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TECHNICAL REPORT

December 1, 1994 through February 28, 1995

Project Title: **USE OF FLUIDIZED BED COMBUSTION BY-PRODUCTS FOR LINERS AND ALKALI SUBSTITUTES**

ICCI Project Number: 94-1/3.1B-5M  
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ABSTRACT

Fluidized Bed Combustion (FBC) of coal eliminates most emissions of sulfur and nitrogen oxides, but produces sizable volumes of a solid residue that EPA may require to be placed in capped and lined landfills. Fluidized Bed Combustors are one of the most promising growth markets for Illinois coal and imposing cap and liner requirements would render the technology economically inviable. Fluidized Bed residues are cement-like and when mixed with soil produce a material as impermeable as the clay liners used at landfills. This project will demonstrate that Fluidized Bed Combustion Residues can be mixed with soils by regular construction equipment and used in place of clays as a liner material. The demonstration cap will cover an area of seven acres, and will prevent water infiltration into acid producing material.

Baseline studies of Briar Creek indicate that the water is now highly degraded by acid drainage. Construction delays have enhanced the data collected on Briar Creek by allowing monitoring to continue through major seasonal changes without any effects attributable to the FBC ash. The materials needed to place the wells and lysimeters as soon as the weather improves this spring have been purchased and delivered. Also experiments suggest that it may be possible to control dust by foam conditioning the FBC ash at the power station.

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## EXECUTIVE SUMMARY

Fluidized Bed Combustion of coal eliminates most sulfur dioxide and nitrogen oxide emissions. It is considered a best available control technology, and is the favored technology for new steam and electric power generation amongst Non-Utility Generators. Non-Utility Generators are expected to be the major developers of the U.S. new electric generating capacity, and are a key growth market for the Illinois Coal Industry.

This new clean coal technology is at risk due to provisions of the Resource Conservation and Recovery Act (RCRA) because EPA has not yet made a determination that the solid residues from FBC combustion are non-hazardous. Cap and liner requirements if imposed on FBC combustion by-products would make the technology not economically viable. Previous work by the investigators, has shown that FBC combustion by-products, when mixed with soils and degraded mine rock, produce stabilized materials with permeabilities as low as the natural clay liners required for disposal of RCRA subtitle C and D wastes. This project will demonstrate that FBC by-products can be used to make impermeable caps and liners by building a large cap over a seven acre field site. The project will also demonstrate construction techniques using conventional earth moving machinery, as well as methods of dust control. Successful demonstration may provide large new markets for FBC by-products as substitutes for natural clay, as well as provide a documented basis for claims that FBC by-products are self lining, should cap and liner requirements be imposed.

Progress this quarter has been in three areas. First, monitoring of Briar Creek has continued on a monthly basis. Major effects of the seasonal change on water quality have been observed, although baseline water quality is always poor. Second, material to build the wells and lysimeters as soon as the weather breaks in spring have been obtained. Third, some dust control experiments have been performed on a laboratory scale in preparation for on site dust control work as soon as construction begins.

## OBJECTIVES

This project is a field scale demonstration. The objectives of this project are:

1. Demonstrate that Fluidized Bed Combustion (FBC) by-products can be used to augment natural soils to produce liners for landfills and waste disposal facilities.
2. Demonstrate that FBC by-products can be handled and mixed in the field on a large scale using readily available construction equipment.
3. Demonstrate that FBC by-products can be used as a substitute for alkali chemicals in environmental management work.

To achieve these objectives a seven acre field site will be prepared. An open final cut strip mine (Thunderbird) drains into Briar Creek near Dykersburg, Illinois. The pit will be filled with a soil-like mixture of degraded rock disturbed by past mining activity. The material is called GOB and the breakdown of pyrite in the GOB will produce acid and metals rich drainage if the GOB is exposed to water. The GOB will be encased in low permeability material produced by mixing GOB and soil with FBC by-products. The FBC by-products will consist of fly ash and spent bed from the Archer Daniels Midland plant in Decatur, Illinois. It will be mixed with GOB and soil material at the Thunderbird mine site using heavy construction equipment. If the seepage barriers and liners are effective, there will be little wetting of the GOB, and acid mine drainage will not be produced. The layers used to "encapsulate" the GOB will consist of an upgradient and downgradient barrier wall to block the lateral movement of groundwater through the GOB, and a surface cap to block the infiltration of rain-water and run-off into the GOB. It is the surface cap which will have a structure similar to a liner that would be used in a landfill. The site will be monitored for seepage using lysimeters, monitor wells, and water quality in Briar Creek. The integrity of the liner will be monitored visually and by surveying of monuments placed in the liner to indicate heave and movement.

## INTRODUCTION AND BACKGROUND

Ash from the combustion of coal has been considered for regulation as a dangerous solid waste for over 10 years. During the review period, coal combustion ash was exempted from stringent regulations under the Resource Conservation and Recovery Act (RCRA) by the Bellville Amendment. In 1993, the EPA ruled that coal combustion ash from regular power plants was non-hazardous and exempted from RCRA regulation. No ruling has been made on FBC power plant ashes, which continue their uncertain future under the Bellville Amendment.

FBC power plants are a key market for the Illinois Coal Industry. There is no doubt that the Clean Air Act Amendments will cause a loss of market for Illinois Coal with conventional power plants that must face expensive scrubber retrofits or continuing SO<sub>2</sub> allowance

purchases. Non-Utility Generators (NUGs) are not under the SO<sub>2</sub> cap and are required only to use the best available control technology to eliminate as much SO<sub>2</sub> emission as possible. FBC is the most frequent control technology of choice amongst the NUGs. Non-Utility Generators are expected to build most of the new units needed to meet U.S. power needs. Archer Daniels Midland (ADM) (one of the cooperating organizations for this project) is projecting to double their production by just after the year 2000, and enough capacity addition to increase production by 50% has already been contracted. The existing boilers at ADM already are the equivalent of a 280 megawatt generating station, but coal consumption is far higher than needed for electricity alone, since the boilers also provide heat for grain processing.

If Illinois is to capture the new growth market for power and steam production, protecting and promoting FBC technology will be crucial. FBC power plants produce 250% of the solid by-products of conventional pulverized coal units and RCRA regulations requiring disposal in lined and capped landfills at 7 times the price of conventional monofill disposal would render the technology economically infeasible. (FBC units directly fire limestone with coal to adsorb SO<sub>2</sub> as it is created and thus have a larger volume of non-combustible material). At the heart of the issue of whether FBC by-products are environmentally hazardous are their high content of calcium oxides (created by exposing limestone to boiler temperatures). The portlandite formed in this way is responsible for the same high pH values seen during the curing of concrete. In previous laboratory and small scale field studies by the P.I., these reactions also allowed FBC fly ash to act as a soil stabilizer, just as cement does, and for FBC soil mixtures to achieve the same low permeabilities as clay liners used for landfills. In fact one of the problems in many percolation tests conducted by the P.I. in previous work has been that FBC by-products are so impermeable that they produce no leachate to analyze. Thus, one of the prospects to be explored in this study is whether FBC by-products can be used as a soil additive to substitute for clay in landfill liners. Demonstrating the construction techniques for use of FBC by-products in liners and proof of their performance in a cap covering a 7 acre site (as is being done in this study) promises to open new markets for FBC by-products as construction materials rather than waste.

For many low value bulk materials, the cost of transportation approaches or exceeds the value of the material itself. FBC ash can be used to amend natural soils and degraded rock material to produce a substance as impermeable as the clay liners used in landfills. The cap and seepage barrier at the Thunderbird site will be made from about 20% FBC ash and 80% onsite soil materials. This ratio would mean that companies planning to build impermeable liners would only have to haul in 20% of the liner material instead of 100% as is the case with clays. The ability of FBC ash to amend onsite soils would give it potentially significant market penetration advantages. Further, demonstrating that FBC materials are self lining and self capping should eliminate the most expensive problems should un-marketed FBC by-products be placed under RCRA.

## EXPERIMENTAL PROCEDURE

Because this project is a field demonstration, rather than a lab study, the experimental procedure is in many ways closer to a construction plan and sequence. The study begins with

baseline water quality monitoring on Briar Creek prior to construction. Results from the baseline study show Briar Creek to be highly degraded by Acid Mine Drainage (AMD) at this time.

Several truck loads of FBC by-products are to be brought and stock-piled at the site. When these trucks are unloaded, there will be no dust control, but high volume samplers are to be in operation, to help establish a baseline for dust generation. The stockpiled fly ash will be used to build the key for the upgradient seepage barrier. The upgradient barrier will be built-up as the pit is filled with GOB. When the pit is filled with GOB, construction will slow for about two weeks, during which time lysimeters and wells will be placed around the seven acre cap site, with around four or more lysimeters in each subplot. GOB and FBC by-products will then be brought into the site and will be placed and mixed over the top of the lysimeters to form the cap layer. Seven different one acre plots will be set up with differing ratios of fly ash, spent bed, and either GOB or soil material. The site plans and ratios from the IAMLRC bid documents are included as Figure 1. The down gradient seepage barrier will be built up during capping as an over-flow for FBC by-products that may not arrive so that they can be synchronized with GOB and soil placement. (Coordinating materials arrival and placement at a large rural field site is expected to need some stock-pile and storage buffers to keep equipment sequences from being bottle-necked). Layers of GOB, soil, and FBC by-products will be placed in lifts and then mixed by heavy equipment. Equipment to be tried will include a Rome disc, a Front End Loader, soil sub-base mixing equipment, and possibly a slurry system. As the FBC by-products are brought in for the capping operations, various dust control technologies will be applied. The technologies will likely include, a trailing tarp, regular water truck wetting, and wetting with fine misting spray bars. Experiments conducted this quarter indicate that it may also be possible to condition the ash at the ADM power plant. Further discussion of this possibility is found in the results and discussion section. Dust monitoring will be conducted during unloading exercises to appraise the effectiveness of dust control. Dust control effectiveness will be assessed based on high volume sampling, and video taping to assess opacity impacts. The effectiveness of the mixing systems will be assessed by discussions with the contractor and the onsite research personnel, and by observing the degree of mixing in cores taken from the cap.

Following cap placement, a covering of topsoil will be placed. Next the cap and topsoil will be cored to provide samples for the assessment of mixing, and to provide holes for the placement of subsidence monuments. FBC materials are expansive when wetted and the subsidence monuments will be surveyed in and used as a measure of heave and swell during curing. Lysimeters and wells will be checked for indications of water infiltration through the cap. Briar Creek will be monitored for indications of impacts of acid seepage from the GOB.

## RESULTS AND DISCUSSION

Many of the intended tasks for the past quarter have been delayed due to the weather. Plans were made to place the cap and lysimeters in the field during the Christmas break at the University. At the end of November, rains wet the site and halted all construction activities. The break in the weather that was hoped for in December did not occur, and there was been

no construction at the site since November. The earth work contractor on the site is Richardson Excavating. Building of the cap is just part of a \$3 million contract with the IAMLRC. Although Richardson Excavating left the equipment on site and maintains a trailer, they have been unable to do work on any other portion of the Thunderbird site either.

Progress on the project during the last quarter has been achieved in three areas:

1. Briar Creek has been sampled and monitored two more times during the last quarter during the month of December, January, and again on the March 3rd. The March samples have not been analyzed for this report. The Briar Creek monitoring has two major purposes. Acid mine drainage has essentially sterilized the creek. Figures 2 through 5 show the pH, iron, manganese, and aluminum contents of the creek (pH, iron, manganese, and aluminum are usually the best indicators of AMD problems). The X axis represents the sampling station. Station number 1 is at the head waters of Briar Creek, and represents water with minimal AMD effect. Station 2 is just upstream of the cap site. Station 3 is at the mouth of the T lake pit where the cap is to be placed. Stations 4 and 5 are just down stream of the cap site. If the cap is successful, acid seepage into Briar Creek at site 3 should stop since the cap would prevent water from wetting the GOB materials and promoting break-down of pyrite.

A second important consideration from the sampling of Briar Creek is to confirm that FBC ash used in the cap does not contaminate surface run-off. Coal combustion ashes are usually far less polluting to water than they are popularly considered to be, but several metals may be indicative of ash break-down (not all ashes have the same trace metals). Combustion ashes will sometimes leach arsenic, boron, cadmium, calcium, chromium, copper, nickel, sodium, or lead. Monitoring of Briar Creek to date has found no arsenic, and only near noise level detections of cadmium, chromium, and copper. This will provide a near pure baseline for these metals. It is important to note that other metals such as boron, nickel and lead do not have a pure baseline, and finding these elements in the drainage does not necessarily indicate an effect of the combustion ashes.

While the construction delays are a source of frustration, they have allowed monitoring of Briar Creek through a major seasonal change, before any ash is placed. This will strengthen the ability to distinguish between ash run-off and simple changes in seasonal water chemistry. As an example, lead was found in Briar Creek only during times of heavy water recharge in the winter. Calcium and zinc, shown in figures 6 and 7, have a more classic pattern of dilution during times of heavy fresh rainfall.

2. The second area of progress has been in procuring the supplies for the lysimeters and monitoring wells. The geology drill rig has been upgraded to have more power to drill in hard material. The equipment and procedures for Anion testing have also been started.

3. The last area of progress is in the dust control area. Initial experiments have been done with the ADM fly ash using low dosages of fire retardant foam mixed with the ash. In small scale experiments, foam doses of less than 1 pound per ton appeared to suppress fly ash dust. Consideration has been given to mixing ash through a screw conveyor, and initial contacts have been made with ADM about the possibility of conditioning the ash before it is delivered to the site. The test plan in this proposal has not yet been modified to include a foam suppression system, until a better indication of the large scale feasibility of such a system can be accessed.

The major problem area in this project is the delay in building the cap. Because the cap was not built in November and December as hoped, the main groundwater recharge events in January and February have been missed. To prove that FBC materials are an effective cap and liner it will be necessary to show that water infiltration has been stopped, and that the liner does not swell and fracture. After the cap is constructed, it will only be possible to monitor during the dry summer months before the end of the project. While the data will be of value in showing that FBC ash can be an effective liner, it will almost certainly be necessary to have a longer monitoring time, and particularly one going through the groundwater recharge season before results will be conclusive enough to carry weight with regulatory agencies. A project continuation proposal has been submitted to ICCI to provide the additional follow-up.

### CONCLUSIONS AND RECOMMENDATIONS

The weather has pushed back construction of the cap at Thunderbird into the spring. The delay will significantly enhance the baseline water quality data available on Briar Creek, but the amount of data on the cap permeability performance has been significantly reduced. Especially damaging is the loss of the main groundwater recharge events in January and February. One of the main purposes of the project is to show that FBC liner resist groundwater infiltration, even for caps of full commercial scale. Showing the blockage of water infiltration during the main groundwater recharge season would be especially valuable in this respect. A project extension has been submitted to ICCI to ensure that this data is collected. The construction work in this project will be completed within the current project time period, and all contractual obligations of the project should be met without difficulty.

### DISCLAIMER STATEMENT

This report was prepared by Dr. B.C. Paul of Southern Illinois University at Carbondale with support, impart by grants made possible by the U.S. Department of Energy Cooperative Agreement Number DE-FC22-92PC92521 and the Illinois Department of Energy through the Illinois Coal Development Board and the Illinois Clean Coal Institute. Neither the Dr. B.C. Paul, or Southern Illinois University at Carbondale, nor any of its subcontractors, nor the U.S. Department of Energy, Illinois Department of Energy and Natural Resources, Illinois Coal

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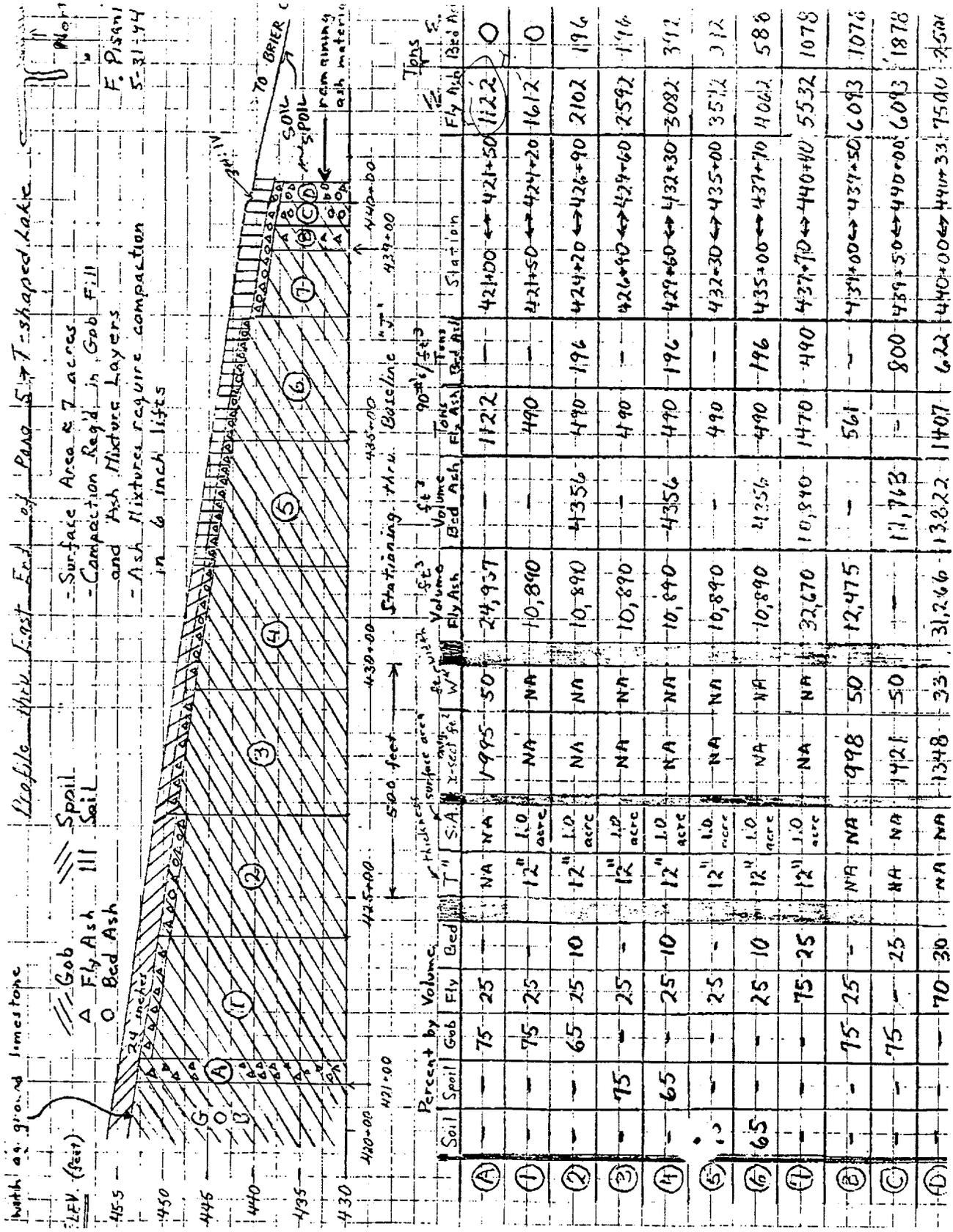
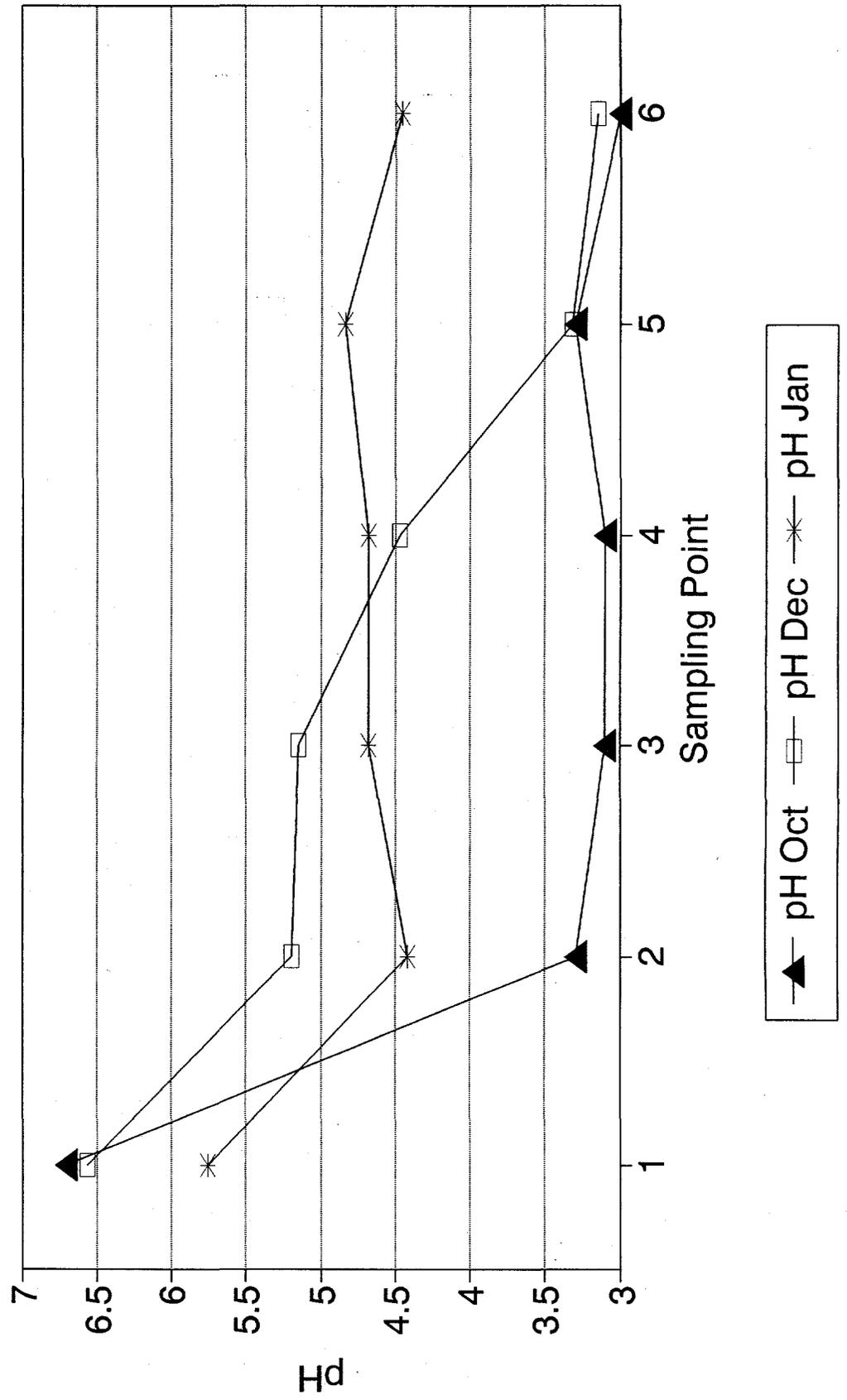


Figure 1. Layout of seven acre cap and liner at Thunderbird

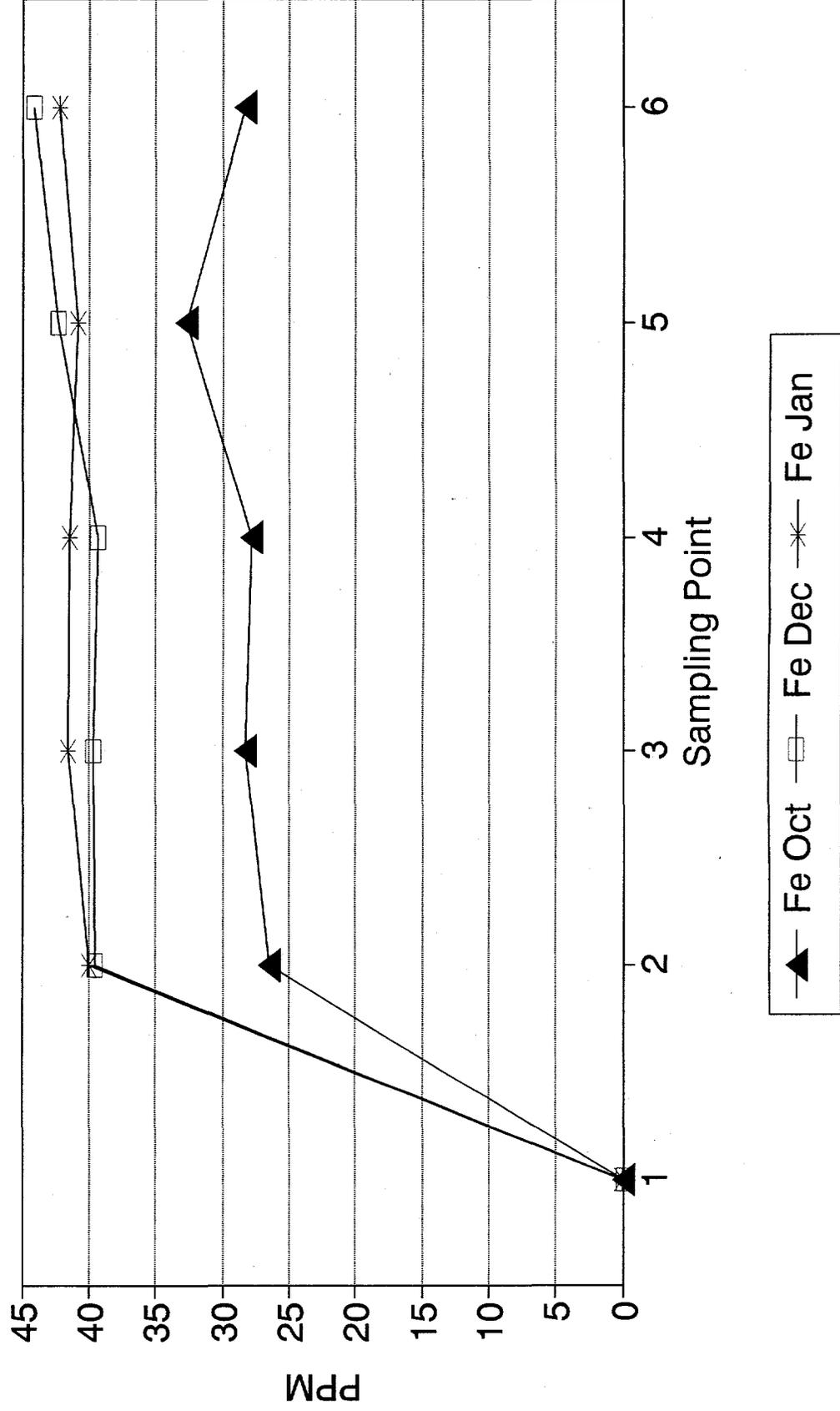
# pH of Briar Creek

Figure 3



# Iron Content of Briar Creek

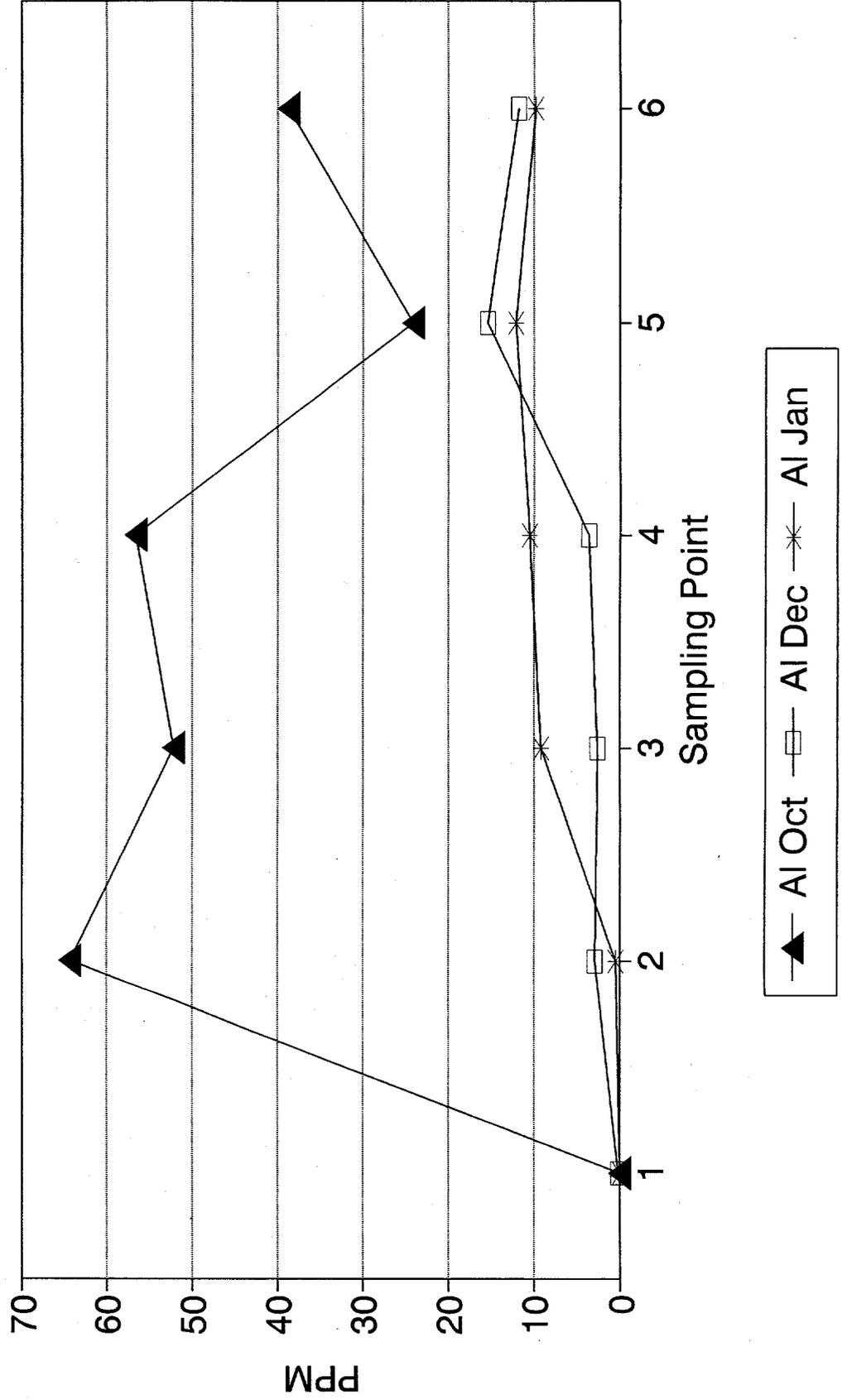
Figure 3



—▲— Fe Oct —□— Fe Dec —\*— Fe Jan

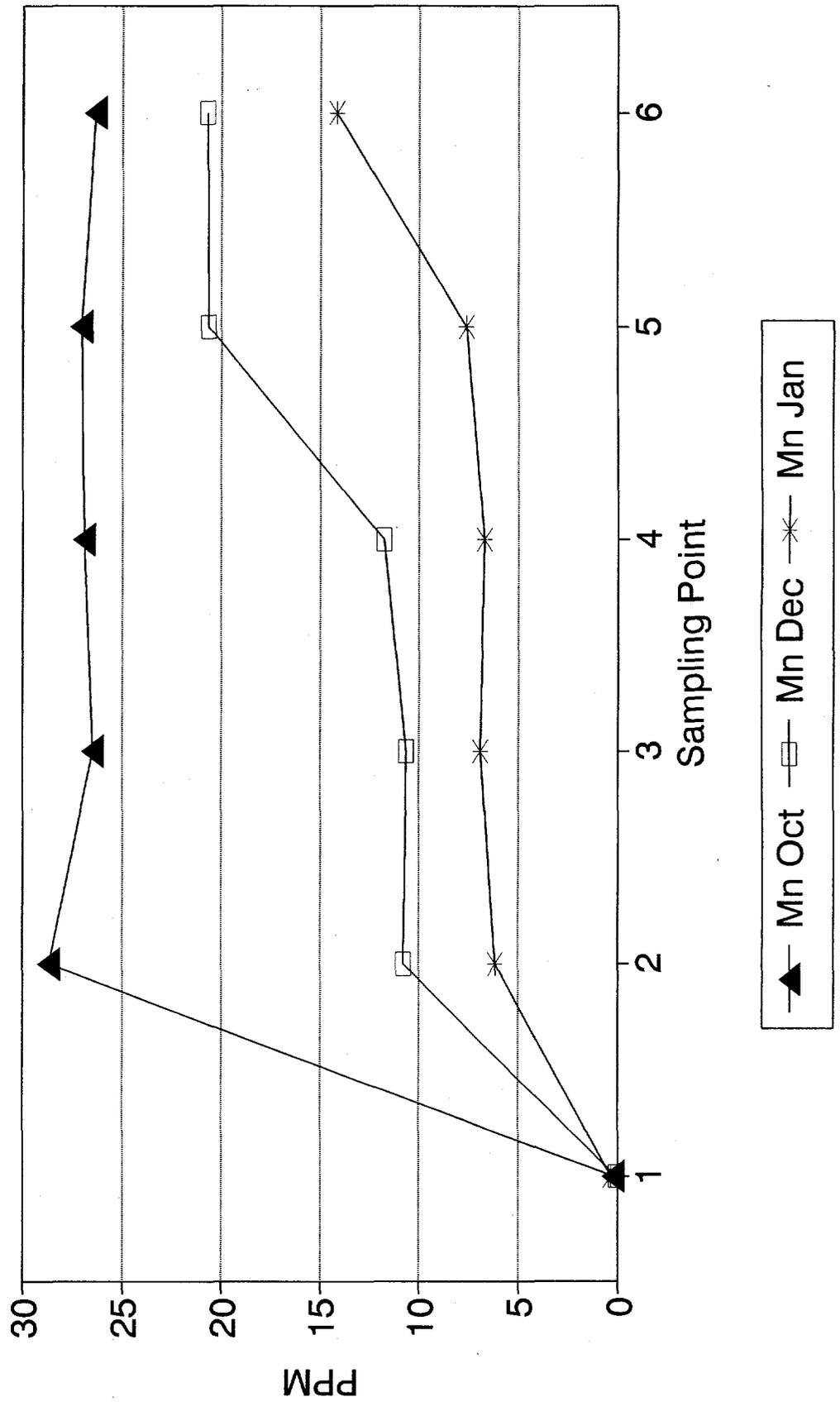
# Aluminum Content of Briar Creek

Figure 4



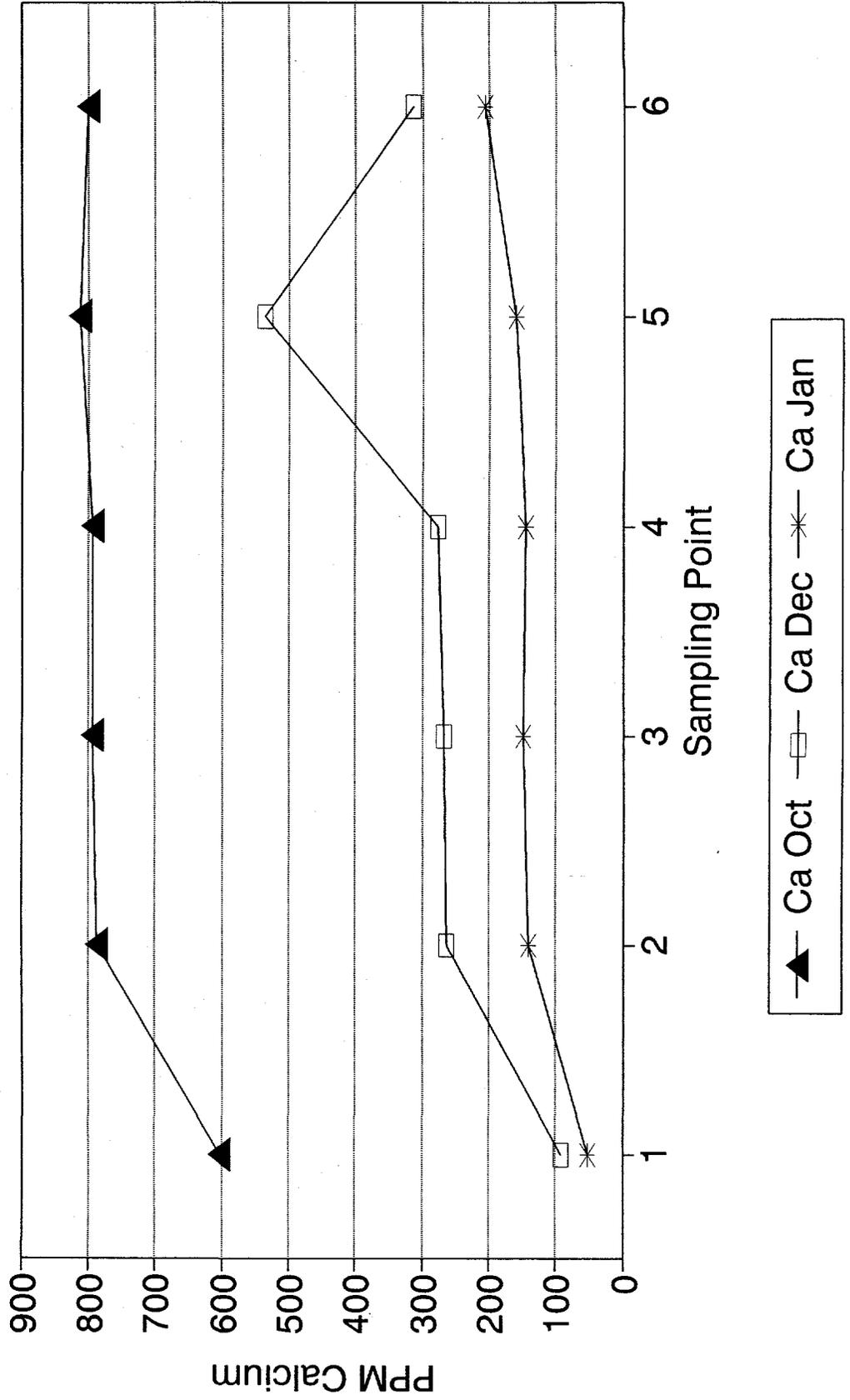
# Manganese Content of Briar Creek

Figure 5



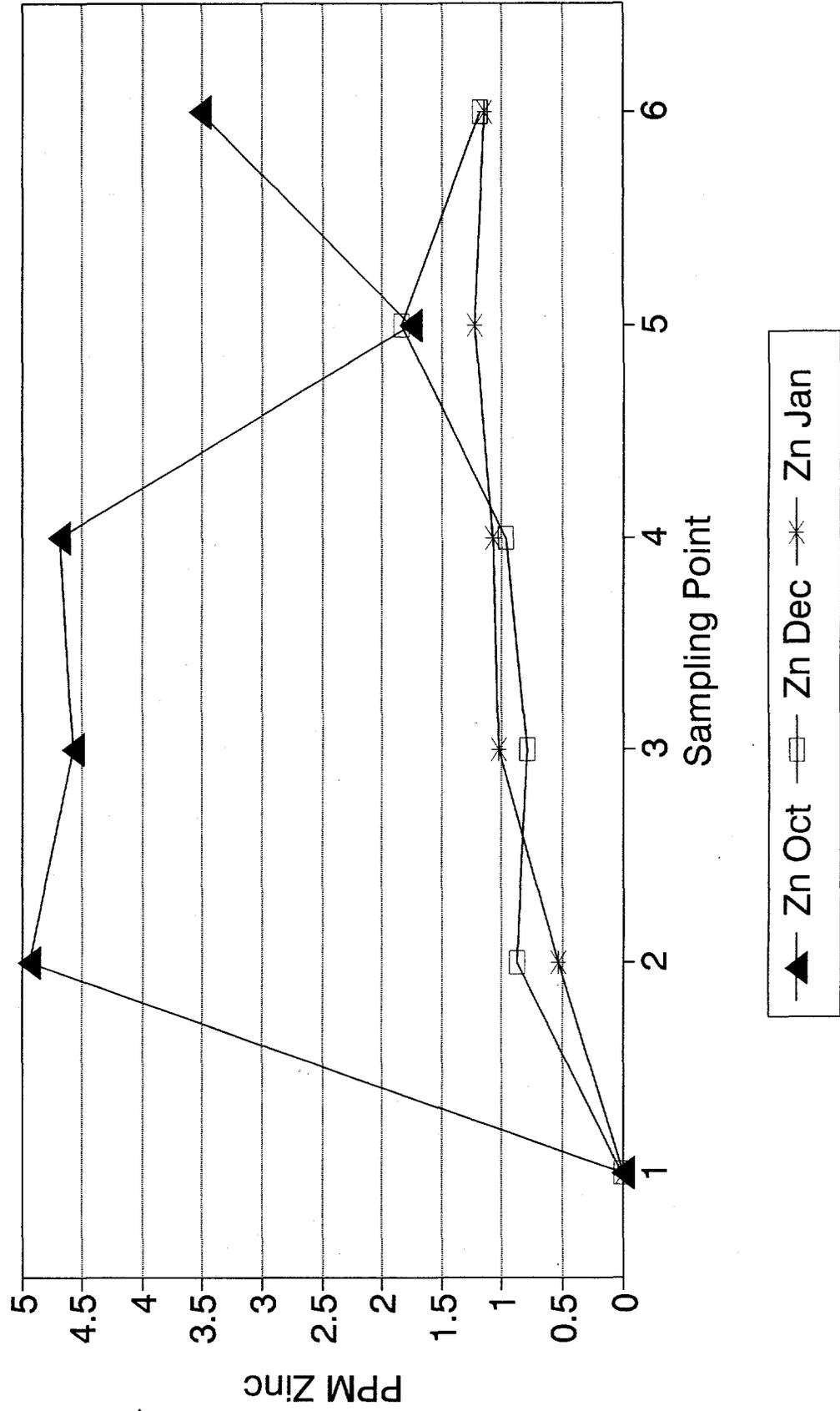
# Calcium Content of Briar Creek

Figure 6



# Zinc Content of Briar Creek

Figure 7



PROJECT MANAGEMENT REPORT  
December 1, 1994 to February 28, 1995

Project Title: **USE OF FLUIDIZED BED COMBUSTION BY-PRODUCTS FOR  
LINERS AND ALKALI SUBSTITUTES**

DOE Cooperative Agreement Number: DE-FC22-92PC92521 (Year 3)  
ICCI Project Number: 94-1/3.1B-5M  
Principal Investigator: Dr. Bradley C. Paul, Department of Mining  
Engineering, Southern Illinois University at  
Carbondale  
Other Investigators: Dr. S. Esling, Southern Illinois University at  
Carbondale; Mr. F. Pisani, Illinois Abandoned  
Mined Lands Reclamation Council;  
Mr. T. Wells, Archer Daniels Midland  
Project Manager: Dr. Dan Banerjee, Illinois Clean Coal Institute

#### COMMENTS

This project is a field construction demonstration, and as such is subject to uncertainties of the weather. No milestones were to have been completed in this quarter. Construction around the cap zone began as scheduled, but has now been held-up by weather for over a month. Task A was to be completion of the cap construction by the end of December. Even with perfect weather in December, this was difficult to achieve. If additional delays result from bad weather, task A will not be completed this quarter. Placement of wells, lysimeters, and survey monuments was to have begun this quarter, and in fact the construction plans were completed. Actual field placement could not occur in November as originally shown because the site was shut down by weather. Baseline water monitoring did begin on schedule, and data is shown in the report.

Because the site activities requiring the highest degree of personnel activity have not yet occurred, the project expenses are also behind schedule. The link to construction work will cause very rapid expenditure of funds as the cap is placed. It is still intended to construct the cap before the next quarterly report.

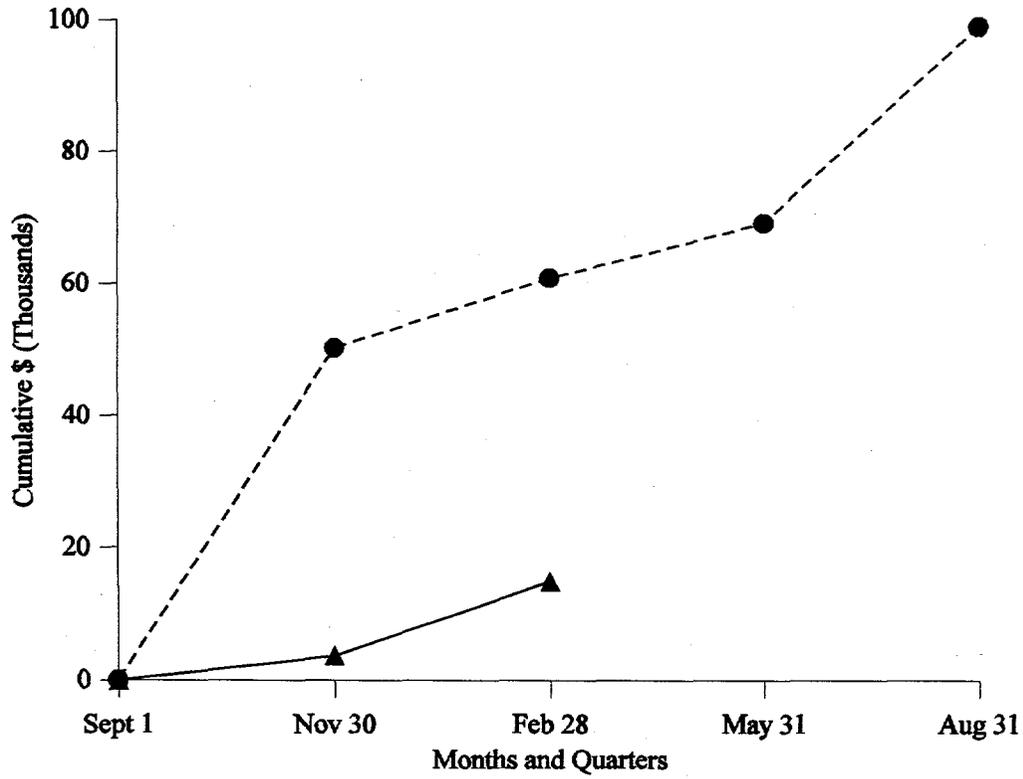
## PROJECTED AND ESTIMATED EXPENDITURES BY QUARTER

Quarter*	Types of Cost	Direct Labor	Fringe Benefits	Materials and Supplies	Travel	Major Equipment	Other Direct Costs	Indirect Cost	Total
Sept. 1, 1994 to Nov. 30, 1994	Projected	6,876	420	8,860	8,325	2,400	19,075	4,356	50,312
	Estimated	1,320	0	770	0	1,360	0	209	3,659
Sept. 1, 1994 to Feb. 28, 1995	Projected	14,484	840	9,560	8,550	2,400	19,720	5,275	60,829
	Estimated	3,341	0	1,357	389	1,360	7,067	1,351	14,865
Sept. 1, 1994 to May 31, 1995	Projected	19,794	840	10,360	8,775	2,400	20,965	6,073	69,207
	Estimated								
Sept. 1, 1994 to Aug. 31, 1995	Projected	40,666	4,182	11,160	10,000	2,400	21,610	9,002	99,020
	Estimated								

\*Cumulative by Quarter

### CUMULATIVE COSTS BY QUARTER

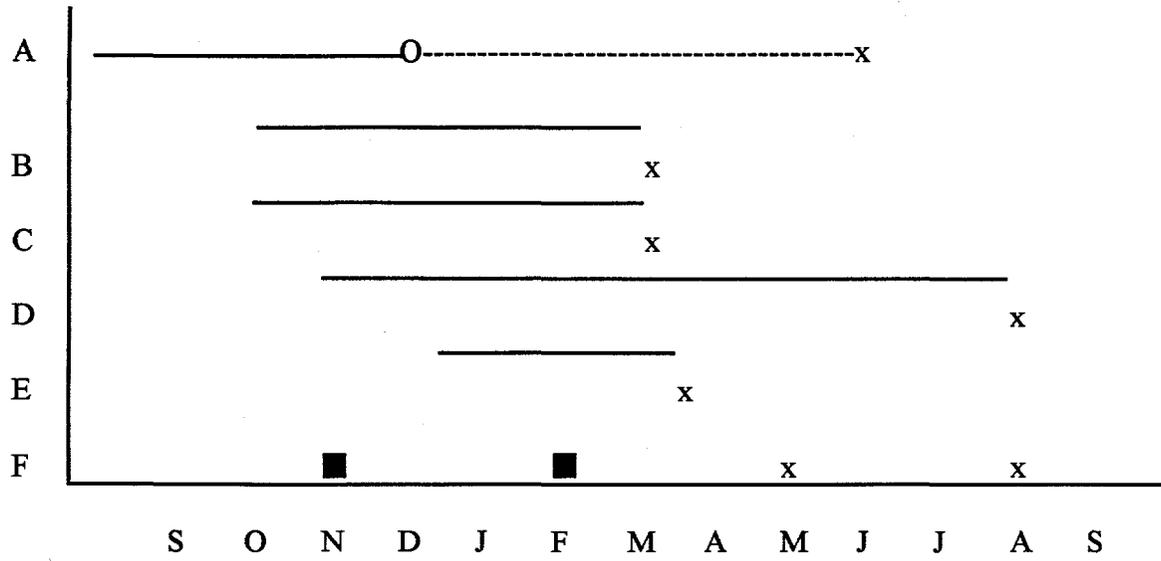
Use of Fluidized Bed Combustion By-Products for Liners and Alkali Substitutes



● = Projected Expenditures - - - - -  
▲ = Actual Expenditures \_\_\_\_\_

Total Illinois Clean Coal Institute Award \$99,020

SCHEDULE OF PROJECT MILESTONES



Begin  
Sept. 1  
1994

Hypothetical Milestones:

- A: Construction and Placement of Liners
- B: Construction and Placement of Wells and Lysimeters
- C: Installation of Survey Network
- D: Twice Monthly Site Monitoring (water and swell)
- E: Data Analysis
- F: ICCI Reports

