

Management of Dry Flue Gas Desulfurization By-Products in Underground Mines

Quarterly Report

July 1 - September 30, 1996

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**MANAGEMENT OF DRY GAS DESULFURIZATION
BY-PRODUCTS IN UNDERGROUND MINES**

Technical Progress Report -- July 1, 1996 - September 30, 1996

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SECTION 1

INTRODUCTION AND SUMMARY

MANAGEMENT OF DRY GAS DESULFURIZATION BY-PRODUCTS IN UNDERGROUND MINES

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INTRODUCTION AND SUMMARY

On September 30, 1996, the U.S. Department of Energy-Morgantown Energy Technology Center (DOE-METC) and Southern Illinois University at Carbondale (SIUC) entered into a cooperative research agreement entitled "Management of Dry Flue Gas Desulfurization By-Products in Underground Mines" (Contract DE-FC21-93MC 30252). Under the agreement SIUC will develop and demonstrate two technologies for the placement of coal combustion by-products in abandoned underground coal mines, and will assess the environmental impact of these technologies for the management of coal combustion by-products. The two technologies for the underground placement that will be developed and demonstrated are: (1) pneumatic placement, using virtually dry materials, and (2) hydraulic placement, using a "paste" mixture of materials with about 70% solids.

Phase II of the overall program began April 1, 1996. The principal objective of Phase II is to develop and fabricate the equipment for both the pneumatic and hydraulic placement technologies, and to conduct a surface demonstration-test of both technologies.

During the current quarter the main thrust was to develop the equipment necessary for the program. Shop drawings were completed for the pneumatic placement equipment, and purchase orders issued for many of the component parts. The final pneumatic placement system will be assembled in the SIUC Carterville facility.

Mr. Fred Brackebusch, consultant for the hydraulic placement portion of the program, visited SIUC in September, to assist in the final configuration of the hydraulic placement system. Along with others, Mr. Brackebusch visited the mixing plant located at the Coffeen electric power plant, which the program was negotiating to purchase. Mr. Brackebusch pronounced the mixing plant very well suited for use in the hydraulic placement.

Readings continued to be taken on the subsidence monuments installed at the Peabody Mine No. 10 demonstration site, to establish a baseline data set for surface subsidence. Also, water samples were taken from the monitoring wells, again to establish baseline data for future use in evaluating the environmental impact of the underground placement.

Project personnel furnished Peabody Coal Company analytical data and written program descriptions for use in applying for a permit from the Illinois Environmental Protection Agency for the surface demonstrations. It is anticipated that the permit will be issued early in the next quarter.

A draft of a topical report on Material Handling and System Economics was prepared during the quarter. A final topical report should be complete during the next quarter.

Also, considerable effort was devoted to preparing material for the presentation at the DOE-METC Mine Emplacement Meeting, to be held in Lexington, Kentucky on October 21-22, 1996. Several persons involved in the program will be attending the meeting.

SECTION 2

ENVIRONMENTAL CHARACTERIZATION

**DR. BRADLEY PAUL
CO-PRINCIPAL INVESTIGATOR**

MANAGEMENT OF DRY GAS DESULFURIZATION BY-PRODUCTS IN UNDERGROUND MINES

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ENVIRONMENTAL CHARACTERIZATION

Progress this Quarter

The work this quarter falls into three areas.

- 1- Developing Data for Permits
- 2- Data Evaluation
- 3- Equipment Design

Peabody Coal Company is currently in the process of obtaining permits for the surface demonstration test of dry FGD byproduct placement systems. The permit for the deep injection has been in place for some time. The surface demonstration faces issues that were not a problem for underground placement as the surface material is above a sandy surface aquifer with higher quality groundwater, whereas the deep underground placement is in extremely tight formations where the groundwater is a brine. Permitting the surface demonstration may in fact be a very significant part of the total demonstration because in addition to disposal of FGD byproducts the system being developed at SIU is designed to alleviate mine subsidence. There are large areas in Illinois and adjoining states where, relatively near surface underground workings threaten expanding suburbs. The preliminary cost data for the SIU placement system potentially indicates far lower costs (about an order of magnitude) for mine stabilization than the grouted backfills that comprise current remediation technology. If the technology and cost live up to their promise there may be significant market potential for this application of FGD byproducts provided that environmental and permitting hurdles can be cleared. Several shake tests and special follow-up analysis were part of the permit work.

The data on the leaching and composition of the pneumatic and hydraulic mixes has been evaluated primarily with respect to the identification of environmental issues. Trace elements do not appear to be a problem for most settings because dilution and attenuation of most surface water systems would be more than adequate to bring leachate from the FGD byproduct mixes into compliance with drinking water standards. Shake tests specify either fine grained or crushed material exposing reactive surface area far larger than would be available for the cemented masses that would develop when the pneumatic and hydraulic mixes are placed underground. Even under unrepresentatively fine conditions, most trace elements meet drinking water standards right out of the shake test apparatus. Those few that do not usually exceed them only by a few parts per billion. For deeper injection into tight rock formations containing low quality groundwater, most states (including Illinois) would have little trouble with any shake test values. If more open near surface aquifers containing high quality waters are contacted the open flow systems would rapidly dilute any trace metal concentration.

SECTION 3

**MATERIALS HANDLING AND SYSTEM
ECONOMICS**

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MANAGEMENT OF DRY GAS DESULFURIZATION BY-PRODUCTS IN UNDERGROUND MINES

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MATERIALS HANDLING AND SYSTEM ECONOMICS

Objectives

The objectives of the materials handling research are: 1) To identify the systems that are technically, economically, and environmentally feasible in handling and transporting the coal combustion by-products from the power plant to the injection site, 2) To demonstrate the operation of one or two of the identified systems.

The objectives of the system economics research are: 1) To conduct economic analyses of the selected materials handling and underground residue placement systems, and 2) To develop a generalized "Economic Evaluation" model that can be used in evaluating various types of materials handling and placement systems for different distances and tonnages.

The term "materials handling" in this research project includes loading, transporting, unloading, and temporary storage of the dry coal combustion by-products for the purpose of disposing them into abandoned areas of the underground coal mines in Illinois. Materials handling systems have been analyzed in four consecutive modules: 1) storage, handling and loading of the residues at the plant site, 2) transportation from the plant to the mine site, 3) unloading, handling and storage at the mine site, and 4) transportation from the mine site to the injection site.

In the past, several transportation and handling technologies were evaluated. These technologies can be classified under two categories:

1. Existing Technologies:

- 1.1 Pneumatic Trucks (PT)**
- 1.2 Pressure differential rail cars (PD-car)**
- 1.3 Open Hopper Coal Cars
- 1.4 Tarped Rear-Dump Trucks
- 1.5 Bottom-Dump Container Trucks

2. Adaptable and Futuristic Technologies:

- 2.1 Collapsible Intermodal Containers (CIC)**
- 2.2 Cylindrical Intermodal Tanks (CIT)**
- 2.3 Intermodal Steel Containers
- 2.4 Coal Hopper Cars with Automatic Retractable Tarping
- 2.5 Covered Hopper Cars - Grain Cars

The first two technologies in each category were found to be environmentally friendly, and, therefore, operating policies for these technologies were developed and engineering and economic analyses were conducted.

Summary of Activities

During the quarter, the major activity was the writing of a topical report in materials handling and systems economics. A first draft of this report was completed. Also in this quarter, some further fine tuning in the developed software were accomplished. Hypothetical cases that are applicable to southern and central Illinois were generated and evaluated using the latest version of the software. In addition, a case study was conducted for the Peabody No. 10 mine which is the future site of the hydraulic and pneumatic placement demonstrations. In the following section, the outcomes of the hypothetical case studies and the Peabody No. 10 mine case will be summarized. The details of these studies were given in the topical report.

Hypothetical Cases

In southern and central Illinois, annual by-product production range between 50,000 to 200,000 tons, and typically plants are 30 to 200 miles away from underground mines. Therefore, all evaluations were conducted for distance-tonnage combinations within these ranges. Using the developed software, cost-per-ton figures were calculated for cases of 50,000 tons, 100,000 tons, and 200,000 tons annual by-product. The distances of transportation considered for each annual tonnage were 30, 100, and 200 miles, respectively. Therefore, nine runs were conducted for each of the four selected transportation and handling technologies, namely; PT, PD-car, CIC and CIT.

The outcomes of the evaluations are shown in Figures 3.1, 3.2, and 3.3. The cost-per-ton values shown in these figures reflect the costs of transportation, handling, and pneumatic placement of the by-products. As seen, at production rates of 50,000, 100,000, and 200,000 tons, the PT alternative gave lower costs than the other alternatives for distances up to 125, 100, and 70 miles, respectively. At 50,000 tons, the PD-car and the CIT technologies indicated almost the same cost for all distances, and they were better than the CIC alternative up to a distance of approximately 140 miles. At 100,000 tons, the PD-car, the CIT, and the CIC technologies indicated almost the same cost up to a distance of 100 miles, after which the CIC technology gave lower costs than the first two. At 200,000 tons, the picture was almost identical to that of 100,000 tons, except that the CIC alternative became better than the CIT and PD-car technologies after 70 miles.

Case Study

Under the cooperative research program, Peabody No. 10 mine in Pawnee, Illinois, is the site for underground placement demonstration. To enhance this demonstration, it is decided to use the latest version of the developed software to conduct an engineering design and economic analysis specifically for this site.

Pneumatic and hydraulic placement systems developed in the cooperative research program will be demonstrated at this site. The source of FBC fly ash and spent-bed ash for the pneumatic placement will be the Archer Daniel Midland Company (ADM) power generating plant at Decatur, Illinois. The source of scrubber sludge and fly ash for the hydraulic placement will be City Water, Light and Power (CWLP) Company Dallman plant in Springfield Illinois. The locations of these two plants and the Peabody No. 10 mine are shown in Figure 3.4 below. As seen, the mine is about 25 miles south of Dallman Plant and 65 miles southwest of ADM Plant. Concurrent with the findings in the hypothetical case evaluations discussed above, truck transportation was preferred to others since the distances of both plants to the mine favored trucking.

The following assumptions were made in the evaluation of the case study:

| | |
|--------------------------------|---|
| Transportation mode | : trucks |
| Placement technology | : pneumatic for by-product coming from CWLP : hydraulic for by-product coming from ADM |
| Production rate | : 50,000, 100,000, 150,000 tons |
| Injection through one borehole | : 10,000 tons |
| Project life | : 10 years |
| Effective tax rate | : 40 % |
| Discount rate | : 12 % |

The outcomes of the economic evaluation are shown in Figures 3.5 and 3.6. As seen in Figure 3.5, it would cost about \$6.0 per ton to transport and hydraulically place the by-product from Dallman plant. Similarly, as seen in Figure 3.6, it would cost about \$8.0 per ton to transport and pneumatically place the by-product from ADM plant. The underground placement cost alone was found to be about \$2.50 per ton in both cases, although pneumatic placement cost was slightly lower than the hydraulic placement.

Plans For The Next Quarter

In the next quarter two major tasks will be undertaken:

1. Complete the topical report on materials handling and systems economics,
2. Complete the user's manual for the developed systems economics software.

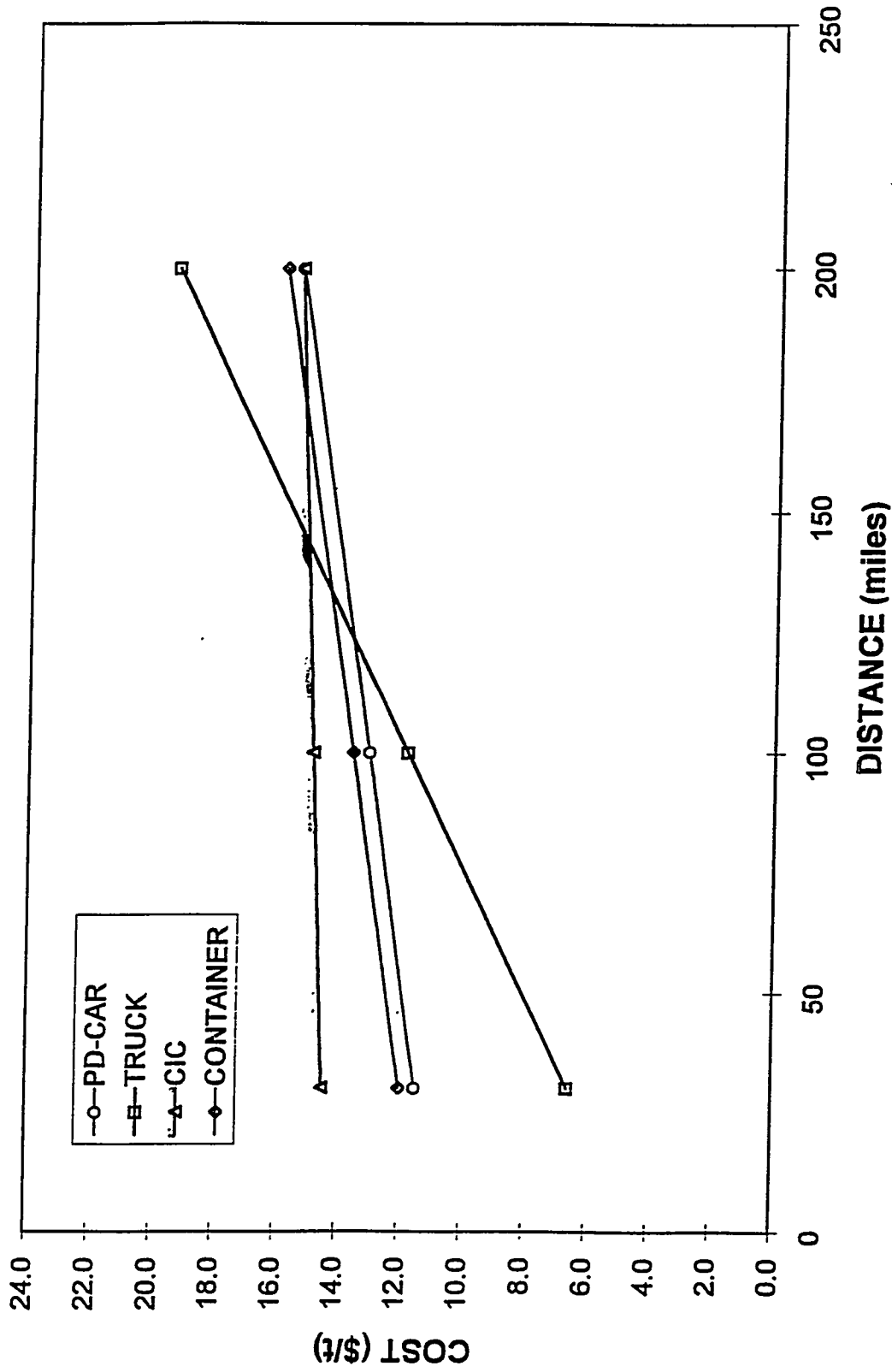


Figure 3.1 Cost-per-ton in four different transportation technology when 50,000 tons of by-product are transported and injected.

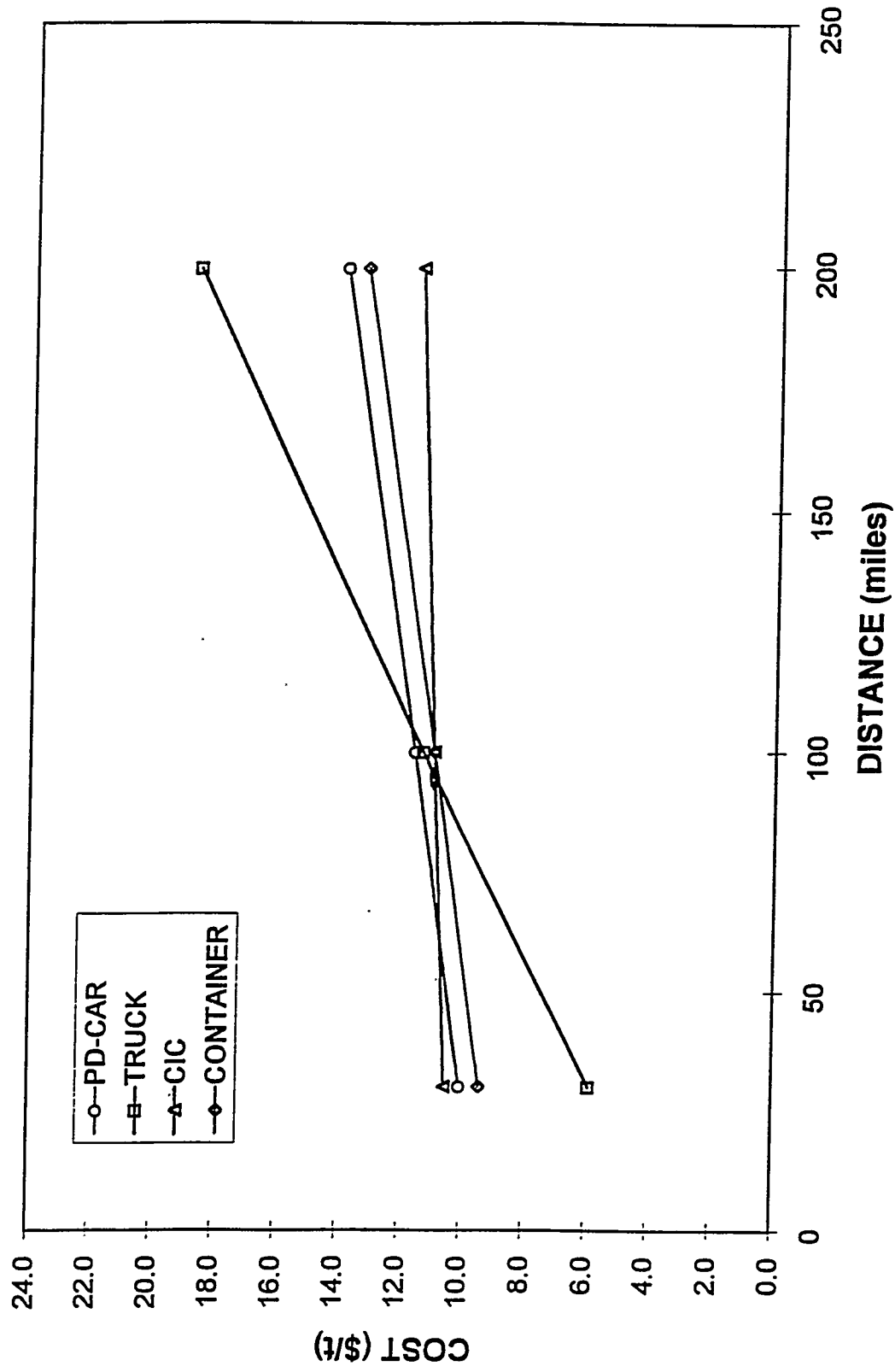


Figure 3.2 Cost-per-ton in four different transportation technology when 100,000 tons of by-product are transported and injected.

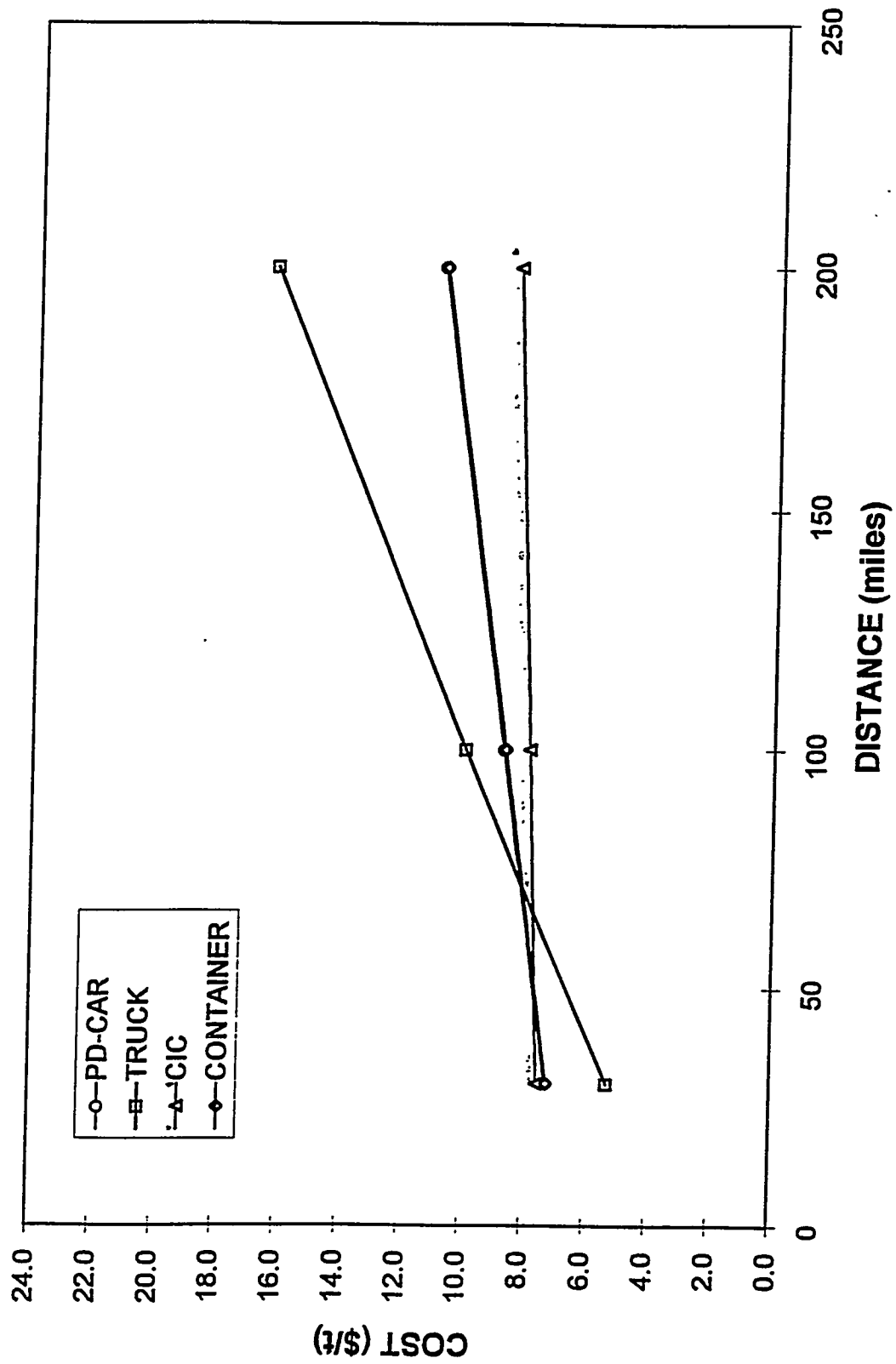


Figure 3.3 Cost-per-ton in four different transportation technology when 200,000 tons of by-product are transported and injected.

10 miles

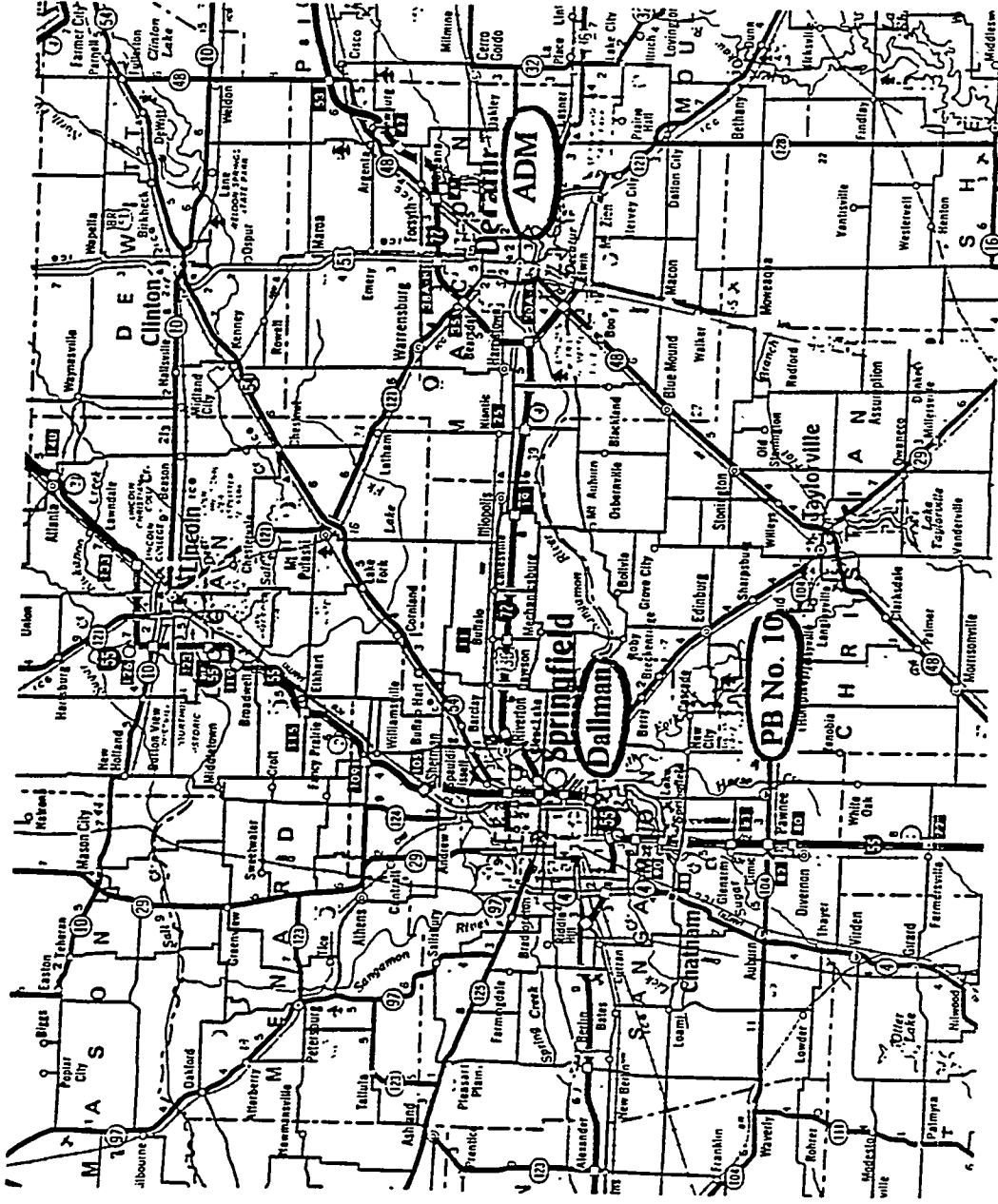


Figure 3.4 Locations of Peabody No. 10 Mine and ADM and Dallman Plants

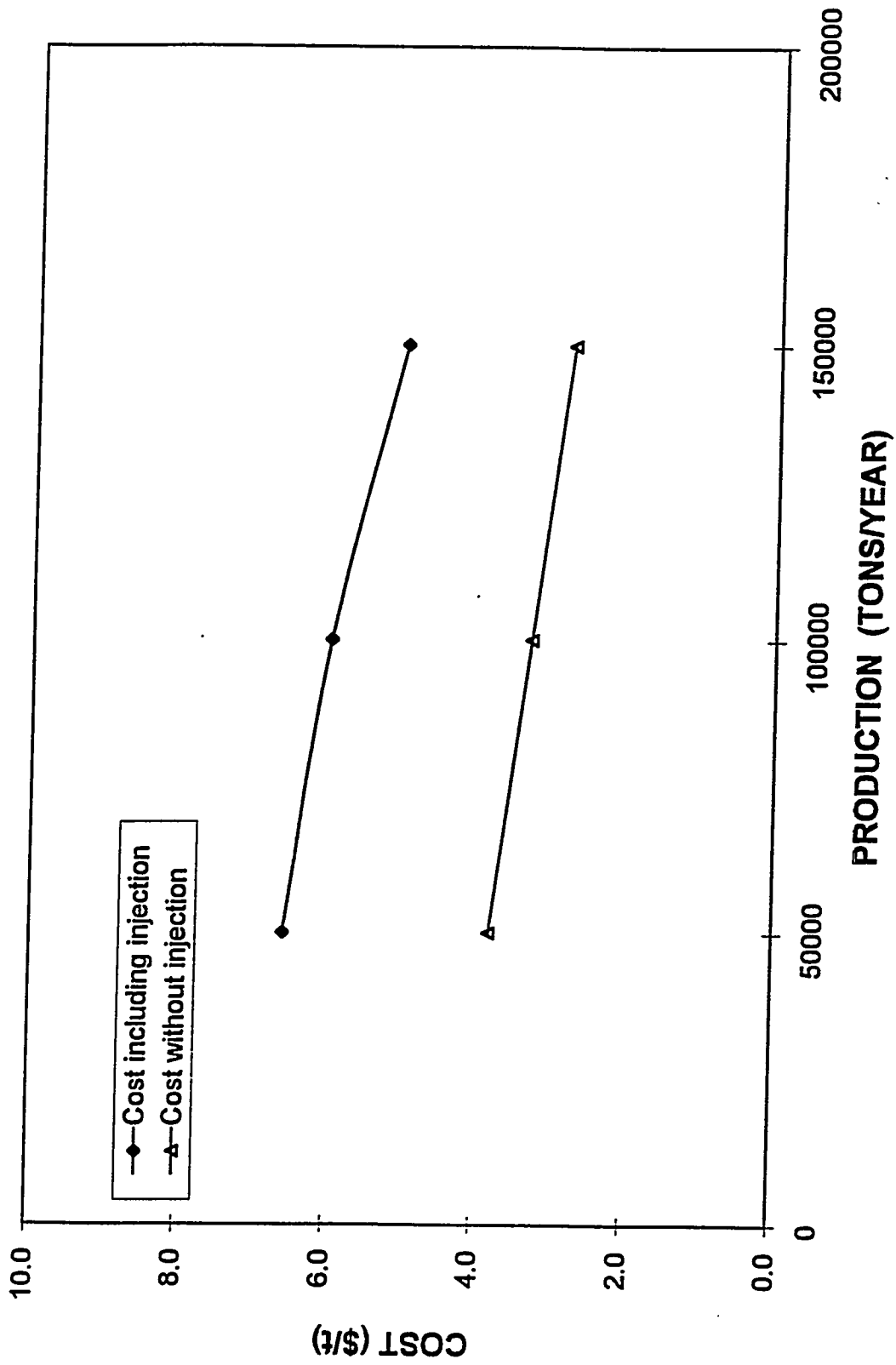


Figure 3.5 Cost-per-ton for by-products transported from Dallman plant to Peabody No. 10 Mine.

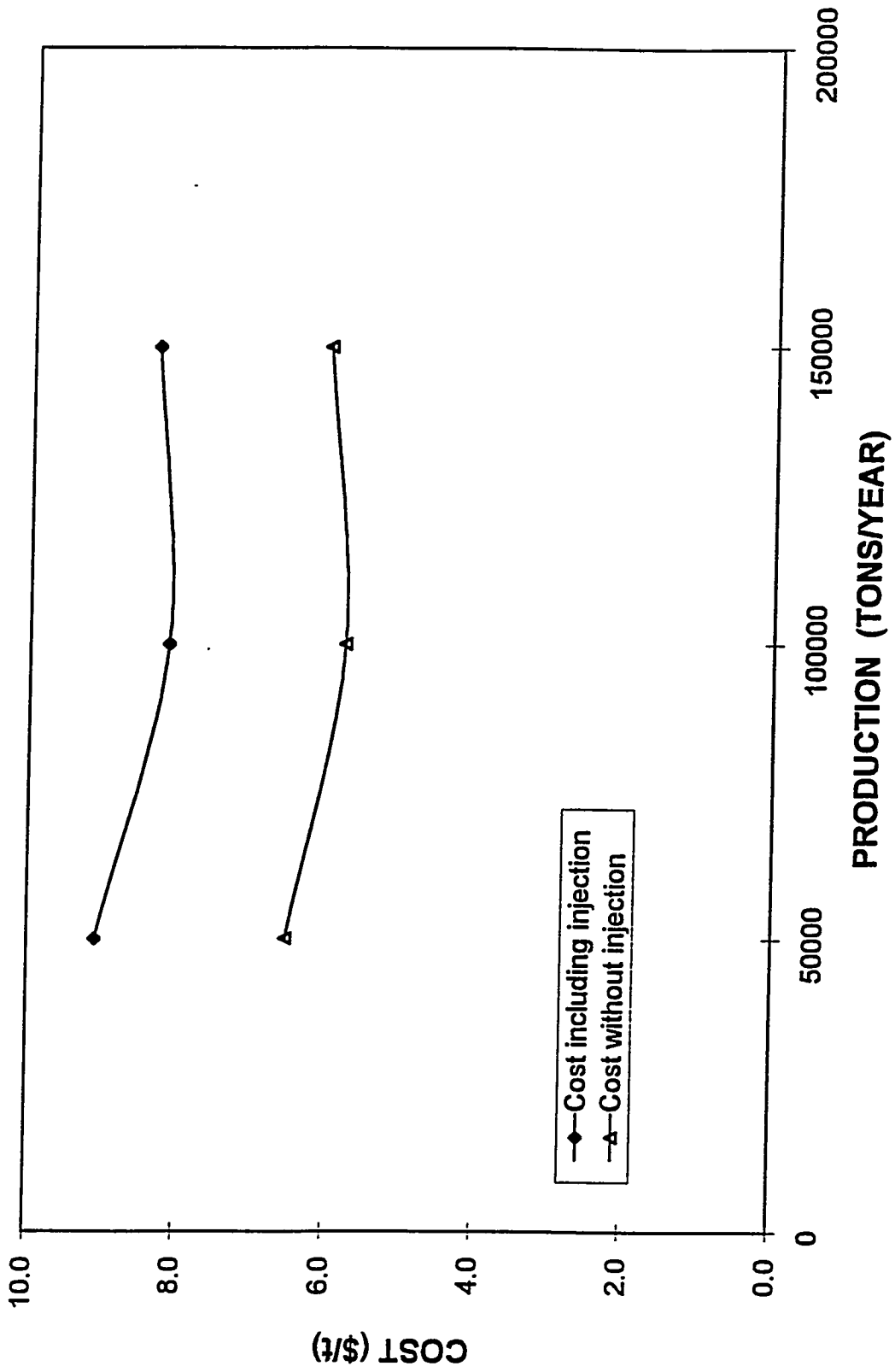


Figure 3.6 Cost-per-ton for by-products transported from ADM plant to Peabody No. 10 Mine.

SECTION 4

**ENVIRONMENTAL ASSESSMENT AND
GEOTECHNICAL STABILITY**

**DR. STEVE ESLING
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MANAGEMENT OF DRY FLUE GAS DESULFURIZATION BY-PRODUCTS IN UNDERGROUND MINES

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ENVIRONMENTAL ASSESSMENT AND GEOTECHNICAL STABILITY AND SUBSIDENCE IMPACTS

Accomplishments

Researchers from SIUC and the ISGS involved with the Environmental Assessment portion of the project continued groundwater monitoring during the last quarter. Wells were sampled in July, August, and October. In addition, water quality analyses are available for samples collected in June. Appendix A summarizes depths to water taken during the study. Appendix B lists the cation and anion concentrations in the well samples as determined by the ISGS Geochemistry Laboratory. Well development by circulating potable water down the well casings just after installation of the monitoring wells has influenced initial groundwater quality. Recent data suggest that the impact of the well development is diminishing, as the concentration of major constituents appears to have stabilized. The water in the units bounding the target panels is a nonpotable brine.

The researchers have also been debugging the data logger programs to take reliable readings from the pressure transducers.

Plans

Plans for the next quarter include continued monitoring of hydraulic head and groundwater chemistry at the study site. In addition, well and equipment damaged by a truck accident at the mien will be repaired. Plans are being considered to sample other wells at the site.

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GEOTECHNICAL STUDIES

Abstract

Geotechnical studies in Phase II of the project concentrate on measurements of surface and sub-surface movements over the proposed injection panels. Laboratory studies of long-term swelling strain measurements of pneumatic mixes is underway. Any additional laboratory studies will depend on the need for additional data that may be required for assessing the effectiveness of backfilling. During the surface demonstration in Phase II, freshly prepared hydraulic mixture samples will be tested for slump. Samples will also be collected for strength testing in the laboratory. In-situ strength of the hydraulic mixture as placed in the trench during the surface demonstration will be monitored using a field penetrometer.

Surface Subsidence Measurements

Sixty-six (66) surface subsidence monuments were installed over the two (2) injection panels to monitor the surface movements prior to underground placement. Figure 5.1 shows the grid employed to install the subsidence monuments.

Baseline measurements of surface subsidence monuments were taken in March, 1996. Figures 5.2 and 5.3 show the measured subsidence over a six-month period. Six months data show movements within the error band (± 3 mm including measurement errors). Underground roof-to-floor convergence measurements in Phase I of the program indicated approximately 0.5 inches of convergence per year. Thus translates to 0.17 inches (or 4.2 mm) of surface movements per year. The surface movement data over a period of six-months is consistent with the underground measured underground roof-to-floor convergence data.

For baseline measurement, the sonic probe was introduced in the two subsurface measurement boreholes. The probe in the boreholes over hydraulic and pneumatic panels could be lowered only 282 ft. and 248 ft. from the surface respectively, indicating that the geotechnical boreholes collapsed after the installation of the settlement sensors. No readings could be taken from these two boreholes as the sensors are located at a depth between 290 ft and 340 ft below the surface, well below the collapsed region. However, the elevation of the top of the steel casing of the geotechnical boreholes are being measured by the autotset level.

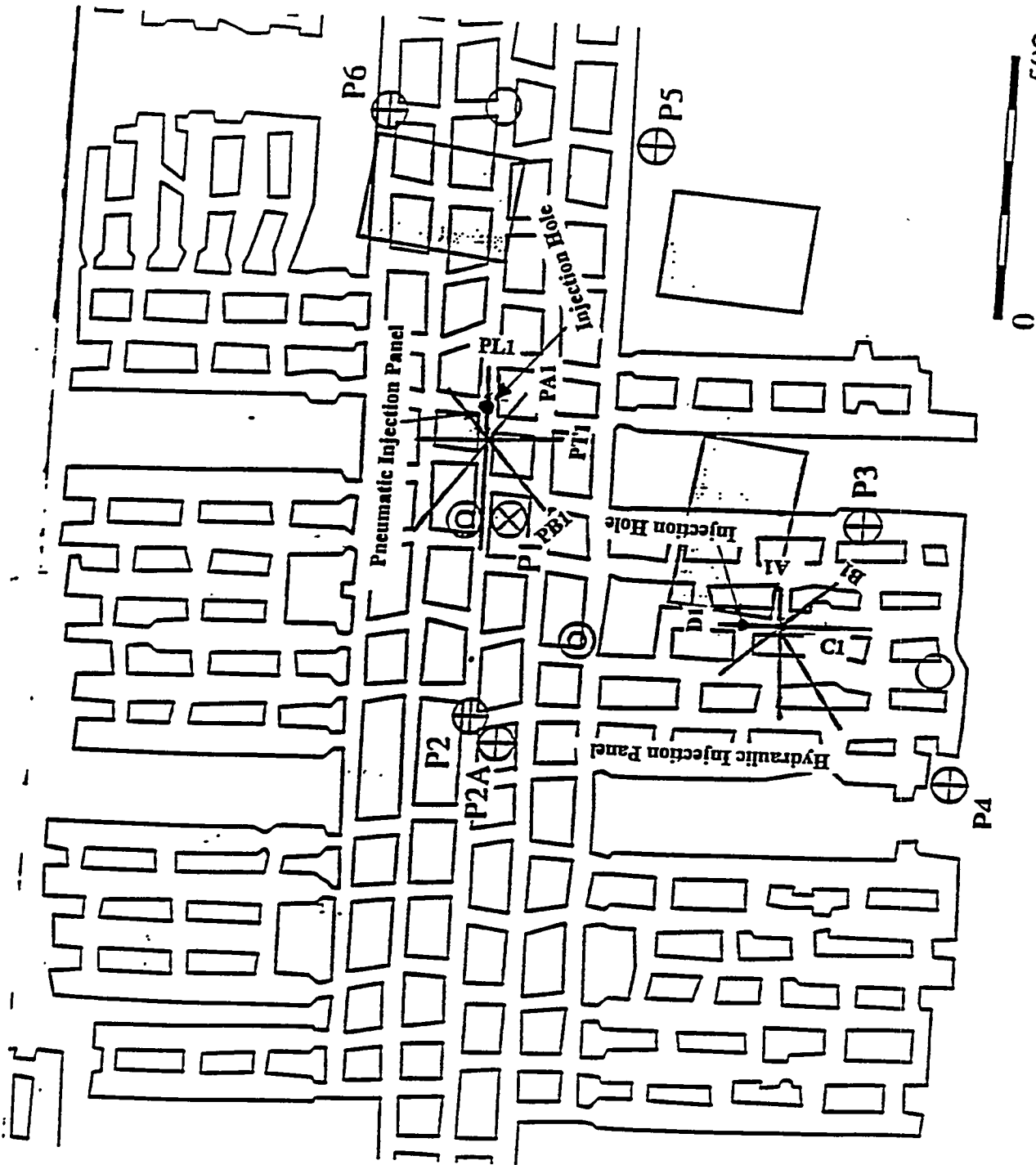


Figure 5.1 Locations of subsidence grids over injection panels.

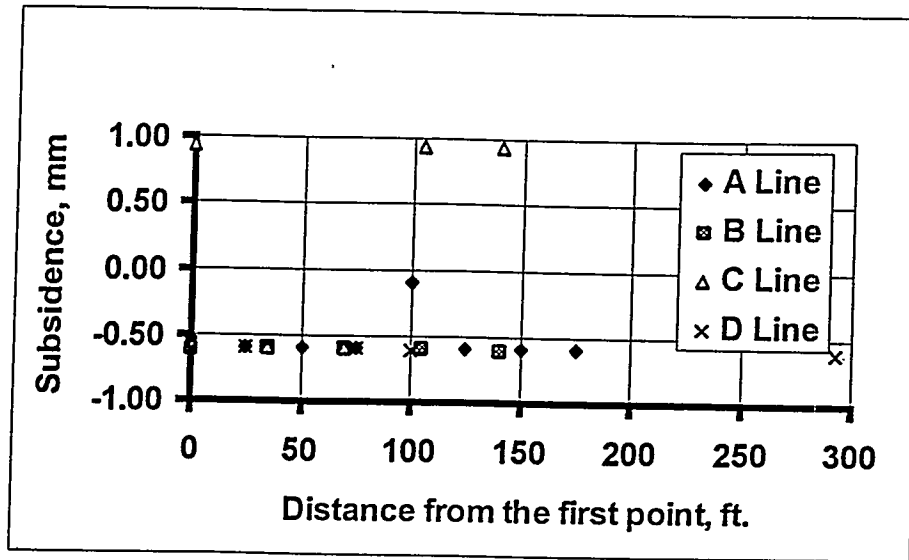


Figure 5.2 Measured subsidence over hydraulic injection panel.

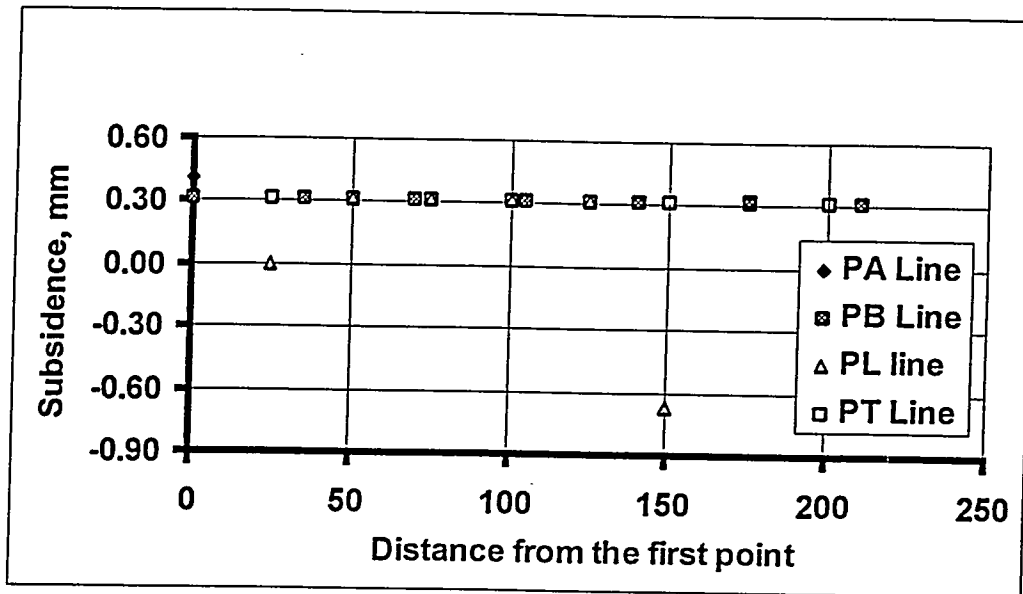


Figure 5.3 Measured subsidence over pneumatic injection panel.

Long-term Swelling Strain Measurements

Three samples of pneumatic mix with 80% FBC fly ash and 20% spent bed ash were monitored for long-term free swelling strain. Figure 5.4 shows the schematic of the measurement apparatus. The plastic container was filled with water after placing the sample in the container. The swelling of the sample was measured using a dial gauge (shown in Figure 5.4). Figure 5.5 shows the average swelling strain of the three samples. Average swelling strain after 36 days is approximately 1%. Because the samples were made using preconditioned FBC fly ash, the observed long-term swelling strain was low.

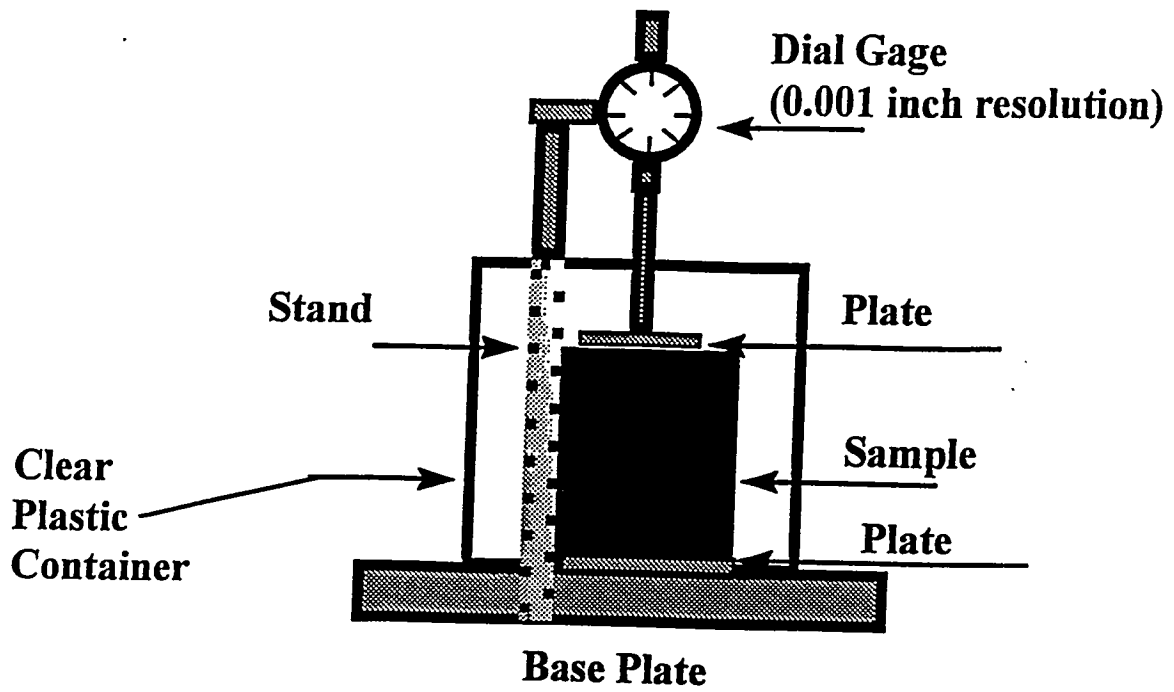


Figure 5.4 Schematic of experimental setup for swelling strain measurement.

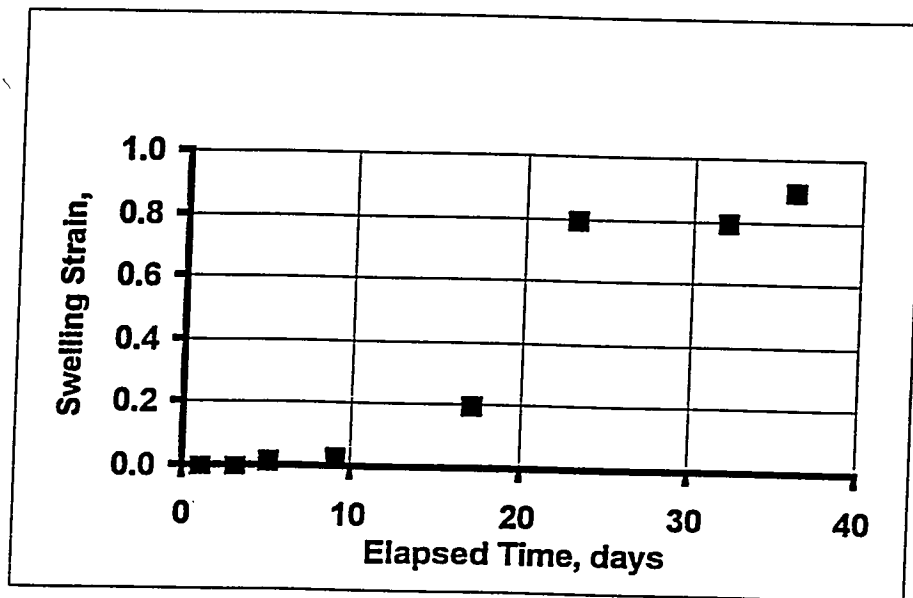


Figure 5.5 Long-term swelling strain of pneumatic mix.

SECTION 6

UNDERGROUND PLACEMENT

Yoginder P. Chugh - Co-Principal Investigator
Eric R. Powell - Pneumatic Placement Consultant
Fred Brackebusch - Hydraulic Placement Consultant

MANAGEMENT OF DRY GAS DESULFURIZATION BY-PRODUCTS IN UNDERGROUND MINES

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UNDERGROUND PLACEMENT

Introduction

Emphasis this quarter has been on the arrangements for the material preparation, i.e., mixing fly ash and spent bed components and mixing the fly ash with water for conditioning. Shop fabrication drawings of the injection equipment were completed, instrumentation and recording equipment for the demonstration were selected, and purchase orders issued for the balance of these items. As a result of the change in policy to purchase rather than rent the major items of the mixing and conditioning equipment, it became necessary to request the previously selected steel fabrication shops to re-submit their bids.

Hydraulic Placement Technology

The conditioning of fly ash with water, and the mixing of the combination of fly ash and spent bed material for the pneumatic injection was considered best undertaken in a pug mill. This is the normal practice in power plants that condition fly ash prior to transporting it to land fill sites. As the hydraulic past backfill material also has to be thoroughly mixed, the possibility of a mixing plant suitable for both pneumatic and hydraulic injection was investigated. Manufacturers of mixing equipment were contacted to obtain estimated leasing costs of both paddle mixers and pug mills. A visit was made to the test facilities of the United Conveyor Corporation in Waukegan, Illinois. The company specializes in the manufacture of ash handling equipment, including ash conditioners. A sample of fly ash and scrubber sludge was mixed in their laboratory mixer, with inconclusive results.

Contacts with the mixer manufacturers indicated that new mixers are virtually impossible to obtain on a short-term (i.e., less than one year) lease, as would be required under the program. Also, the delivery time for a new mixing plant was greater than the program could tolerate, and the cost of a new mixing plant for purchase exceeded budget projections. It also became apparent that support equipment such as hoppers, belt conveyors with weight scales, controls, and recording equipment are not readily available for rent or lease. Considering both the cost and delivery time factors, it appeared that the purchase of used equipment, wherever possible, was the most viable option. Several suppliers of used equipment were contacted, but none had the needed equipment readily available.

A complete used mixing plant owned and operated jointly by Montgomery and Macoupin Counties became available for sale following the last mix of material. The counties had used the plant for several years to mix coal combustion by-products for the CIPS Coffeen power plant for use in road construction and repair. For various reasons, the counties wished to cease mixing their own road materials and sell the plant. The last mix by the plant was planned for the end of

August. Several visits were made to thoroughly inspect the plant, including one visit when the plant was in operation. Also, during his visit in early September, Mr. Fred Brackebusch visited the plant. Mr. Brackebusch is the consultant for hydraulic placement, and during his visit he agreed with other program personnel that the plant was quite suitable for use in preparing the hydraulic mix for injection.

By the end of September negotiations were complete and the plant had been purchased. The plant was designed to mix fly ash, lime, slag, and water, and conveyor belts are either speed controlled or equipped with weigh scales. Water for mixing is supplied by a pump with a flow control valve. All functions report to a computer unit from where the operator can make instant changes in the composition of the mixture. As noted above, the plant is well suited for use in the program, although some minor modifications will be necessary. The plant will be disassembled, moved to the Peabody Mine No. 10 demonstration site, and reassembled. The necessary modifications will be made to allow greater retention time in the pug mill, thus giving a better mix of the component ingredients. Also, the slag hopper/conveyor will be repositioned to handle scrubber sludge.

During September the search continued for several other pieces of equipment necessary for the hydraulic injection. A high-pressure concrete pump was located near the end of the quarter, but arrangements for its lease or purchase had not been completed. Also, a large (12 ft. diameter by 12 ft. high) slurry tank with a mixing agitator is essential for the hydraulic placement package. At the end of the quarter a suitable tank had not been located, although several sources were being investigated.

Pneumatic Placement Technology

Shop drawings of the components for the pneumatic injection system were complete at the end of the quarter, and a steel fabricator had been selected to undertake the work. Purchase orders were pending in the University procurement office.

Smaller items (valves, hydraulic lines, etc.) were on order or had been delivered by the end of the quarter. Fabrication of the larger items referred to above have a delivery time of approximately six weeks; thus final assembly of the pneumatic injection system cannot be undertaken until the larger items are delivered.

Instrumentation of the pneumatic system variables such as material capacity, air pressure, air flow, water pressure, and water flow have been selected; however, further consideration is needed to develop the recording system to be used.

Peabody Coal Company Mine No. 10 Demonstration Site

Although Peabody Coal Company is in the process of transferring operations at the Mine No. 10 property to the Pawnee Capital Group, L.L.C. ("Pawnee"), Peabody will continue to act as the sub-contractor to the program. Pawnee will be actively engaged in the day to day operation of the surface demonstration-test and the underground placement program. Several meetings were held with senior management of Pawnee and Peabody, both at the University and

at the mixing plant in Coffeen. Both the pneumatic and hydraulic injection technologies were explained in detail to the Pawnee management, so that they have an understanding of the support services required. This included the provision of loading equipment, location of the surface demonstration test trenches and trench cover arrangements, and water supply for the mixing process.

SECTION 7

**STEEL INTERMODAL CONTAINER
DEVELOPMENT**

**Mr. Gary Wangler
Researcher**

MANAGEMENT OF DRY GAS DESULFURIZATION BY-PRODUCTS IN UNDERGROUND MINES

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STEEL INTERMODAL CONTAINER DEVELOPMENT

Abstract

During the quarter work on the steel intermodal container development program concentrated on modifications of the floor design on the large (3" = 1' scale) wooden model. However, a design which combines ease of emptying and economical modification of full size steel intermodal containers has yet to be developed.

End-Dump of Container

Tilting the model to simulate a mechanical lift similar to a standard dump truck was tried using the large model (24 inches wide, 24 inches high, and 60 inches long – scale 3 inches = 1 foot), with the tilt being at various angles. End dumping from the model tends to create unacceptable levels of fugitive dust, and it is believed the same situation will occur in the full-size container. However, dust control technologies may be applied, and end dumping may be feasible in some circumstances. Work and experimentation needs to be continued to develop the most efficient and economical end-dump technology.

Floor Design

Laboratory model experimentation has indicated that, in order to successfully empty the SIC using vacuum equipment, it may be necessary to aerate the fly ash in the SIC while vacuuming. A recognized technology for aerating fine materials is the use of aeration cloth floors or air slides. A sample of aeration cloth was obtained, and the model configured for its use. A false floor was built into the model, about two inches above the original floor, the false floor consisting of a frame covered with the aeration cloth. The area between the original floor and the false floor was used to inject low-pressure air into the system.

Several tests were conducted with this floor design. In one test, forty pounds (40 lbs.) of fly ash was loaded into the container. As air was injected into the area between the floors, it "bubbled" through the aeration cloth and the fly ash load. In doing so it moved the fly ash to a low area of the model container, where it could be easily emptied with vacuum equipment.

In a second test, about 120 pounds of fly ash was placed in the SIC, and the test with the aeration cloth floor repeated. The fly ash had remained in the SIC over a weekend, to more accurately simulate conditions that may be encountered in actual practice. In this case, the use of the aeration cloth floor with the low-pressure air failed to aerate the fly ash load sufficiently to permit emptying the SIC with vacuum equipment. It is believed that two factors affected the test:

permit emptying the SIC with vacuum equipment. It is believed that two factors affected the test: (1) the aeration cloth floor was not sealed tightly enough, thus allowing air to escape through leaks rather than through the aeration cloth; and (2) the volume of air used to aerate the fly ash was insufficient.

During the next quarter, a few concepts are proposed to be developed in cooperation with Wilson Manufacturing Company and Illinois Central Railroad. Technically and economically viable concepts will be discussed with the U.S. Department of Energy prior to implementation.

Appendix A
Water Level Data

| Well nest | 2A | 2A | 2A | 3 | 3 | 4 |
|--------------------------|-------|---------------|---------|---------|-------------|-------------|
| Screened interval (feet) | 75-80 | 213.25-218.25 | 340-345 | 201-206 | 282.5-287.5 | 343.5-348.5 |
| 9/25/95* | 16.87 | 83.7 | 237.45 | 27.5 | 13.17 | 257.73 |
| 1/8/96 | 21.22 | 82.46 | NW | 42.92 | 23.67 | - |
| 2/6/96 | 14.48 | 73.52 | NW | - | - | 341.43 |
| 2/7/96 | - | - | - | 44.51 | 274.21 | - |
| 3/1/96 | - | - | - | - | 279.18 | 341.77 |
| 3/2/96 | 12.9 | 72.5 | NW | - | - | - |
| 3/11/96 | 15.35 | 72.27 | NW | 47.36 | 282.8 | 344.16 |
| 3/29/96 | 14.37 | 71.54 | NW | 48.25 | 281.95 | 343.13 |
| 4/9/96 | 14.16 | 71.26 | NW | 48.83 | 282.81 | 343.91 |
| 5/7/96 | 14.46 | 70.33 | NW | 49.87 | 281.49 | 342.48 |
| 5/15/96 | 14.36 | 70.07 | NW | 49.97 | NW | 343.61 |
| 6/10/96 | - | - | - | 50.36 | 282.14 | 342.69 |
| 6/11/96 | 14.33 | 69.36 | NW | - | - | - |
| 6/23/96 | 14.09 | 69.25 | NW | 48.81 | NW | 343.44 |
| 7/18/96 | 14.65 | 68.90 | NA | 49.33 | NA | NA |
| 7/26/96 | 14.80 | 68.80 | NW | 49.51 | NW | 314.33 |
| 8/23/96 | 14.82 | 68.42 | NA | ** | ** | NA |
| 8/30/96 | 14.78 | 68.36 | NA | 51.95* | 283.28* | NA |
| 10/2/96 | 14.64 | 68.02 | NW | ** | ** | NW |
| 10/12/96 | 14.65 | 67.99 | NW | ** | ** | 344.99 |

| Well nest | 5 | 5 | 5 | 6 | 6 | 6 |
|--------------------------|-------|---------|---------|-------|-------------|---------|
| Screened interval (feet) | 73-78 | 215-220 | 337-342 | 71-76 | 216.5-221.5 | 311-316 |
| 9/25/95* | 8.1 | 18.9 | 66.7 | 16.18 | 48.85 | 260.4 |
| 1/8/96 | - | - | - | - | - | - |
| 2/6/96 | 4.12 | 65.23 | N/A | 10.84 | 13.77 | NW |
| 2/7/96 | 4.56 | 83.94 | 313.44 | 13.4 | 21.47 | 312.77 |
| 3/1/96 | - | - | - | - | - | - |
| 3/2/96 | 3.38 | 55.13 | 326.4 | 11.1 | 25.8 | NW |
| 3/11/96 | N/A | N/A | N/A | N/A | N/A | NW |
| 3/29/96 | 3.34 | 64.37 | NW | 10.79 | 27.67 | NW |
| 4/9/96 | 35.2 | 64.17 | NW | 10.28 | 28.29 | NW |
| 5/7/96 | N/A | N/A | N/A | N/A | N/A | N/A |
| 5/15/96 | 2.75 | 62.89 | 325.84 | 10.31 | 30.16 | NW |
| 6/10/96 | - | - | - | - | - | - |
| 6/11/96 | 3.86 | 64.66 | 325.24 | 10.18 | 31.82 | NW |
| 6/23/96 | 4.19 | 62.31 | 325.26 | 10.03 | 25.21 | NW |
| 7/18/96 | 4.31 | 62.93 | NA | 9.45 | 26.28 | NA |
| 7/26/96 | 4.38 | 42.33 | NW | 9.24 | 26.55 | NW |
| 8/23/96 | 3.96 | 63.36 | NA | 9.33 | 27.59 | NA |
| 8/30/96 | 4.30 | 62.87 | NA | NA | NA | NA |
| 10/2/96 | 4.34 | 64.33 | NW | 9.36 | 28.87 | NW |
| 10/12/96 | 5.93 | 63.32 | 327.44 | 9.62 | 29.12 | NW |

N/A Indicates broken tape measure.

NW Indicates no measurable water level.

* Measuring tape not fully labeled so there is a greater, and unknown error with these readings.

- No measurement taken on this date.

Appendix B

Water Quality Data

| | | | | | | | | | | | | |
|--------|---------|--------|-------|------|-------|-------|-------|-------|-------|-------|-------|-------|
| Lab # | Date | Well # | Al | As | B | Ba | Be * | Ca | Cd | CO | CR | CU |
| W01003 | 2/6/96 | 4 | <0.02 | <0.1 | 0.42 | 0.14 | <2 | 39.7 | <0.01 | <0.01 | <0.01 | <0.01 |
| W01005 | 2/6/96 | 5 | 0.29 | <0.1 | 0.42 | 1.73 | <2 | 115 | <0.01 | <0.01 | <0.01 | <0.01 |
| W01006 | 2/7/96 | 3 | 0.11 | <0.1 | 0.54 | 0.37 | <2 | 10.1 | <0.01 | <0.01 | <0.01 | <0.01 |
| W01004 | 2/7/96 | 4 | <0.02 | <0.1 | 0.4 | 0.12 | <2 | 38.8 | <0.01 | <0.01 | <0.01 | <0.01 |
| W01007 | 2/7/96 | blank | <0.02 | <0.1 | <0.02 | <0.02 | <2 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| W01063 | 3/10/96 | 3 | 0.1 | <0.1 | 0.77 | 0.19 | <2 | 14.8 | <0.01 | <0.01 | <0.01 | <0.01 |
| W01064 | 3/10/96 | 4 | 0.03 | <0.1 | 0.51 | 0.14 | <2 | 67.8 | <0.01 | <0.01 | <0.01 | <0.01 |
| W01065 | 3/10/96 | blank | <0.01 | <0.1 | <0.02 | <0.01 | <2 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Lab # | Date | Well # | FE | K | LA * | LI | MG | MN | MO | NA | NI | PB |
| W01003 | 2/6/96 | 4 | 0.02 | 7 | <2 | 0.03 | 12 | 0.09 | 0.03 | 377 | <0.03 | <0.05 |
| W01005 | 2/6/96 | 5 | 0.01 | 224 | <2 | 1.51 | 0.01 | <0.01 | 0.12 | 1605 | <0.03 | <0.05 |
| W01006 | 2/7/96 | 3 | 0.01 | 418 | <2 | 1.22 | 0.02 | <0.01 | 0.13 | 1027 | <0.03 | <0.05 |
| W01004 | 2/7/96 | 4 | 0.01 | 8 | <2 | 0.03 | 12 | 0.08 | 0.02 | 374 | <0.03 | <0.05 |
| W01007 | 2/7/96 | blank | <0.01 | <1 | <2 | <0.01 | <0.01 | <0.01 | <0.02 | <0.1 | <0.03 | <0.05 |
| W01063 | 3/10/96 | 3 | 0.01 | 324 | <2 | 1.02 | 0.01 | <0.01 | 0.11 | 1680 | <0.03 | <0.08 |
| W01064 | 3/10/96 | 4 | 0.04 | 12 | <2 | 0.05 | 20.2 | <0.01 | <0.02 | 705 | <0.03 | <0.08 |
| W01065 | 3/10/96 | blank | <0.01 | <1 | <2 | <0.01 | <0.01 | <0.01 | <0.02 | 0.6 | <0.03 | <0.08 |
| Lab # | Date | Well # | SB | SC * | SE | SI | SR | TI | TL | V | ZN | ZR |
| W01003 | 2/6/96 | 4 | <0.2 | <3 | <0.1 | 1.79 | 0.62 | <0.01 | <0.6 | <0.01 | 0.01 | <0.01 |
| W01005 | 2/6/96 | 5 | <0.2 | <3 | <0.1 | 1.77 | 8.68 | <0.01 | <0.6 | <0.01 | 0.3 | <0.01 |
| W01006 | 2/7/96 | 3 | <0.2 | <3 | <0.1 | 1.79 | 1.54 | <0.01 | <0.6 | <0.01 | 0.01 | <0.01 |
| W01004 | 2/7/96 | 4 | <0.2 | <3 | <0.1 | 1.82 | 0.6 | <0.01 | <0.6 | <0.01 | 0.02 | <0.01 |
| W01007 | 2/7/96 | blank | <0.2 | <3 | <0.1 | <0.01 | <0.01 | <0.01 | <0.6 | <0.01 | <0.01 | <0.01 |
| W01063 | 3/10/96 | 3 | <0.1 | <3 | <0.1 | 2.11 | 1.86 | <0.01 | <0.3 | <0.01 | 0.01 | <0.01 |
| W01064 | 3/10/96 | 4 | <0.1 | <3 | <0.1 | 2.13 | 1.31 | <0.01 | <0.3 | <0.01 | 0.01 | <0.01 |
| W01065 | 3/10/96 | blank | <0.1 | <3 | <0.1 | <0.01 | <0.01 | <0.01 | <0.3 | <0.01 | <0.01 | <0.01 |

| Lab # | Date | Well # | HG * | CL | F | NO3 ** | SO4 ** | Total K *** | Pal K *** | Acid *** |
|--------|---------|--------|-------|------|----|--------|--------|-------------|-----------|----------|
| W01003 | 2/6/96 | 4 | <0.05 | ND | ND | ND | ND | 93.5 | ND | 4 |
| W01005 | 2/6/96 | 5 | <0.05 | 1064 | ND | 0.09 | 81.9 | 2532 | 2418 | ND |
| W01006 | 2/7/96 | 3 | <0.05 | 705 | ND | 0.19 | 250 | 901.3 | 823.1 | ND |
| W01004 | 2/7/96 | 4 | <0.05 | 478 | ND | 0.1 | 214 | 127.6 | ND | 3 |
| W01007 | 2/7/96 | blank | <0.05 | ND | ND | ND | ND | ND | ND | ND |
| W01063 | 3/10/96 | 3 | <0.05 | 1668 | ND | 0.07 | 549 | 1033 | 953 | ND |
| W01064 | 3/10/96 | 4 | <0.05 | 1113 | ND | 0.08 | 291 | 150.9 | ND | 5 |
| W01065 | 3/10/96 | blank | 0.07 | 2.14 | ND | <0.01 | 0.31 | 1 | ND | 2 |

Remarks:

Total K Alkalinity to pH 4.5 as mg CaCO₃/L
 Pal K Alkalinity to pH 8.3 as mg CaCO₃/L
 Acid Acidity to pH 8.3 as mg CaCO₃/L

Analytic Method Codes:

All reported as mg/l except as noted below

- * µg/L, Inductively coupled plasma
- ** mg/L, Ion chromatography
- *** mg/L, Titrimetric
- ND No detection

| | | | | | | | | | | | | |
|--------|---------|--------|-------|------|-------|-------|-------|-------|-------|-------|-------|-------|
| Lab # | Date | Well # | Al | As | B | Ba | Be * | Ca | Cd | CO | CR | CU |
| W01122 | 4/9/96 | 3 | 0.1 | <0.1 | 0.77 | 0.14 | <1 | 20.2 | <0.01 | <0.01 | <0.1 | <0.01 |
| W01123 | 4/9/96 | 4 | 0.04 | <0.1 | 0.58 | 0.14 | <1 | 97.6 | <0.01 | <0.01 | <0.1 | <0.01 |
| W01229 | 5/15/96 | 3 | 0.04 | <0.1 | 0.78 | 0.13 | <1 | 19.4 | <0.1 | <0.1 | <0.1 | 0.01 |
| W01228 | 5/15/96 | 4 | <0.2 | <0.1 | 0.66 | 0.15 | 1 | 118 | <0.1 | <0.1 | <0.1 | 0.01 |
| W01230 | 5/15/96 | blank | <0.2 | <0.1 | <0.01 | <0.01 | <1 | 0.02 | <0.1 | <0.1 | <0.1 | <0.01 |
| W01363 | 6/23/96 | 3 | 0.05 | <0.1 | 0.78 | 0.13 | 1 | 23 | <0.1 | <0.1 | <0.1 | <0.01 |
| W01362 | 6/23/96 | 4 | 0.04 | <0.1 | 0.82 | 0.16 | 2 | 168 | <0.1 | <0.1 | <0.1 | 0.01 |
| W01364 | 6/23/96 | 5 | 0.24 | <0.1 | 0.27 | 4.78 | 2 | 328 | <0.1 | <0.1 | <0.1 | <0.01 |
| W01365 | 6/23/96 | blank | <0.2 | <0.1 | <0.02 | <0.01 | <1 | 0.06 | <0.1 | <0.1 | <0.1 | <0.01 |
| Lab # | Date | Well # | FE | K | LA * | LI | MG | MN | MO | NA | NI | PB |
| W01122 | 4/9/96 | 3 | 0.03 | 255 | <2 | 0.88 | 0.03 | <0.01 | 0.12 | 1780 | <0.03 | <0.05 |
| W01123 | 4/9/96 | 4 | 0.09 | 12 | <2 | 0.06 | 30 | 0.03 | <0.02 | 1030 | <0.03 | <0.05 |
| W01229 | 5/15/96 | 3 | <0.01 | 229 | <2 | 0.81 | 0.02 | <0.01 | 0.12 | 1830 | <0.3 | <0.5 |
| W01228 | 5/15/96 | 4 | 0.07 | 14 | <2 | 0.07 | 36.7 | 0.03 | <0.02 | 1260 | <0.3 | <0.5 |
| W01230 | 5/15/96 | blank | <0.01 | <1 | <2 | <0.01 | <0.01 | <0.01 | <0.02 | 1.1 | <0.3 | <0.5 |
| W01363 | 6/23/96 | 3 | 0.04 | 185 | <2 | 0.66 | 0.12 | <0.01 | 0.1 | 2280 | <0.02 | <0.08 |
| W01362 | 6/23/96 | 4 | 0.15 | 19 | <2 | 0.09 | 52.7 | 0.04 | <0.02 | 2040 | <0.02 | <0.08 |
| W01364 | 6/23/96 | 5 | 0.02 | 159 | <2 | 1.07 | 0.01 | <0.01 | 0.15 | 4100 | <0.2 | <0.8 |
| W01365 | 6/23/96 | blank | 0.02 | <1 | <2 | <0.01 | <0.01 | <0.01 | <0.02 | 0.36 | <0.2 | <0.8 |
| Lab # | Date | Well # | SB | SC * | SE | SI | SR | TI | TL | V | ZN | ZR |
| W01122 | 4/9/96 | 3 | <0.1 | <3 | <0.1 | 1.81 | 1.9 | <0.01 | <0.3 | <0.01 | <0.01 | <0.01 |
| W01123 | 4/9/96 | 4 | <0.1 | <3 | <0.1 | 2.46 | 2.1 | <0.01 | <0.3 | <0.01 | 0.01 | <0.01 |
| W01229 | 5/15/96 | 3 | <0.1 | <3 | <0.2 | 1.68 | 1.97 | <0.1 | <0.3 | <0.1 | <0.01 | <0.1 |
| W01228 | 5/15/96 | 4 | <0.1 | <3 | <0.2 | 2.7 | 2.79 | <0.1 | 0.4 | <0.1 | 0.01 | <0.1 |
| W01230 | 5/15/96 | blank | <0.1 | <3 | <0.2 | <0.01 | <0.01 | <0.1 | <0.3 | <0.1 | <0.01 | <0.1 |
| W01363 | 6/23/96 | 3 | <0.2 | <3 | <0.2 | 1.59 | 2.25 | <0.1 | <0.3 | <0.1 | <0.01 | <0.1 |
| W01362 | 6/23/96 | 4 | <0.2 | <3 | <0.2 | 3.12 | 4.01 | <0.1 | <0.3 | <0.1 | <0.01 | <0.1 |
| W01364 | 6/23/96 | 5 | <0.2 | <3 | <0.2 | 0.68 | 12.75 | <0.1 | <0.3 | <0.1 | 0.02 | <0.1 |
| W01365 | 6/23/96 | blank | <0.2 | <3 | <0.2 | <0.01 | 0.01 | <0.1 | <0.3 | <0.1 | 0.02 | <0.1 |

| Lab # | Date | Well # | HG * | CL | F | NO3 ** | SO4 ** | Total K *** | Pal K *** | Acid *** |
|--------|---------|--------|-------|-------|----|--------|--------|-------------|-----------|----------|
| W01122 | 4/9/96 | 3 | 0.31 | 2039 | ND | 0.04 | 684 | 833.6 | 789.4 | ND |
| W01123 | 4/9/96 | 4 | 0.34 | 1527 | ND | 0.06 | 383 | 162.2 | ND | 7 |
| W01229 | 5/15/96 | 3 | 0.06 | 2614 | ND | <0.01 | 682 | 629.9 | 597.7 | ND |
| W01228 | 5/15/96 | 4 | 0.09 | 2062 | ND | <0.01 | 327 | 171.3 | ND | 9 |
| W01230 | 5/15/96 | blank | 0.09 | <0.01 | ND | <0.01 | <0.01 | 1.8 | ND | ND |
| W01363 | 6/23/96 | 3 | 0.08 | 2994 | ND | 0.39 | 745 | 382.6 | 367.5 | ND |
| W01362 | 6/23/96 | 4 | <0.05 | 3385 | ND | 0.44 | 401 | 205.5 | ND | 13 |
| W01364 | 6/23/96 | 5 | <0.05 | 6045 | ND | <0.01 | 26.8 | 2804 | 2760 | ND |
| W01365 | 6/23/96 | blank | <0.05 | 0.29 | ND | <0.01 | <0.01 | 0.9 | ND | 1 |

Remarks:

Total K Alkalinity to pH 4.5 as mg CaCO₃/L
 Pal K Alkalinity to pH 8.3 as mg CaCO₃/L
 Acid Acidity to pH 8.3 as mg CaCO₃/L

Analytic Method Codes:

All reported as mg/l except as noted below

- * µg/L, Inductively coupled plasma
- ** mg/L, Ion chromatography
- *** mg/L, Titrimetric
- ND No detection

| | | | | | | | | | | | | |
|--------|----------|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Lab # | Date | Well # | Al | As | B | Ba | Be * | Ca | Cd | CO | CR | CU |
| W01497 | 7/26/96 | 3 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| W01496 | 7/26/96 | 4 | <0.02 | <0.01 | 0.86 | 0.14 | 1 | 176 | <0.01 | <0.01 | <0.01 | <0.01 |
| W01498 | 7/26/96 | blank | <0.02 | <0.01 | <0.01 | <0.01 | <1 | 0.07 | <0.01 | <0.01 | <0.01 | <0.01 |
| W01585 | 8/30/96 | 4 | 0.04 | <0.01 | 1.00 | 0.15 | 3 | 200 | <0.01 | <0.01 | <0.01 | <0.01 |
| W01586 | 8/30/96 | blank | <0.01 | <0.01 | <0.02 | <0.01 | <1 | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| | 10/12/96 | 4 | | | | | | | | | | |
| | 10/12/96 | blank | | | | | | | | | | |
| Lab # | Date | Well # | FE | K | LA * | LI | MG | MN | MO | NA | NI | PB |
| W01497 | 7/26/96 | 3 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| W01496 | 7/26/96 | 4 | 0.11 | 20 | <2 | 0.09 | 56.9 | 0.07 | <0.02 | 2290 | <0.03 | <0.04 |
| W01498 | 7/26/96 | blank | <0.01 | <1 | <2 | <0.01 | 0.02 | <0.01 | <0.02 | 1 | <0.03 | <0.04 |
| W01585 | 8/30/96 | 4 | 0.10 | 22 | <2 | 0.09 | 63.5 | 0.10 | <0.02 | 2770 | 0.05 | <0.05 |
| W01586 | 8/30/96 | blank | <0.01 | <1 | <2 | <0.03 | 0.01 | <0.01 | <0.02 | 1 | <0.03 | <0.05 |
| | 10/12/96 | 4 | | | | | | | | | | |
| | 10/12/96 | blank | | | | | | | | | | |
| Lab # | Date | Well # | SB | SC * | SE | SI | SR | TI | TL | V | ZN | ZR |
| W01497 | 7/26/96 | 3 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| W01496 | 7/26/96 | 4 | <0.2 | <3 | <0.2 | 3.16 | 4.40 | <0.01 | <0.2 | <0.01 | 0.01 | <0.01 |
| W01498 | 7/26/96 | blank | <0.2 | <3 | <0.2 | <0.01 | <0.01 | <0.01 | <0.2 | <0.01 | <0.01 | <0.01 |
| W01585 | 8/30/96 | 4 | <0.02 | <7 | <0.2 | 3.52 | 5.11 | <0.01 | <0.3 | <0.01 | 0.02 | <0.01 |
| W01586 | 8/30/96 | blank | <0.02 | <7 | <0.2 | <0.01 | <0.01 | <0.01 | <0.3 | <0.01 | <0.01 | <0.01 |
| | 10/12/96 | 4 | | | | | | | | | | |
| | 10/12/96 | blank | | | | | | | | | | |

| Lab # | Date | Well # | HG * | CL | F | NO3 ** | SO4 ** | Total K *** | Pal K *** | Acid *** |
|--------|----------|--------|------|----|---|--------|--------|-------------|-----------|----------|
| W01497 | 7/26/96 | 3 | | | | | | 210.5 | 205.8 | 6 |
| W01496 | 7/26/96 | 4 | | | | | | 226.9 | ND | 7 |
| W01498 | 7/26/96 | blank | | | | | | 2 | ND | ND |
| W01585 | 8/30/96 | 4 | | | | | | 239.2 | ND | 8 |
| W01586 | 8/30/96 | blank | | | | | | <2 | ND | ND |
| | 10/12/96 | 4 | | | | | | | | |
| | 10/12/96 | blank | | | | | | | | |

Remarks:

Total K Alkalinity to pH 4.5 as mg CaCO₃/L
 Pal K Alkalinity to pH 8.3 as mg CaCO₃/L
 Acid Acidity to pH 8.3 as mg CaCO₃/L

Analytic Method Codes:

All reported as mg/l except as noted below
 * µg/L, Inductively coupled plasma
 ** mg/L, Ion chromatography
 *** mg/L, Titrimetric
 ND No detection