Project Title: USE OF FBC ASH AND SO2 CONTROL BY-PRODUCTS FOR LINERS AND ALKALI SUBSTITUTES

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ABSTRACT

In this project SO2 control byproducts were used to construct full commercial scale liners and infiltration barriers at two sites. Liners are used by municipal and special waste landfills to prevent water from contacting materials that might release contaminants into the environment. These liners have traditionally been built of clay and/or geomembranes. Wet sulfite scrubber byproduct can be packed to clay like permeabilities and FBC ashes can be added to regular soils to produce permeabilities lower than most clays. It was the objective of this study to conduct a full scale pilot project to show that SO2 control byproducts are economical and effective as alternatives to traditional liner materials. Both projects demonstrated that the SO2 control byproducts could be easily handled by conventional earth moving equipment at prices as low or lower than the use of traditional clays. A video showing the construction techniques used was produced as an extra benefit of this years project. Monitoring of the sites has to date indicated that the liners built are highly effective as infiltration barriers and do not loose their integrity at least in the first year. Networks of environmental monitoring stations and equipment have found no contamination of ground or surface waters as a result of using these materials and the direct leachate and run-off of FBC ash has been shown to contain only high levels of sodium and potassium, but no unusual toxic trace elements. The sites are to be monitored for two more years with a final report to ICCI on long term behavior and impacts.

As a result of successful pilot projects, one of Illinois's three scrubbed power stations now ships 100% of its scrubber byproduct for recycling as cap and liner material. The power plant has dismantled its on site landfilling capability since it is no longer needed. Plans for rail facilities to haul between 1/4th and 1/2 of Illinois's FBC ashes for liner applications are being made, though final agreement and construction is still pending. One issue is the fugitive dust from FBC ash handling in the field. A dust containment device is being built with ICCI sponsorship next year to address the dust problem.
EXECUTIVE SUMMARY

In this project SO2 control byproducts were used to construct full commercial scale liners and infiltration barriers at two sites. Liners are used by municipal and special waste landfills to prevent water from contacting materials that might release contaminants into the environment. These liners have traditionally been built of clay and/or geomembranes. Wet sulfite scrubber byproduct can be packed to clay like permeabilities and FBC ashes can be added to regular soils to produce permeabilities lower than most clays. It was the objective of this study to conduct a full scale pilot project to show that SO2 control byproducts are economical and effective as alternatives to traditional liner materials and that when used in this way pose no threat to the environment.

To accomplish this objective, two tasks were spelled out for this years project.

Task #1 Monitor the FBC ash cap at Thunderbird.

Task #2 Instrument and monitor a sulfite scrubber byproduct cap at Harco.

To fulfill task #1, five types of monitoring were specified.

1- Monitor rainfall to determine the amount of water available to infiltrate through the cap.
2- Monitor groundwater wells to discern direction of flow and to determine if contaminants were entering the groundwater as a result of the 10,000 tons of FBC ash used in the 7 acre cap.
3- Monitor a series of elevation monuments placed to determine if the expansive cementitious reactions common for FBC ash were causing heaving that might threaten liner integrity.
4- Monitor lysimeters placed beneath the cap last year to determine if water was seeping through the cap and how much.
5- Monitor sampling stations along Briar Creek to determine if contaminants from the cap were being carried into the creek by surface run-off.

Although final answers to some of the questions implied by this type of monitoring require the two additional year monitoring study funded by ICCI, at the end of this years project the investigators are pleased to announce that these tasks have been completed, that the liner has been completely effective in blocking vertical infiltration, that there are no signs of heave to threaten liner integrity, and there are no indications of contamination to surface or groundwater resources.
Task #2 specified installation and operation of the following types of monitoring devices

1- A rain gage.
2- Four free draining lysimeters to detect infiltration through the cap and to investigate the purity of any water that does infiltrate.
3- Six time domain reflectometer probes and six tensiometers to measure water front position in the vadose zone beneath the cap and to distinguish between lateral and vertical water infiltration.
4- Six suction lysimeters to cross check water front positions and measure the quality of pore water that may be in too small a quantity to flow without an external driving force.
5- Ring infiltrometers to test the response of instrumentation to induced infiltration and to possibly measure the permeability of the cap in the field.
6- Groundwater monitoring wells to determine impacts on groundwater quality.

The above equipment was to be installed in two instrument stations. The construction work, which was not funded by ICCI or under the direct control of the researchers, was delayed by internal reorganization at the Department of Natural Resources. The cap has now been built and the two instrument stations installed. Some devices for the stations will not be delivered till September 10 and will be installed at that time. The monitoring wells must be installed after the changes in groundwater flow due to construction have been established. As the parts and agreements for the well installations have been made, there will be no cost or problem going forward with next years monitoring project.

The projects at both Harco and Thunderbird demonstrated that the SO2 control byproducts could be easily handled by conventional earth moving equipment at prices as low or lower than the use of traditional clays. A video showing the construction techniques used was produced as an extra benefit of this years project. Monitoring of the sites has to date indicated that the liners built are highly effective as infiltration barriers and do not loose their integrity at least in the first year. Networks of environmental monitoring stations and equipment have found no contamination of ground or surface waters as a result of using these materials and the direct leachate and run-off of FBC ash has been shown to contain only high levels of sodium and potassium, but no unusual toxic trace elements. The sites are to be monitored for two more years with a final report to ICCI on long term behavior and impacts.
OBJECTIVES

The objective of this project was to demonstrate handling, effectiveness, and utilization of FBC ash and wet scrubber sludge in liner and alkali reagent applications. The project involved tasks at two mine sites, though applications were not intended to be limited to mining operations.

1- Monitor the Thunderbird FBC liner site for environmental and performance related data;

2- Instrument and monitor a scrubber sludge based alkaline recharge at the Harco site;

Task 1. Monitor Thunderbird Cap for Environmental Impact and Performance

In the first task, last year ICCI, in cooperation with the Illinois Abandoned Mined Lands Reclamation Council, and Southern Illinois University at Carbondale, created a seven-acre liner using 10,000 tons of FBC ash at the abandoned Thunderbird Mine site. The liner was intended to keep water out of acid forming materials, just as municipal and other landfills try to prevent water infiltration and contamination through waste materials stored at their sites.

Previous laboratory tests had shown that FBC could be mixed with soils and mine wastes to produce materials with permeabilities as low as commercial clay liners. Testing the finding at a full scale field site had two objectives. First, confirming the liner potential of FBC materials would create new markets for FBC materials. Because only 20% FBC ash could make on site soils into the equivalent of a clay liner, buyers would only have to pay for longer distance haulage of 20% of the required material instead of 100%. Because the cost of freight is often several times the value of the material for such bulk commodities, FBC ashes would have the potential to make inroads into the liner market against conventional clays. The second reason for demonstrating liner performance is that EPA has not yet ruled FBC ashes as being exempt from the cap and liner requirements of RCRA. Cap and liner requirements could create disposal costs of $70/ton for FBC ashes, which is equivalent to about $17.50/ton of coal burned. Such costs would potentially destroy the viability of FBC combustion of high sulfur coals. A demonstration that FBC ashes can be self lining could both reduce the cost of RCRA regulation, and reduce the likelihood that EPA would impose the restriction in the first place.

The current project monitored the integrity of the liner and checked for adverse ground and surface water impacts for the past year. Such monitoring is crucial to establish the performance of FBC liners. Groundwater monitor wells will make sure that water is not rerouting around the seepage barriers, and that the liner itself is not contaminating the groundwater. Surface run-off stations examined Briar Creek to make sure that acid drainage was prevented and that the liner did not contaminated surface waters. (Baseline monitoring of Briar Creek has been proceeding since the beginning of last years ICCI project). Lysimeters measured seepage through the liner, and a network of survey points monitored for swelling or heaving that could fracture the liner.
Task 2. Instrument and Monitor the Scrubber Sludge Alkaline Recharge at Harco

The cooperating partners on this project Illinois Department of Natural Resources (DNR) and Southern Illinois Power Cooperative (SIP) have built a combination cap and alkaline recharge over a 35 acre area using approximately 55,000 tons of sulfite rich wet scrubber sludge. The site will be instrumented with free draining lysimeters, suction lysimeters, tensiometer, infiltrometers, time domain reflectometry stations, and surface and groundwater monitoring. The Harco cap will ensure both a reduced infiltration and a higher but managed pH of 9 or less. The instrumentation will document that scrubber sludge can minimize infiltration, neutralize acidity, and not exceed upper pH limits all at the same time. The demonstration will also provide a comparative field performance of all of the measuring techniques discussed above so that mine or landfill operators can use the simplest and most efficient techniques for any future monitoring that might be required of other commercial ventures.

INTRODUCTION AND BACKGROUND

Under the terms of the clean air act, there is little doubt that most use of Illinois coal will be linked to some form of SO2 control technology or practice, either on the specific boiler burning the Illinois coal, or on another facility from which emission allowances are transferred. Only Fluidized Bed Combustion and wet scrubbing have found full scale application in Illinois.

SO2 control byproducts currently have the fewest beneficial use outlets of any of the coal combustion byproducts (2% compared to 25% and 50% utilization for fly ash and bottom ash). The only significant existing beneficial use outlet for these materials is wallboard manufacture with fully oxidized byproduct gypsum. In Illinois only one power station currently can benefit from such an outlet. The other scrubbers are not fully oxidized and the byproducts they produce cannot be used for conventional wallboard. What is badly needed by utilities is large volume outlets that do not require high levels of product uniformity that today's wet scrubber technology seldom can achieve.

This project addressed the needs of the unoxidized scrubbers in the state by diverting most of the years production of scrubber sludge from an actual commercial power station in Illinois to a 35-acre mine reclamation site. Once there, the scrubber sludge replaced the agricultural limestone that is commonly used to neutralize the potential acidity in acid forming materials at the site. The use of scrubber sludge at the mine site goes beyond simple replacement of agricultural limestone. The scrubber sludge will achieve hydraulic conductivities of 10-5 cm/sec even without compaction. Such permeabilities are far lower than could be achieved with native soil and certainly with agricultural limestone. This will enable the scrubber sludge to function simultaneously as an infiltration barrier and as an alkaline recharge at the same time. Conventional reclamation additives and practices cannot achieve both acid drainage suppression techniques at the same time.

The beneficial use demonstrated by this years expanded project scope simultaneously opens two cost saving options to electric utilities using wet scrubbing.
1- Mine haulback of combustion byproducts saves utilities money on disposal costs. Savings can be further expanded if coal companies do not have to add unit operations and costs to handle the combustion residues at the mine site. Use of utility byproduct materials in reclamation, mineral waste management schemes, and site construction may serve to couple the byproduct handling into existing operations.

2- The problem of acid and infiltration control is not unique to mining operations. While the scrubber sludge portion of this project was not targeted to demonstrate landfill applications of scrubber sludge, the handling techniques demonstrated, plus the use of time domain reflectometry as a check for liner integrity, plus demonstration of a leachate barrier that also neutralizes acidity and treats water, all set up a technological base from which additional commercial outlets can be developed.

The project also addressed the needs of the fluidized bed industrial boiler and cogenerating facilities that form a primary growth market for Illinois coal that is scheduled to double by the year 2000. FBC wastes have not been cleared by EPA from possible regulation under RCRA. A ruling on FBC materials is not scheduled until 1997. Because the combustion byproduct volume produced by FBC units is about 25% of the coal consumed and because disposal costs for a RCRA regulated waste would be in the $30 to $70 per ton range, an unfavorable ruling by EPA could destroy the economics of the process, and strike a further serious blow to the Illinois coal market.

This proposal addressed the needs of FBC units by demonstrating on a large field scale that FBC combustion byproducts can be mixed with native soils to form an infiltration barrier as effective as the clay liners required under RCRA. A previous project involved placing a cap of FBC residues, Gobs and soils over seven acres of acid producing materials. The cap has been instrumented with lysimeters and monitor wells. Monitoring of the cap is essential to demonstrate that the cap will be effective. Establishing the cap and liner potential of FBC materials will aid the industry in two ways,

1- If FBC materials can form their own caps and liners, any potential regulation under RCRA would be less economically serious.

2- FBC byproducts, which currently have almost no market, would have a significant market as a competitor of clay in landfill cap and liner construction. Potential users would only have to bear transportation costs to bring in about 20% of the material needed for cap and liner construction. The ongoing Thunderbird demonstration will show that 80% of the cap can be composed of native soils or Gobs from the site itself if the native materials are amended with FBC combustion byproducts.

The following sections discuss the work and monitoring done at the site and how the work contributes to the achievement of the goals set forth in this project. Some questions of an environmental nature require more than two years of monitoring to amass the data and establish the techniques necessary to provide clearance for future projects, particularly those in more environmentally vulnerable locations. The monitoring network laid down in this project
will be monitored for another two years under a follow on project. Thus, considerable emphasis in this report will focus on the monitoring capabilities established at these sites.

EXPERIMENTAL PROCEDURES

Basic Needs

In order for SO2 control byproducts to be used as viable cap construction materials and alkali amendments, research and demonstration must establish four things.

1- Placement and handling of SO2 control byproducts on a large scale and in the arrangements needed for cap type construction must be technically and safely achievable using equipment readily available with contractors for this type of work.

2- The cost of building such structures must be competitive with conventional capping techniques and preferably lower to facilitate market entry and penetration.

3- The caps when built at a field scale must perform their functions as effectively as competing materials and must effectively scale-up the laboratory procedures and promises.

4- The caps must not produce damage to the environment unique to the alternate materials being used.

Experiments to Establish Technical and Economic Feasibility (Needs 1 and 2)

Although the tasks funded by ICCI as part of this project do not explicitly commit the investigators to demonstrating needs #1 and #2 above, this project was done in cooperation with the Illinois Abandoned Mined Lands Division of the Illinois Department of Natural Resources (DNR), Southern Illinois Power Cooperative (SIP), and the Archer Daniels Midland Corporation (ADM). The cooperating partners in this project scheduled and managed the contractors and paid for all materials delivery and construction charges. Laboratory testing and consulting on materials handling sequences were provided by the investigators to the cooperating partners.

Several laboratory experiments done by the investigators guided the field work at the two demonstration sites. The construction work at the Harco site was linked specifically to this years project, while the Thunderbird construction work was part of the previous years project.

At Harco, DNR had to make a selection between two types of scrubber byproduct material to use in the cap construction. The Lake of Egypt or Marion Station uses a wet limestone scrubber to produce a sulfite based scrubber byproduct. Calcium sulfite dominated materials are soft, sticky, and prone to liquefaction. To cope with the obvious materials handling problems with such a material, Marion station followed the traditional practice of mixing fly ash in with the scrubber byproduct. The free lime and calcium in the scrubber byproduct react with the pozzalonic mulite glasses in the fly ash to produce cementitious reactions that set the “stabilized” sludge up as a very low grade concrete that resembles a soil. The stabilizing step is
performed using a pug mill at the power plant. It was also possible to obtain the scrubber byproduct without the fly ash stabilization. Researchers were dispatched to the power plant to collect samples of both types of material. A test known as the Calcium Carbonate Equivalent test (CCE) was performed on both scrubber byproducts from SIP. One of the intended uses of the scrubber material was to act as an alkaline source for waters infiltrating into acid forming materials at the site. The application rate for the alkaline amendment was to be dictated by the amount of alkalinity the cap material could release. Not surprisingly the unstabilized calcium carbonate and sulfite material had a higher CCE than when non-soluble silicate glasses became part of the mix. Another test performed was the ASTM shake test which is now used by state regulators in permitting mine haul-back and beneficial use of coal combustion byproducts. The test showed that the stabilized material had a significant initial flush of boron in the leachate, while the boron flush was practically absent from the unstabilized material. The result was not surprising, since previous work by the investigators had shown that fly ash is frequently a carrier of leachable boron. (Boron is plant nutrient that is biologically concentrated in plant tissues and is carried into the combustible portion of the coal when plants become fossilized). Boron is volatile and when the coal is burned it is gasified and carried up the stack with the fly ash. As the temperatures cool the boron then condenses on the fly ash particles. Since boron is water soluble it tends to be carried into the water when the ash is leached. Boron is a salt forming element and can harm some highly salt sensitive plant species. As such, there are limits placed on the amount of boron accepted in the highest quality waters in the state. Although boron is usually quickly attenuated in ground water, the investigators recommended to DNR to consider using the unstabilized scrubber byproduct so that the elements that might produce groundwater quality issues would be avoided.

Using unstabilized scrubber byproduct raised materials handling issues. California Bearing Ratio tests done by the investigators indicated that rutting would be a major problem if trucks or scrapers attempted passage across the byproduct surfaces. The stickiness suggested by the Atterburgh Limits test aggravated the problem, implying that the tires would become caked with slippery gue as the vehicles plowed through deepening ruts. Although not an established test procedure, the investigators had collected and cured SIP sludge in a bucket for several months previous. Even without the fly ash being pugged into the mix, the unfixed scrubber byproduct eventually set-up and was easily handable in the lab. SIP had generated some unfixed scrubber byproduct for its on site landfill when the pugmill had broken down and this material had also cured over a long period of time. No one had ever attempted field curing of the massive piles needed for a full years scrubber byproduct production. DNR determined to attempt the laboratory self setting for unstabilized scrubber sludge in the field in order to gain a more potent CCE and avoid any possible leachate issues with boron. A plan was made to begin delivery of scrubber byproduct to the site 6 months before the contractor was scheduled to begin work and to cure the byproduct in large piles.

Reorganization of state agencies directed by Governor Edgar in 1995 delayed DNRs scheduled contractor bids and when the contractor began work at the Harco site about 2 months later than originally planned, the wet conditions and mild winter forced the contractor to first redevelop roads and treat the burgeoning lakes and ponds of acid mine drainage. As a result, the scrubber byproduct was not picked up for cap construction at the Harco site until early July of 1996. The scrubber material had cured at the site for over a year. The material was picked
up by scrapers and placed in lifts by the same equipment. It was then roller compacted. The material handled like a well drained soil and posed no handling problems. In one area of the cap, an old coal processing slurry pond was to be covered. The pond surface was full of soft spots that flowed like a viscous fluid. In these areas the scrubber byproduct was unloaded at the edge and pushed into place by bulldozers before roller compacting. The cured unfixed scrubber byproduct had no problems with dusting to distinguish it from ordinary damp soil.

The construction work with FBC fly ash at Thunderbird was part of the previous years ICCI project. Last years Final Technical Report discussed the successful and economic handling of the FBC ash. Large amounts of video footage were shot last year at Thunderbird. This year a major effort was made to edit and compile the video footage into a presentation showing how FBC fly ash could be successfully handled. (Some of the most convincing evidence in a field demonstration project cannot be presented in a typed paper format). A copy of the video was presented at the 1996 contractors meeting and presented to ICCI for their records.

Experiments to Establish the Performance of Caps (Need #3)

The experimental network at Harco is the more sophisticated of the two sites, while the network at Thunderbird covers a larger area, and since it was already in place produced the bulk of the data in previous quarterly reports this year. The network at Harco is established at two stations, located in a 4 acre portion of the 35 acre total cap area. The main performance issue at Harco is the impermeability of the cap. A series of instruments have, or are being placed in each station. All are intended to measure water infiltration through the vadose zone beneath the cap. (A vadose zone is the area above the water table where the pore spaces are not filled with water and the water pressure is less than the air pressure). Assuming that water movement in the upper part of the vadose zone comes from a vertical direction, this water movement will infer the permeability of the cap through the amount of water that was able to penetrate.

The first feature at each site is a rain gage. In order to infer permeability of a cap by the water coming through it, it is necessary to know how much water was available to infiltrate. Under uncontrolled, non-submerged, open field conditions this means rain water. The gage, shown in Figure 1, consists of an 8 inch section of PVC pipe located near the ground surface to minimize the impact of wind. (Wind can cause rain water to blow over the gage without being captured. Wind velocities near ground level are small even under strong gusting wind conditions). The lip of the gage is located above ground level to prevent run-off water from flowing into the gage. The 8 inch collection section drains into a 2 inch diameter PVC pipe collection reservoir where the water level is measured by a vibrating wire transducer.
Figure 1. Schematic Diagram of Rain Gage

Even in the field it is possible to create an artificial controlled rain to where the amount of water available for infiltration is known. The device used to do this is called a ring infiltrometer. It is composed of heavy sheet plastic driven through the soil covering and about 18 cm into the cap and closed in a circle. A known amount of water is then poured into this "wading pool" with the bottom consisting of the ground beneath it (i.e. the soil immediately over the cap). Obviously care must be taken to ensure that water doesn't channel at the edge of the ring. The intended use of the infiltrometer located at each station is to create an artificial rain event at each station so that the response of the instruments at each station can be tested under controlled conditions. Another more dubious use of the ring infiltrometer is to measure the rate at which water level falls and then infer the cap permeability. Since the ring seals lateral water movements the device is a giant field falling head permeameter. There is room for uncertainty as to what is being measured. In a laboratory falling head permeameter the column of test material from top to bottom is contained in the pipe that was carefully packed from top to bottom. With a ring infiltrometer the plastic sheet does not go all the way through the cap so lateral water movement is not precluded. The material was laid down by scrapers and then rolled, rather than hand packed. This kind of materials handling produces anisotropic permeability usually characterized by low vertical permeability and higher lateral permeability. The structure of the ring infiltrometer blocks the lateral permeability through the first 18 cm only. The assumption that the rate of water fall in the ring infiltrometer equals the amount of water penetrating vertically through the cap may thus not be valid at all times. Of course the rate of fall in water will be monitored when the infiltrometer is operated to compare the permeability inferred by the ring to that measured by other instruments.
The next series of devices are placed at four levels below the cap. About 20 and 40 cm below the cap are free draining lysimeters. These devices, shown in Figure 2, consist of five gallon plastic bucket with a drain at the bottom. The bottom of the bucket is filled with silica sand. Next is a layer of spoil material packed as closely to the density of the field placed spoil around it as possible. Water infiltrating downward through the vadose zone flows into the bucket and is collected. The pool of water that forms in the free draining sand layer at the bottom of the bucket flows into the attached PVC pipe water reservoir. The amount of water in the reservoir indicates the amount of water that successfully infiltrated through the cap and moved downward through the vadose zone. Of course one cannot preclude the possibility that water may move laterally, but it should be born in mind that these measuring stations are located on a four acre plot that is part of a 35 acre cap. Another safeguard against lateral water movement distortion is the placement of the free draining lysimeters at multiple levels. Lateral flow phenomenon usually occur at discrete levels. By placing the free draining lysimeters at multiple levels it becomes likely that the readings on closely located lysimeters will conflict if a lateral flow zone is located between the lysimeters, thus alerting investigators to the condition.

One weakness of the free draining lysimeter is that enough water must accumulate to form a perched water table above the sand layer and build up enough head to overcome the atmospheric pressure before water will be collected. Under dry conditions the water in the

![Schematic Diagram of Harco Style Lysimeter](image)
perched water table may be wicked back up and out of the lysimeter. Additional instrumentation is used to augment the Harco network against these problems. Time Domain Reflectometers (TDR) are to be placed at three levels over the deep lysimeter. TDR devices measure the dielectric constant of material by the rate at which electrical pulses are transmitted through the ground. Since the dielectric is strongly impacted by the presence of water it is possible to measure moisture content. By placing TDR probes at different levels the Harco instrument stations can measure the advance of the water front down to the free draining lysimeters, and if wicking occurs, back up out of the lysimeter. Changes in moisture content at different levels not consistent with either a descending or ascending water flow will signal possible lateral water movements.

The results of the TDR data are cross-checked by another instrument, known as a tensiometer, also placed at three levels. The negative pressure head characteristic of a vadose zone is a function of the degree of saturation of the soil. By measuring negative pressure heads it is possible to infer degree of saturation and thus the advance of an infiltration front through the vadose zone. Monitoring of infiltration front position by two independent techniques allows greater confidence in the data obtained.

The sluggish response of free draining lysimeters to small water flows is guarded against by the use of suction lysimeters. Where as a free draining lysimeter must build a perched water table and a pressure head in the soil before any water will be collected, a suction lysimeter uses a negative pressure in a collection tube with a porous cap to draw water out of the vadose zone and into the lysimeter. The amount of water that can be drawn at a given negative pressure indicates the amount of water available in the soil. These devices are placed at three levels to measure not only the position of the water front, but the amount of water that has reached a certain level.

One of the greatest strengths of the Harco network over that at Thunderbird is that the Harco network can resolve water filtering down from the cap from water moving laterally and perhaps not representing infiltration through the cap. The Harco cap is made of a single semi-homogenous material. Neither the material nor the construction technique was deliberately changed from one part of the cap to another. The material was handled by routine construction techniques as if it were a soil. There was thus no need to monitor the full cap and emphasis was placed on design of an instrument network that could obtain extremely precise and cross-validated data from a limited number of locations. At Thunderbird by contrast, there were seven 1 acre subplots, each made up of a different combination of ashes and soils that were mixed but never one material. A major issue at Thunderbird was whether routine construction equipment could produce a uniformly and reliably mixed and constructed cap over a large area. A limited number of sample locations could not give this kind of confidence. More-over, there was a need to establish that a wide range of soils could be treated with FBC ash; thus the need for so many subplots, each of which had to be monitored. While it would be nice to build 32 instrument stations of the sophistication at Harco, the cost would obviously be prohibitive for the budgetary constraints of ICCI.

At Thunderbird free draining lysimeters were used exclusively to measure infiltration. A rain gage provided data on precipitation. There was no way to know for sure that the water
entering a lysimeter actually came from directly above, but since the cap zone was large and the most likely lateral water flows would come from the sides of the plot, not across subplot boundaries, whether the lysimeter measured water penetration through the cap directly above or water infiltration through the cap from a location 50 feet away was rather unimportant to the interpretation of the data. The lysimeters were set in a line across the diagonals of each subplot. If large amounts of water flowed laterally into the lysimeters from the hill regions around the cap it would likely trigger high water flows in the boundary lysimeters, warning the investigators of the suspect data. Further the area to the side of the test plots was large enough relative to the size of the subplot that massive lateral water movements might trigger lysimeter infiltration readings around the edge of the plots higher than the rainfall, again alerting investigators to the suspect data. Finally, the first flush of water through FBC ash is calcium rich and high pH. Water from the surrounding regions was lower in pH and higher in iron and manganese. Thus the water in the lysimeters would have distinct chemical signatures to disclose its path of travel.

The lysimeters at Thunderbird needed to be placed beneath cap material placed by heavy equipment that was being operated in a normal fashion for large scale construction. In other words, lysimeters could not be placed beneath material that was hand placed and mixed or even by equipment that was decelerating and turning to avoid hitting lysimeter stand pipes. To make such a lysimeter network possible, it was determined to dig trenches before the cap was built and place long lateral pipe runs off from the lysimeter drains to stand pipes hundreds of feet away at the edge of the plot. Figure 3 shows a Thunderbird style free draining lysimeter. The video mentioned previously shows the construction of the lysimeter network. There was concern that heavy equipment driving over the buried lysimeters might break or damage them. To guard against this possibility, the bulb pressure of the tires at various depths was estimated from soil mechanics principles and the results were then discussed with and compared to the contractors previous field experience with "pumping" of buried debris to the surface. It was decided to bury the rims of the lysimeters 18 inches below the surface where the cap would be placed.

Data from the lysimeter network has been previously reported and discussed. Lateral infiltration from the edges of the plots was a problem in some locations, and in these locations the chemical signatures and water amounts relative to rainfall did indeed disclose the problem. The lysimeters in plots where functioning was normal recorded no infiltration the first year confirming that the tight impervious conditions desired had been achieved. In other subplots, however, all the lysimeters measured iron rich lower pH water in excess of the rainfall. Several lysimeters giving suspect data, particularly one near the center of subplot 4 where lateral water flow from the side should not have reached were dug up to determine if damage was responsible for the readings and whether the cap was in tact and the ground below it dry or very wet like the lysimeter was indicating. The cap was hard and difficult to penetrate with a backhoe and the ground below the cap was dry, but the soil deeper in the trench was wet and appeared to contain a perched water table. The problem experienced on some subplots was that the soil in the trench was not as tightly compacted when the trench was filled as the soil around it. This trench became a preferred channel for water flow and carried water in from the side of the subplot. The tight soil conditions around the trench formed a perched water table that would rise above the edges of the lysimeter collection basins during rainfall causing
readings of lateral water shed infiltration instead of infiltration through the cap. The data from several plots was totally useless because of this problem.

Figure 3. Schematic Diagram of Thunderbird Style Lysimeter

To compensate for the problem, 12 isolated lysimeters of the Harco style (Figure 2) where installed by digging small down gradient holes and digging up under the cap to place the collection bucket. For several plots, these new lysimeters will completely replace the data from the trench lysimeters, while for other subplots where the perched water problem does not distort readings the new lysimeters will simply function as a cross-check.

Another concern with the cap at Thunderbird was that FBC ashes expand significantly as they cure. Just as excess expansion in a highway can cause buckling, so to a strong and tight cap might be fractured and opened up by buckling. The thinner cap and mixture with soil were believed likely to keep this problem under control, and a previous test bed at Burning star had expansions of only a few percent. To make sure that heaving was not a problem, a network of subsidence monitoring points were installed and surveyed. If the cap swelled or heaved the monitoring points would raise, thus disclosing the problem. No indication of heave was found during the last year, which is consistent with the data from the now two year old test bed at Burning Star.
Experiments to Confirm That the Environment is not Damaged (Need #4)

The type of environmental damage most often cited as a fear in the use of combustion ashes is water contamination from toxic trace metals concentrated on the surface of fly ash particles. At Harco, the scrubber byproduct used has been tested continuously in leaching columns for over 4 years now. The decision to avoid the fly ash removed the concern about the only elements that seemed to leach in any harmful concentration, boron and molybdenum. The scrubber byproduct had also been used at as a substitute backfill at the Forsythe Energy site and had been monitored for 3 years and found to actually clean the groundwater. Despite definite indications of the environmental safety of the scrubber byproduct, a network of monitoring wells is to be installed and one monitoring well was put in before any construction for baseline data.

The lysimeters at Harco also have the potential of furnishing data on water that has immediately infiltrated through the cap (if any ever does get through). Free draining lysimeters have their reservoirs pumped out each time water level is measured. This furnishes more than enough water for analysis. Chemical and pH analysis of water entering the lysimeters at Thunderbird was used to determine where the water came from. On plots 6 and 7 where the ash was left in piles over the winter, run-off filtered into the ground and was collected in the lysimeters showing that the run-off from FBC ash is higher in sodium and potassium than water typical of the site, but that no usual other trace metals were found. Similar water samples may be available at Harco if any water is collected. In a vadose zone water adheres to the particles and water drawn out by a suction lysimeter will have been indirect contact with particles. The water samples from suction lysimeters will be much smaller in size and tend to be more concentrated since there is some dilution when enough water builds up to produce a regular flow such as that captured by a free draining lysimeter. One problem with water quality measurements on lysimeter samples is that the sample must slowly collect in a reservoir where it is open to air. Some parameter, particularly those influenced by dissolved gasses change rapidly on exposure to the air. EH and pH may change and influence the solubility of some elements. Although often this has no significant impact on water analysis, EPA sampling procedures guard against this source of error. This is one of the reasons that water samples are filtered and acidified in the field to make sure that dissolved trace elements are not lost or confused with suspended solids. It is the researchers opinion from observations at other sites and in the laboratory that there is not a serious problem with dissolved trace metal changes over the time intervals before collection in the case of combustion residues at mine sites, however, one should be aware that data from lysimeter samples may be attacked by some critics.

Because the questions of water contamination are stronger at Thunderbird than Harco, a network of monitoring points have been established along Briar creek to determine if run-off from the test plots only a few hundred feet away is influencing water quality. The sample points are simply locations chosen where researchers return each quarter to take a water sample. At Thunderbird the points were monitored for nearly a year before construction began and through a winter when the major water recharge events occurred.
RESULTS AND DISCUSSION

Review of Progress Toward Tasks

This project consisted of two tasks. First, there was to be monitoring of the Thunderbird FBC cap for performance in achieving low permeability while not shedding contaminants into the environment. Second, the Harco scrubber byproduct cap was to be instrumented and monitored.

Task #1

The first task promised the following types of monitoring:

1- monitoring of weather stations for rainfall. A single rain gage of the type described in the Experimental Procedures section has been installed at Thunderbird. Rain gage data is important to knowing the total rainfall available for infiltration. Comparisons between available and actual infiltration indicate whether the cap is performing effectively as a seal against water entry. Rainfall measurements during the year were key to knowing that lysimeter infiltration on plot 4 and other areas with problem lysimeters were collecting more than the total available rainfall.

2- monitoring wells. Monitoring wells measure the direction of flow and are used to determine if any unusual contaminants are entering the groundwater. The direction of groundwater flow is important because contaminants cannot be carried to locations were the groundwater does not go. In a site where other potential sources of contamination are present it is important to know where the groundwater from the test area is going. Another key use of monitoring well data is to determine upgradient water quality in order to distinguish pre-existing conditions in the water from those developed within the test area. Of course down-gradient wells can be compared to upgradient wells to determine if statistically significant changes in water chemistry have occurred. EPA has designed a test procedure for making this determination but it depends on carefully located monitor wells. To ensure that the EPA protocols could be used at the site it was first necessary to allow time for changes caused by construction activities around the test site to alter the water table, and second to understand the direction of water flow so that the water quality monitoring wells could be appropriately located. First a series of head wells were installed. These wells functioned to establish the depth to the water table. By establishing the pressure heads in different parts of the test area it is possible to know the direction of flow, since water flows from areas of higher pressure to areas of lower pressure. As soon as stable flow patterns appeared to be defined, the actual monitoring wells were put in place.

One unexpected boost in performance for the sampling network was that technicians under Dr. Esling identified parts sources that allowed them to build their own dedicated well pumps for less money than would be required for dedicated bailers. Monitoring wells are usually sampled either by repeatedly lowering small buckets down the well (about 2 inches in diameter) and purging water that has been sitting in the well to ensure fresh groundwater collection and then
taking the sample. The second way is to install a permanent bladder pump in the well and then use either compressed gas or a gasoline powered compressor to pump a steady stream of water to the surface. Not only does the bladder pump method save considerable personnel time (it can take all day for one person to sample 2 or 3 shallow wells by the bailer method), but it also produces a higher quality and more consistent sample.

One problem encountered in the monitoring promised in the proposal was with the timing. At the time of proposal writing the weather was dry and the construction of the test plots was promised to begin in later March or early April. In fact the wet spring of 1995 did not allow the plot construction to begin till late July. An extension on last years project provided for the plots to be finished as promised, but in this years project only the pressure head data for locating the groundwater monitoring wells could be obtained. All needed monitoring wells are installed but expected sampling data is not available. The completed monitoring wells are described in detail in the well completion reports constituting Figures 4 through 11. There is no problem with missing data since it is known from other measurements that no water seeped through the cap and only lateral water movements took place. This is one of the advantages of having multiply instrumented test sites since the instruments cross-check one another and allow assessment of whether missing or defective data is serious.

3- Monitoring a network of survey points. The test plots were equipped with a series of subsidence monuments. These devices a piece of rebar cemented into the ground below the frost line and protected by PVC pipe and insulation so that it is free to move up and down with the ground to which it is anchored. FBC ashes are notorious for expansive cementitious reactions. This is one of the factors that limit FBC ash in more lucrative markets such as concrete and highway construction. (Expansive reactions will buckle the pavement). In this project the FBC ash was mixed with soil that should both temper and act as a cushion against expansion. An issue that would none-the-less be raised was whether the cap would expand, heave, and fracture, destroying the integrity of the liner. No heave of expansion of the cap has been evident from the survey data, or visual observations of the surface. Test holes dug into the cap indicate excellent liner integrity and greater cementitious strength than expected.

4- lysimeter monitoring. The purpose of lysimeters is to capture infiltration through the cap and indicate the degree of impermeability or leakage taking place. Some of the lysimeters installed with last years project functioned properly and some did not. The problem of perched water tables in the trenches has been discussed in the Experimental Procedures section. Where the lysimeters functioned, there was no water collected which is consistent with a 100% effective cap. Where perched water tables flooded over the lips of the lysimeters the problem was detected and a supplemental lysimeter network was installed this year to replace the lost data. The new lysimeters appear to be functioning, though rainfalls this summer have not been heavy and more will be known when the major groundwater recharge season in December to February arrives.

The lysimeters yielded an unexpected piece of beneficial data. The contractor did not finish plots 6 and 7 till this year and the ash was stored in piles on these plots all through the winter. This allowed run-off from the piles to seep into the ground and be collected by the lysimeter network under the plots. This event has yielded what may very well be the only groundwater
**Department of Geology, Southern Illinois University, Carbondale, Illinois 62901**

**Well Completion Report**

<table>
<thead>
<tr>
<th>Site: Thunderbird Colleries</th>
<th>County: Williamson</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location: See location map</td>
<td>Well: #1</td>
</tr>
<tr>
<td>Drilling Contractor:</td>
<td>Date Drilling Began: 12-15-95</td>
</tr>
<tr>
<td>Department of Geology,</td>
<td>Date Completed: 1-30-96</td>
</tr>
<tr>
<td>Southern Illinois University</td>
<td>Geologist: L. Boren</td>
</tr>
<tr>
<td>Driller: L. Boren and D.</td>
<td>Drilling Fluids: None</td>
</tr>
<tr>
<td>Anderson</td>
<td></td>
</tr>
</tbody>
</table>

**Annular Space Details**

- **Type of Surface Seal:** Concrete
- **Type of Annular Seal:** Cement/bentonite
  - Amount of cement: 5 bags: lbs per bag: 94
  - Amount of bentonite: 5% by volume
- **Type of Bentonite Seal:** 0.25 in round
  - Amount of bentonite: 3 gallons
- **Type of Sand Pack:** Ottawa
- **Source of Sand:** Wedron Silica
  - Amount of Sand: 28 gallons

**Well Construction Materials**

- **Riser coupling joint:** PVC
- **Riser pipe above w.t.:** PVC
- **Riser pipe below w.t.:** PVC
- **Screen:** PVC
- **Coupling joint screen to riser:** PVC
- **Protective casing:** PVC

**Measurements (0.01 ft where applicable)**

- **Riser pipe length:** 40.0
- **Protective casing length:** N/A
- **Screen length:** 397
- **Bottom of screen to end cap:** 0.60
- **Top of screen to first joint:** 0.45
- **Total length of casing:** 45.5
- **Screen slot size:** 0.01 in
- **Diameter of borehole (in):** 6
- **ID of riser pipe (in):** 1.25

**Depths (0.01 ft)**

- **MSL Top of protective casing:** N/A
- **MSL Top of riser pipe:** N/A
- **Exposed casing:** N/A
- **MSL Ground surface:** N/A
- **Top of annular sealant:** 3.0
- **Top of bentonite seal:** 31.0
- **Total bentonite seal interval:** 2.0
- **Top of sand:** 33.0
- **Top of screen:** 37.5
- **Total screen interval:** 3.97
- **Bottom of screen:** 41.5
- **Bottom of borehole:** 42.0

Surveyed by: N/A

---

**Figure 4. Well Completion Report for Well #1 Thunderbird Site**
Well Completion Report

Site: Thunderbird Collieres
Location: See location map
Drilling Contractor: Department of Geology, Southern Illinois University
Driller: L. Boren and C. Hemingway
Drilling Method: Auger

County: Williamson
Well: #2
Date Drilling Began: 11-9-95
Date Completed: 11-9-95
Geologist: L. Boren
Drilling Fluids: None

Annular Space Details

Type of Surface Seal: Concrete

Type of Annular Seal: Cement/bentonite
  Amount of cement: 3 bags: lbs per bag: 94
  Amount of bentonite: 5% by volume

Type of Bentonite Seal: 0.25 in round
  Amount of bentonite: 3 gallons

Type of Sand Pack: Ottawa

Source of Sand: Wedron Silica
  Amount of Sand: 20 gallons

Well Construction Materials

Riser coupling joint: PVC
Riser pipe above w.t.: PVC
Riser pipe below w.t.: PVC
Screen: PVC
Coupling joint screen to riser: PVC
Protective casing: PVC

Measurements (0.01 ft where applicable)

Riser pipe length: 300
Protective casing length: N/A
Screen length: 397
Bottom of screen to end cap: 0.60
Top of screen to first joint: 0.45
Total length of casing: 35.5
Screen slot size: 0.01 in
Diameter of borehole (in): 6
ID of riser pipe (in): 1.25

Surveyed by: N/A

Depths (0.01 ft)

MSL Top of protective casing: N/A
MSL Top of riser pipe: N/A
Exposed casing: N/A
MSL Ground surface: N/A
Top of annular sealant: 3.0

Top of bentonite seal: 21.5
Total bentonite seal interval: 2.0
Top of sand: 23.5
Top of screen: 26.5
Total screen interval: 3.97
Bottom of screen: 30.5
Bottom of borehole: 31.0

Figure 5. Well Completion Report for Well #2  Thunderbird Site
### Anular Space Details

- **Type of Surface Seal:** Concrete
- **Type of Annular Seal:** Cement/bentonite
  - Amount of cement: 5 bags, 60 lbs per bag, 94 lbs in total
  - Amount of bentonite: 3% by volume
- **Type of Bentonite Seal:** 0.25 in by 3 in round
  - Amount of bentonite: 3 gallons
- **Type of Sand Pack:** Ottawa
- **Source of Sand:** Wedron Silica
  - Amount of Sand: 17 gallons

### Well Construction Materials

- **Riser coupling joint:** PVC
- **Riser pipe above w.t.:** PVC
- **Riser pipe below w.t.:** PVC
- **Screen:** PVC
- **Coupling joint screen to riser:** PVC
- **Protective casing:** PVC

### Measurements (0.01 ft where applicable)

- **Riser pipe length:** 40.0 ft
- **Protective casing length:** N/A
- **Screen length:** 397 ft
- **Bottom of screen to end cap:** 0.60 ft
- **Top of screen to first joint:** 0.45 ft
- **Total length of casing:** 45.5 ft
- **Screen slot size:** 0.01 in
- **Diameter of borehole (in):** 6
- **ID of riser pipe (in):** 1.25

### Depths (0.01 ft)

- **Top of protective casing:** N/A
- **Top of riser pipe:** N/A
- **Exposed casing:** N/A
- **Top of annular sealant:** 3.0
- **Top of bentonite seal:** 33.0 ft
- **Total bentonite seal interval:** 2.0 ft
- **Top of sand:** 35.0 ft
- **Top of screen:** 37.5 ft
- **Total screen interval:** 3.97 ft
- **Bottom of screen:** 41.5 ft
- **Bottom of borehole:** 42.0 ft

---

Figure 6. Well Completion Report for Well #3 Thunderbird Site
Department of Geology, Southern Illinois University, Carbondale, Illinois 62901
Well Completion Report

Site: Thunderbird Collieries
Location: See location map
Drilling Contractor: Department of Geology, Southern Illinois University
Driller: L. Boren and E. Chatterton
Drilling Method: Auger

County: Williamson
Date Drilling Began: 6-15-96
Date Completed: 6-15-96
Geologist: L. Boren
Drilling Fluids: None

Annular Space Details

Type of Surface Seal: Concrete

Type of Annular Seal: Cement/bentonite
   Amount of cement: 1.25 bags; lbs per bag: 94
   Amount of bentonite: 5% by volume

Type of Bentonite Seal: 0.25 in round
   Amount of bentonite: 4 gallons

Type of Sand Pack: Ottawa

Source of Sand: Wedron Silica
   Amount of Sand: 35 gallons

Well Construction Materials

Riser coupling joint: PVC
Riser pipe above w.t.: PVC
Riser pipe below w.t.: PVC
Screen: PVC
Coupling joint screen to riser: PVC
Protective casing: PVC

Measurements (0.01 ft where applicable)

Riser pipe length: 20.0
Protective casing length: N/A
Screen length: 397
Bottom of screen to end cap: 0.60
Top of screen to first joint: 0.45
Total length of casing: 25.5
Screen slot size: 0.01 in
Diameter of borehole (in): 6
ID of riser pipe (in): 2.0

Surveyed by: N/A

Depth (0.01 ft)

MSL Top of protective casing: N/A
MSL Top of riser pipe: N/A
Exposed casing: N/A
MSL Ground surface: N/A

Top of annular sealant: 3.0

Top of bentonite seal: 14.0
Total bentonite seal interval: 3.0

Top of sand: 17.0
Top of screen: 19.5

Total screen interval: 3.97
Bottom of screen: 23.5
Bottom of borehole: 30.0

Figure 7. Well Completion Report for Well #4 Thunderbird Site
Site: Thunderbird Colleries
Location: See location map
Drilling Contractor: Department of Geology, Southern Illinois University
Driller: L. Boren and E. Chatterton
Drilling Method: Auger

County: Williamson
Date Drilling Began: 6-15-96
Date Completed: 6-15-96
Geologist: L. Boren
Drilling Fluids: None

---

**Annular Space Details**

Type of Surface Seal: Concrete

Type of Annular Seal: Cement/bentonite
  - Amount of cement: 1.25 bags, lbs per bag: 94
  - Amount of bentonite: 5% by volume

Type of Bentonite Seal: 0.25 in round
  - Amount of bentonite: 2 gallons

Type of Sand Pack: Ottawa

Source of Sand: Wedron Silica
  - Amount of Sand: 20 gallons

---

**Well Construction Materials**

Riser coupling joint: PVC
Riser pipe above w.t.: PVC
Riser pipe below w.t.: PVC
Screen: PVC
Coupling joint screen to riser: PVC
Protective casing: PVC

---

**Measurements (0.01 ft where applicable)**

Riser pipe length: 200
Protective casing length: N/A
Screen length: 397
Bottom of screen to end cap: 0.60
Top of screen to first joint: 0.45
Total length of casing: 25.5
Screen slot size: 0.01 in
Diameter of borehole (in): 6
ID of riser pipe (in): 2.0

Top of bentonite seal: 12.0
Total bentonite seal interval: 2.0
Top of sand: 14.0
Top of screen: 16.5
Total screen interval: 3.97
Bottom of screen: 20.5
Bottom of borehole: 27.0

---

Surveyed by: N/A

---

**Depths (0.01 ft)**

MSL Top of protective casing: N/A
MSL Top of riser pipe: N/A
Exposed casing: N/A
MSL Ground surface: N/A
Top of annular sealant: 3.0

---

Figure 8. Well Completion Report for Well #5 Thunderbird Site
**Well Completion Report**

**Site:** Thunderbird Colliers  
**Location:** See location map  
**Drilling Contractor:** Department of Geology, Southern Illinois University  
**Driller:** L. Boren, E. Chatterton, and T. Lannert  
**Drilling Method:** Auger  
**County:** Williamson  
**Date Drilling Began:** 6-16-96  
**Date Completed:** 6-16-96  
**Geologist:** L. Boren  
**Drilling Fluids:** None

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<th>Annular Space Details</th>
<th>Depths (0.01 ft)</th>
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<tr>
<td><strong>Type of Surface Seal:</strong> Concrete</td>
<td>MSL Top of protective casing: N/A</td>
</tr>
<tr>
<td><strong>Type of Annular Seal:</strong> Cement/bentonite</td>
<td>MSL Top of riser pipe: N/A</td>
</tr>
<tr>
<td>Amount of cement: 1 bag: 94 lbs per bag</td>
<td>Exposed casing: N/A</td>
</tr>
<tr>
<td>Amount of bentonite: 5% by volume</td>
<td>MSL Ground surface: N/A</td>
</tr>
<tr>
<td><strong>Type of Bentonite Seal:</strong> 0.25 in round</td>
<td>Top of annular sealant: 3.0</td>
</tr>
<tr>
<td>Amount of bentonite: 3 gallons</td>
<td></td>
</tr>
<tr>
<td><strong>Type of Sand Pack:</strong> Ottawa</td>
<td></td>
</tr>
<tr>
<td><strong>Source of Sand:</strong> Wedron Silica</td>
<td></td>
</tr>
<tr>
<td>Amount of Sand: 20 gallons</td>
<td></td>
</tr>
</tbody>
</table>

**Well Construction Materials**

- **Riser coupling joint:** PVC  
- **Riser pipe above w.l:** PVC  
- **Riser pipe below w.l:** PVC  
- **Screen:** PVC  
- **Coupling joint screen to riser:** PVC  
- **Protective casing:** PVC

**Measurements (0.01 ft where applicable)**

- **Riser pipe length:** 30.0 ft  
- **Protective casing length:** N/A  
- **Screen length:** 397 ft  
- **Bottom of screen to end cap:** 0.60 ft  
- **Top of screen to first joint:** 0.45 ft  
- **Total length of casing:** 35.5 ft  
- **Screen slot size:** 0.01 in  
- **Diameter of borehole (in):** 6  
- **ID of riser pipe (in):** 2.0

**Surveyed by:** N/A

---

Figure 9. Well Completion Report for Well #6 Thunderbird Site
Annular Space Details

Type of Surface Seal: Concrete

Type of Annular Seal: Cement/bentonite
   Amount of cement: 0.5 bag: lbs per bag: 94
   Amount of bentonite: 5% by volume

Type of Bentonite Seal: 0.25 in round
   Amount of bentonite: 5 gallons

Type of Sand Pack: Ottawa

Source of Sand: Wedron Silica
   Amount of Sand: 20 gallons

Well Construction Materials

Riser coupling joint: PVC
Riser pipe above w.t.: PVC
Riser pipe below w.t.: PVC
Screen: PVC
Coupling joint screen to riser: PVC
Protective casing: PVC

Measurements (0.01 ft where applicable)

Riser pipe length: 20.0
Protective casing length: N/A
Screen length: 397
Bottom of screen to end cap: 0.60
Top of screen to first joint: 0.45
Total length of casing: 25.5
Screen slot size: 0.01 in
Diameter of borehole (in): 6
ID of riser pipe (in): 2.0

Surveyed by: N/A

Depths (0.01 ft)

MSL Top of protective casing: N/A
MSL Top of riser pipe: N/A
Exposed casing: N/A
MSL Ground surface: N/A
Top of annular sealant: 3.0
Top of bentonite seal: 9.0
Total bentonite seal interval: 3.0
Top of sand: 12.0
Top of screen: 14.5
Total screen interval: 3.97
Bottom of screen: 18.5
Bottom of borehole: 19.0

Figure 10. Well Completion Report for Well #7 Thunderbird Site
Annular Space Details

Type of Surface Seal: Concrete

Type of Annular Seal: Cement/bentonite
  Amount of cement: 3 bags: lbs per bag: 94
  Amount of bentonite: 5% by volume

Type of Bentonite Seal: 0.25 in round
  Amount of bentonite: 1.5 gallons

Type of Sand Pack: Ottawa

Source of Sand: Wedron Silica
  Amount of Sand: 12 gallons

Well Construction Materials

Riser coupling joint: PVC
Riser pipe above w.t.: PVC
Riser pipe below w.t.: PVC
Screen: PVC
Coupling joint screen to riser: PVC
Protective casing: PVC

Measurements (0.01 ft where applicable)

Riser pipe length: 40.0
Protective casing length: N/A
Screen length: 397
Bottom of screen to end cap: 0.60
Top of screen to first joint: 0.45
Total length of casing: 45.5
Screen slot size: 0.01 in
Diameter of borehole (in): 6
ID of riser pipe (in): 2.0

Surveyed by: N/A

Depths (0.01 ft)

MSL Top of protective casing: N/A
MSL Top of riser pipe: N/A
Exposed casing: N/A
MSL Ground surface: N/A
Top of annular sealant: 3.0

Figure 11. Well Completion Report for Well #8 Thunderbird Site
sample of ash-affected water that will ever be obtained in this study, even over the two year monitoring period that is now following this work. (The cap appears to be so effective that almost no water will ever pass through it.) This glimpse of water from the ash in the field indicates that the ash will release sodium and potassium in concentrations above the background for the site, but that the leachate has no apparent toxic trace metals. Although this result is not a surprise to the investigators who have done considerable in lab testing and even dissolved the ash directly into a small lake in the field, it may be quite startling to critics of ash use who have insisted that toxic trace metals would be released. Another ICCI project being directed by Dr. Paul Chugh on mixed minerals waste is yielding important information on why boron (which even the investigators would have expected to see) is missing.

5- Briar Creek Sampling. The network of sampling points along Briar Creek has been monitored this year as promised. It has been a focus of one of the quarterly reports which contains most of the key data obtained this year. Briar Creek could potentially be impacted by surface run-off from the cap or by contaminated groundwater. Obviously where water from the cap has not ever reached the groundwater there can be no groundwater effects this year, however, an effective cap will turn rain into surface run-off which will enter Briar Creek. One problem in studying Briar Creek for run-off impacts is that the pH of the once acid stream has improved so drastically that the solubility of many metals would be impacted. Elements that would not see significant solubility changes had to be selected for study. Fortuitously, the best candidate elements were sodium and potassium which are the very elements known to have leached from the ash piles that were on plots 6 and 7 during the winter. No changes in these element concentrations are evident in the stream. This could be because these elements naturally attenuate before reaching the stream or that water volumes from the test site are too small to have a detectable impact. At any rate the conclusion from this years monitoring of the Thunderbird FBC cap is that the cap has functioned completely and without any negative environmental impacts.

Task #2

Task #2 promised to instrument and monitor a scrubber byproduct cap at Harco.

Obviously it is impossible to instrument a cap before it is constructed. The cap was constructed by cooperating partners, not the investigators, and the cooperating partners did experience delays due to reorganizations within their own agencies. The DNR contractor, Gibbs Construction, has been wonderfully cooperative and helpful. This spring when the investigators met with the contractor to discuss their need to get the cap started so it could be instrumented the contractor changed his entire construction sequence to guarantee that the at least 4 acres of the cap would be done in time for the instrument stations to be set in place during the time of this project (in fact at the conclusion of this years project Gibbs has completed most of the 35 acre cap). A big earth moving contractor with a million dollar project that will change his plans for a whole construction season gives an idea of the quality of cooperation the investigators have received from DNR and their contractors.

Task #2 promised two monitoring stations and a network of groundwater monitoring wells. The design of the monitoring stations has been discussed in the Experimental Procedures
section. As this project officially concluded on Aug. 31, the two monitoring stations were installed (though not fully instrumented) and the monitoring wells were not installed. Installation of the cap and instrument stations and ordering of supplies occurred during the last quarter so data is not available. Clearly, it would be a mistake to have put the monitoring wells down until the impact of construction in the area had ceased changing groundwater flow directions. (The reason that monitoring wells must be installed into a known groundwater flow pattern has been previously discussed).

The most time consuming and difficult task in installing the instrument stations is placing lysimeters. This task must be coordinated with construction since the lysimeter must be under a portion of the cap built by normal construction techniques. At Harco this was done by having the contractor place the cap, digging a small hole and tunneling under the cap to place the lysimeter, and then sealing the installation hole. When the top soil cap is placed Gibbs Construction has agreed to work around the lysimeter stand pipes. This cooperation has made it possible for the stations to be installed during this project without the use of trenches which created the perched water table problems at Thunderbird. The TDR probes, tensiometers, and suction lysimeters can be installed in small auger holes. All this equipment has been ordered, though the investigators have been informed that delivery will occur around September 10. Although all well supplies have also been ordered, the wells should not be placed until construction has cleared the area. (There was time to place the wells before the Aug. 31 closing date but the risk of having well locations at sub-optimal locations was not considered wise since both Thunderbird and Harco are to be monitored for two more years).

All expenses associated with completing the Harco site network as promised have already been incurred. Even the labor has been arranged since graduate students agree to serve on projects in exchange for financial support during the summer months and the right to use data in developing their thesis. Thus in the case of task #2, Harco instrumentation, delays must be admitted, but these delays do not pose any risk in terms of financial obligations or the ability to perform the two year follow on monitoring study as promised.

CONCLUSIONS AND RECOMMENDATIONS

Ultimately the objective of any pilot demonstration study, such as this one, is to furnish the data necessary to make a practice ready for use by industry. In the case of this project, the ultimate goal is to have industry open a window for utilization of SO2 control byproducts with few current markets (unfixed scrubber sludges and FBC ashes). The four things that must occur for this market window to open have been discussed at the beginning of the Experimental Procedures Section. Both the Harco and Thunderbird projects have demonstrated that these materials can be economically handled to build the type of cap needed in many landfill and reclamation projects. It has also been established that FBC caps are highly effective after initial installation, and that there is no short term contamination to site ground or surface waters. Some longer term questions can only be answered by longer term monitoring such as ICCI has committed to fund for the next two years.

DNR has utilized the experience from the Thunderbird and Harco pilot projects, along with the environmental data generated, to begin and obtain EPA permits for 8 sites and hundreds of
acres of this type of work in Saline County. The Lake of Egypt power station has signed a long term commitment with DNR to supply unfixed scrubber byproduct to the sites. As a result SIP utilizes 100% of its scrubber byproduct and has dismantled the facilities for on site landfilling of the scrubber residue. SIP plans no landfilling of scrubber byproduct for the foreseeable future. With CIPs decision to dismantle the Newton scrubber, Lake of Egypt is one of three scrubbed power stations in the State. With a national average of 2% wet scrubber byproduct utilization, Illinois will now lead the rest of the country by an order of magnitude, since Dallman recycles their gyspum and SIP recycles their calcium sulftie byproduct.

Archer Daniels Midland is investigating installation of rail facilities for ash handling that will allow their ash to be shipped to reclamation sites around the state. If the DNR agreements piloted at Thunderbird come to full development, between 1/4th and 1/2 of the ADM ash byproduct will be recycled. Because the ADM agreement will involve considerable capital facilities investment it is proceeding with more caution. Also with FBC fly ash the question of dealing with fugitive dust in a moving field setting has not been resolved. An ICCI project for next year will develop a mobile field dust management system that should resolve the dust barrier.

Much of the credit for the very real commercial level changes that have already occurred in the state as a result of this project must be given to ICCI which financed data collection networks that DNR would not have been allowed to build and without which DNR could not have proceeded. Research alone, however, does not make success. Mr. Frank Pisani of the Department of Natural Resources has aggressively pursued the use of recycled materials within his agency and has set his division at the forefront of the nations abandoned mined lands programs in use of these materials. While ICCI provided the funding for the instrumentation of the Thunderbird and Harco field sites, the actual field construction was paid for by DNR. Opportunities for rapid development of beneficial use outlets for SO2 control byproducts are now available because of this project and because individuals like Mr. Pisani in DNR actually tried to develop the uses.

Industries using SO2 control products for true municipal and special waste landfill liners will probably wait for the long term performance and environmental data planned over the next two years with ICCI.

The project appears to have been successful not only in achieving the specific task goals of the research, but in achieving the ultimate goal of changing the way SO2 control byproducts are handled in industrial practice.

DISCLAIMER STATEMENT

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Notice to Journalists and Publishers: If you borrow information from any part of this fine report, you must include a statement about the State of Illinois support of the project.
PROJECT MANAGEMENT REPORT  
June 1, 1996, through August 31, 1996

Project Title: **USE OF FBC ASH AND SO₂ CONTROL BY-PRODUCTS FOR LINERS AND ALKALI SUBSTITUTES**

ICCI Project Number: 95-1/3.2A-5  
Principal Investigator: Dr. B.C. Paul, Southern Illinois University at Carbondale  
Other Investigators: Dr. S. Esling, Southern Illinois University at Carbondale  
Project Manager: Dan Banerjee, ICCI

**COMMENTS**

All funds for this project have been expended within the guidelines originally provided by ICCI. All work and supplies for the tasks in this project have been purchased.
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<th>Quarter*</th>
<th>Types of Cost</th>
<th>Direct Labor</th>
<th>Fringe Benefits</th>
<th>Materials and Supplies</th>
<th>Travel</th>
<th>Major Equipment</th>
<th>Other Direct Costs</th>
<th>Indirect Cost</th>
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*Cumulative by Quarter
CUMULATIVE COSTS BY QUARTER

Use of FBC Ash and SO₂ Control By-Products for Liners and Alkali Substitutes

\[ \text{Cumulative \$ (Thousands)} \]

\[ \text{Months and Quarters} \]

- ● = Projected Expenditures
- ▲ = Actual Expenditures

Total Illinois Clean Coal Institute Award $71,108
SCHEDULE OF PROJECT MILESTONES

A
B
C
D
E
F

S O N D J F M A M J J A S

Begin
Sept. 1
1995

Milestones:

A. Monitoring of Thunderbird FBC Ash Liner continues. (Task 1)
B. The cap and alkaline recharge is placed and instrumented at Harco. (Task 2, Part A)
C. The instrumentation is used to monitor the Harco site. (Task 2, part B)
D. Intensive planning of the rail receiving facility in Task 3 begins. (Task 3)
E. Specialized testing in support of NPDES permit modifications. (Task 4)
F. Report submission. (Task 5)

Comments:

None.