0.507		
pH		2.7	2.7	2.7	2.7	2.7	2.83	2.9	2.8	2.7	2.7	2.7	2.5	2.5	2.743		
Conduc. (umol/cm)		2250	2240	2240	2190	2200	2350	2200	2160	2190	2090	2090	1893	2010	2211		
Acid. (mg/l CaCO3)		754	693	694	823	844	888	898	870	1176	835	785	727	866	847.5		
Acid (lbs/day)		967	795	750	548	444	339	297	311	508	711	*na	*na	*na	566.9822		
Fe (mg/l)		104	109	100	139	163	175	147	141	161	143	133	111	141	138.2		
Mn (mg/l)		17.3	17.5	17.8	19	19.1	24.3	19.2	18.6	20.3	17.6	17.4	14.9	19.5	19.07		
Al (mg/l)		50.4	50.9	53	51.9	53.4	57.4	56.4	55	63.8	76.9	72.4	47	60.7	56.91		
Ca (mg/l)		96.4	104	102	128	135	147	140	141	148	135	119	92	127	127.64		
Mg (mg/l)		56.9	65	124	69.1	69.6	72.7	68.4	66.1	77.2	64.9	58.1	51.4	69	73.39		
SO4 (mg/l)		1320	1390	1430	1580	1600	1850	1070	1120	1525	1409	1355	1173	1464	1429.4		
As (mg/l)		0.56	0.57	0.64	0.71	0.77	0.77	0.73	0.7	0.54	0.46	0.42	0.33	0.59	0.645		
Se (mg/l)		0.49	0.46	0.58	0.49	0.53	0.53	0.45	0.48	0.54	0.48	0.46	0.39	0.63	0.503		
Pb (mg/l)		0.22	0.27	0.19	0.21	0.2	0.25	0.25	0.26	0.18	0.12	0.13	0.14	0.18	0.215		
Ba (mg/l)		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05		
Cd (mg/l)		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05		
B (mg/l)		0.07	0.07	0.07	0.13	0.13	0.15	0.18	0.17	0.19	0.15	0.12	0.08	0.1	0.131		
*data not available due to malfunction of flow meter (1) not used in obtaining averages)																	

Figure 5 Weeks vs Flow and Acidity

March 25 Set #33

70.00

46.00

54-00

62.00

30.00

38.00

08:00 Sat

18 MAR 1995

Flow= Δ

08:00

Sum

08:00

Mon

08:00

Tue

08:00

Med

08:00

Thu

08:00

Fri

08:00:31

25 MAR 1995

[illegible]

551124 g31

Figure 6b. Rainfall Plot; Week 33

Type: 674L-8K

inches

Recorder ID:0001

Figure 6c. Running Rainfall Total; Week 33

Saved Recorder Status

Type: 674L-8K Range:-0.00 - 2.55 inches Recorder ID: 0001
 Time at Recorder: 03/25/95 05:49:37 Accum Reset @:03/18/95 08:56:15
 Signal process: Not Applicable Accum: 0.64 inches
 Values being saved: Totals

Totalizing period: 00:03:00 Amount of data recorded: 6 days 20:54:00

Storage Capacity: 4048 values records: 8 days 10:24:00 Prescaler: 1
 Output compressed by a factor of 100

Date	Time	Avg inches	Period Total	Running Total
03/18/95	08:53:15	-0.00	-0.00	-0.00 *
03/18/95	13:53:15	-0.00	-0.00	-0.00 *
03/18/95	18:53:15	-0.00	-0.00	-0.00 *
03/18/95	23:53:15	-0.00	-0.00	-0.00 *
03/19/95	04:53:15	-0.00	-0.00	-0.00 *
03/19/95	09:53:15	-0.00	-0.00	-0.00 *
03/19/95	14:53:15	-0.00	-0.00	-0.00 *
03/19/95	19:53:15	-0.00	-0.00	-0.00 *
03/20/95	00:53:15	-0.00	-0.00	-0.00 *
03/20/95	05:53:15	-0.00	-0.00	-0.00 *
03/20/95	10:53:15	-0.00	-0.00	-0.00 *
03/20/95	15:53:15	-0.00	-0.00	-0.00 *
03/20/95	20:53:15	0.00	0.36	0.36 *
03/21/95	01:53:15	0.00	0.25	0.61 *
03/21/95	06:53:15	-0.00	-0.00	0.61 *
03/21/95	11:53:15	-0.00	-0.00	0.61 *
03/21/95	16:53:15	-0.00	-0.00	0.61 *
03/21/95	21:53:15	0.00	0.03	0.64 *
03/22/95	02:53:15	-0.00	-0.00	0.64 *
03/22/95	07:53:15	-0.00	-0.00	0.64 *
03/22/95	12:53:15	-0.00	-0.00	0.64 *
03/22/95	17:53:15	-0.00	-0.00	0.64 *
03/22/95	22:53:15	-0.00	-0.00	0.64 *
03/23/95	03:53:15	-0.00	-0.00	0.64 *
03/23/95	08:53:15	-0.00	-0.00	0.64 *
03/23/95	13:53:15	-0.00	-0.00	0.64 *
03/23/95	18:53:15	-0.00	-0.00	0.64 *
03/23/95	23:53:15	-0.00	-0.00	0.64 *
03/24/95	04:53:15	-0.00	-0.00	0.64 *
03/24/95	09:53:15	-0.00	-0.00	0.64 *
03/24/95	14:53:15	-0.00	-0.00	0.64 *
03/24/95	19:53:15	-0.00	-0.00	0.64 *

Figure 7 Acidity & Iron vs Flow

Figure 8 Acidity (lbs/d) & Flow (gpm) vs Weeks

Figure 9 As, Se & Pb vs Weeks

Figure 10 As, Se, & Pb vs Flow

D. Subsidence Control & Contaminant Transport

1.0 Task Description

Task 5.0 Grout Strength Requirements

Determine grout strength requirements needed to ensure subsidence control.

Task 6.0 Contaminant Transport

Determine how contaminants will migrate within the grout that is placed in the mine void.

2.0 Summary of Quarter's Accomplishments and Significant Events

2.1 As noted below.

3.0 To Date Accomplishments

3.1 Finite element analysis of the Fairfax mine at section D-D was completed.

3.2 Computed subsidence profiles at Fairfax mine site in the vicinity of drill hole SQ-41. The profiles were plotted for 50%, 75% and 90 % backfill configurations.

3.3 A preliminary estimate of the grout volume required at the Fairfax mine was made.

3.4 The literature search for material relevant to Acid Mine Drainage and Contaminated Transport was continued.

3.5 Characteristic contaminant levels of Acid Mine Drainage at various locations were studied.

3.6 The contaminant levels of water from the Longridge mine were compared to the characteristic levels established through reviewed literature.

3.7 The calculated outflows from the mine were compared to the precipitation over the area using hydrologic calculations to provide input information for the modeling task.

4.0 Technical Progress Report

Finite element analysis of the Fairfax mine at Section D-D was completed. Details of the overburden near section D-D are shown in Figure 7. The material properties used for this analysis are included in Table 3. The cross-section D-D used for this analysis, and other cross-sections to be used for subsequent analyses are shown in Figure 8. For preliminary calculations, the pillar dimensions were

assumed as shown in Figure 9. The actual pillar configurations at Section D-D are displayed in Figure 10. Subsidence profiles at the Fairfax mine site were computed, and the profiles are included in Figures 12 and 13. The profiles were plotted at 50%, 75% and 90% backfill configurations (See Figure 11). The proposed grouting location is shown in Figure 14. A preliminary estimate of grout required for backfilling the proposed grouting location of the Fairfax mine was completed.

Over 160 paper relevant to Contaminant Transport and Acid Mine Drainage have been identified as part of the ongoing literature search and more than 60 of these papers have been collected. The characteristic AMD levels in water from three different mined areas in the region were studied along with the acid loading rates to rivers in these areas for streams carrying AMD. The high AMD levels established from these studies were compared to the drinking water standards and were found to exceed the limits by large margins (See Table 4).

The high AMD levels obtained from reviewed literature were compared to the AMD levels of water flowing out of the Longridge mine (See Table 5). The AMD levels obtained from reviewed literature, exceeded the drinking water standards by large margins (See Table 6). The catchment area over the Longridge mine was marked by studying mine maps with surface and coal seam contours. Based on the available rainfall data at the Longridge mine, the infiltration into the ground was estimated using the SCS method. (Soil Conservation Service, US Dept. Of Agriculture, 1971, Ref.4). These values were compared to the mine outflow data to provide valuable input information for the modeling task (See Table 7 and 8 and figures 15 and 16).

5.0 Plans for Next Quarter

- 5.1 The finite element analysis of the Fairfax mine at Section E-E will be completed.
- 5.2 Detailed calculations for grout strength requirements are to be made.
- 5.3 Appropriate computer software is to identified for the modeling of contaminant transport. Some trial modeling simulations are to be performed.

Figure 7. : Geologic column showing the Soil and Rock stratigraphy at core hole location SQ-41 of Fairfax Mine

Table 3 : Material Properties Used For The Analysis Of Fairfax Mine

Rock Type	Elastic Modulus x 10 ⁶ psi	Poisson's Ratio	Unit Weight pcf	Cohesion c psi	Internal Friction Φ deg	Tensile Strength psi	Coef. of e-pressure at rest k_o
Soil	0.007	0.30	120.0	2.0	20.0	2.0	0.50
Shale	0.960	0.15	160.0	2904.0	33.0	650.0	0.51
Sandy Shale	2.81	0.257	160.0	4260.0	31.4	15184.0	0.48
Sandstone	5.6	0.15	160.0	2336.0	28.0	851.0	0.46
Coal	0.180	0.30	83.0	1000.0	30.0	207.0	0.48

Figure 8 : Location of cross-sections and proposed grouting area at Fairfax mine

Figure 9 : Assumed Pillar Configurations at Fairfax Mine Site

Figure 10 : Pillar Configurations at Section D-D of Fairfax Mine Site

50% Backfill Configuration

Grout

75% Backfill Configuration

Grout

90% Backfill Configuration

Grout

Figure 11: Backfill Configurations Considered at the mines

Figure 12 : Computed Subsidence Profile at the Fairfax Mine Site

Figure 13 : Computed Subsidence Profile at Section D-D of Fairfax Mine Site

Figure 14: Proposed Grouting Location

Figure 15 : Schematic of Acid Mine Drainage

Figure 16 : Schematic of Average Monthly AMD At Longridge Mine

Table 4 : Comparison of AMD Contaminant Levels To Drinking Water Standards

AMD Contaminant/ Parameter	Drinking Water Standards	AMD levels *
pH	6.5-8.5	2.4
Acidity (mg/L)	-	35,000
Alkalinity (mg/L)	-	0
Total Iron (mg/L)	0.3	7,600
Sulfate (mg/L)	<250	31,000
Aluminum (mg/L)	-	51
Manganese (mg/L)	<0.05	675
Turbidity (T U)	<5	36
Dissolved Oxygen	-	4
Total Solids (mg/L)	-	103.5
Total Hardness (mg/L)	-	13,600
Magnesium (mg/L)	-	2990
Calcium (mg/L)	-	507

- * The worst case scenarios of each parameter/contaminant as found from the available literature (extracted from Table 3).
- The AMD levels reported here were not recorded the same day.

**Table 5 : Comparison Of Parameters Of AMD At The Longridge Mine To Drinking Water
Standards And Other Mine Water**

Contaminant/Parameter	Drinking Water Standards	Highest AMD levels (from literature reviewed)	AMD levels in water from Longridge Mine*
pH	6.5-8.5	2.4	2.4
Acidity (mg/L)	-	35000	1264
Acid Load (lbs/day)	-	18283	967
Alkalinity (mg/L)	-	0	-
Total Iron (mg/L)	0.3	7600	238
Sulfate (mg/L)	<250	31000	
Aluminum (mg/L)	-	51	98.3
Manganese (mg/L)	<0.05	675	29.3
Turbidity (TU)	<5	36	-
Dissolved Oxygen (mg/L)	-	4	-
Total Solids (mg/L)	-	103.5	-
Total Hardness (mg/L)	-	13600	2190
Magnesium (mg/L)	-	2990	124
Calcium (mg/L)	-	507	238
Arsenic (mg/L)	0.05	-	0.92
Selenium (mg/L)	0.01	-	0.84
Lead (mg/L)	0.05	-	0.34
Barium (mg/L)	1.0	-	<0.05
Cadmium (mg/L)	0.01	-	<0.05

*The data shown in this table were not all collected on the same day. The table is a representation of the worst case scenario of each parameter from the data available. The data shown in this column was obtained from Dr. W. Sack.

**Table 6: Comparison Of Parameters Of AMD At The Longridge Mine To
Drinking Water Standards**

Contaminant/Parameter	Drinking Water Standards	AMD levels in water from Longridge Mine*
pH	6.5-8.5	2.4
Acidity (mg/L)	-	1264
Acid Load (lbs/day)	-	967
Alkalinity (mg/L)	-	-
Total Iron (mg/L)	0.3	238
Sulfate (mg/L)	<250	
Aluminum (mg/L)	-	98.3
Manganese (mg/L)	<0.05	29.3
Turbidity (TU)	<5	-
Dissolved Oxygen (mg/L)	-	-
Total Solids (mg/L)	-	-
Total Hardness (mg/L)	-	2190
Magnesium (mg/L)	-	124
Calcium (mg/L)	-	238
Arsenic (mg/L)	0.05	0.92
Selenium (mg/L)	0.01	0.84
Lead (mg/L)	0.05	0.34
Barium (mg/L)	1.0	<0.05
Cadmium (mg/L)	0.01	<0.05

*The data shown in this table were not all collected on the same day. The table is a representation of the worst case scenario of each parameter from the data available based on the data provided by Dr. W. Sack.

Table 7 Flow Data At Longridge Mine

Month	Rainfall Vol.* (gal)	Infiltration Vol. (gal)	Outflow from Mine* (gal)	Losses (gal)
August '94	14,454,180	5,281,867.5	2,885,760	2,396,107.5
September '94	5,579,535	3,709,075	1,169,856	2,539,219
October '94	1,702,935	1,661,400	530,100	1,131,300
November '94	2,007,525	1,907,841	401,328	1,506,513
December '94	5,621,070	3,710,460	1,727,835.8	1,982,624.2
January '95	4,901,130	3,469,557	3,278,584.8	190,972.2
February '95	2,478,255	2,247,043.5	2,365,372.8	-118,329.3
March '95	2,796,690	2,451,949	3,881,336.4	-1,429,387.4
April '95	2,796,690	2,451,949.5	1,458,172.8	993,776.7
May '95	5,870,280	3,801,837	3,166,761.6	635,075.4
Average	4,820,829	3,069,298	2,086,510.8	982,787.13

* These columns are based in part on the data provided by Dr. W. Sack.

Table 8 Flow Data At Longridge Mine

Month	Rainfall Vol.	Runoff Vol. (as a %of rain)	Infiltration Vol. (as % of rain)	Mine Outflow* (as %of rain)	Losses (as%of rain)
August '94	100%	64%	36%	19.95%	16.58%
September '94	100%	33.52%	66.48%	20.97%	45.51%
October '94	100%	2.45%	97.55%	31.13%	66.42%
November '94	100%	4.97%	95.03%	19.99%	75.09%
December '94	100%	33.99%	66.01%	30.74%	35.27%
January '95	100%	29.21%	70.79%	58.33%	12.46%
February '95	100%	9.33%	90.67%	95.44%	-4.77%
March '95	100%	12.33%	87.67%	138.78%	-51.11%
April '95	100%	12.33%	87.67%	52.14%	35.53%
May '95	100%	35.24%	64.76%	53.94%	10.82%
Average	100%	36.33%	63.67%	43.28%	20.39%
Average without August	100%	20.67%	79.33	53.26%	26.0