

## Statement of Problem

### Overview of Acid Mine Drainage

Abandoned mine land (AML) areas can contribute large amounts of acidity and toxic metals (chromium, cadmium, etc.) to streams and ground water exiting their boundaries. Rainwater recharge coming in contact with pyretic refuse gains acidity through oxidation reactions and becomes increasingly aggressive towards trace metals, which are mobilized into solution by acidic water. Evaporation during dry months also causes iron sulfate salts to be precipitated on the surface leaving soils that are too acidic for most vegetation. Lack of vegetation then leads to excessive erosion and further exposure of reactive pyretic refuse as well as silting of streams and lakes.

### Methods of Remediating Acid Mine Drainage

Since acidity and trace metal mobilization are two main problems associated with AMD, finding something to minimize them is a priority. Substances such as crushed limestone ( $\text{CaCO}_3$ ) are ideal alkaline materials that neutralize acidic water and immobilize trace metals. However, the alkalinity supplied by the limestone is limited and the larger clasts tend to accumulate iron precipitate on their surfaces rendering them un-effective in a short time.

Coal combustion byproducts (CCB's) are alkaline materials that can be used to increase pH and reduce trace metal mobilization. Their use has been questioned since CCB's contain varying amounts of trace metals themselves. However, CCB's could conceivably raise ground water pH high enough to reduce the dangers of trace metal mobilization caused by low pH. Fly ash is one of the major CCB's used as an alkaline fill material.

Fixated scrubber sludge (FSS) is another combustion byproduct that could prove to be very beneficial in dealing with AMD. FSS has a very low saturated hydraulic conductivity that makes it an ideal barrier to recharge through pyretic refuse.

There is a lack of suitable fill in abandoned mine lands due to the large amounts of pyrite and high concentrations of trace metals located in mine spoil. Alternative fill materials are expensive and hard to find. CCB's, such as fly ash, are abundant and may constitute a practical solution to the pH problem within AML sites. Obtaining permits for landfilling CCB's is currently very difficult. Therefore, it seems logical to place them back in places where they were first removed.

### Hypothesis

Based on the low saturated hydraulic conductivity of fixated scrubber sludge (FSS), it is presumed that this substance acts as an efficient recharge barrier. The hydraulic conductivity of FSS ( $K=10^{-6}$  to  $10^{-9}$  cm/sec, Mullin et al., 1976) is in the same range as clay ( $10^{-6}$  to  $10^{-9}$  cm/sec, Fetter, 1998), an ideal aquitard. Provided that an underlying layer of fly ash (CCB) produces an alkaline effect to pre-existing groundwater, the impermeable FSS should divert infiltrated rainwater to channels leading away from the site and solve many of the AMD problems. An FSS layer should also provide a capillary rise barrier during dry summer months that will restrict salts associated with mine spoil from reaching the surface and hampering vegetation growth.

## Study Area

### Location

The study area is state abandoned mine land (AML) No. 1087 which is commonly known as “Midwestern”. The site is located in the upper regions of the Patoka River watershed- Section 22, T. 2S, R. 7W, Pike County, Indiana (Figures 1 and 2).

### Mining History

In 1906, underground mining commenced in the western part of the study area. The Caledonia Mining Company began a separate underground mining operation around 1917 in the southeastern part of the study area (Spindler 1998). Although there is no clear record of when surface mining began, aerial photographs showing highwall pits indicate that surface mining existed prior to 1954. Surface mining continued until 1983 and coal processing (removal of excess sulfur) continued on the site until 1986. The coal processing plant left large amounts of coarse-grained pyretic refuse in the central part of the study area (Figure 1). A shallow aquifer was located within the refuse that produced acidic water during storms and periods of baseflow. The water exited through a series of gullies in the refuse that emptied into a tributary of the Patoka River.

### Reclamation

The reclamation process started on October 10, 1995. Very little re-grading was done except to lower the slope of the highwall along the southwest border of the site and to install a PALD to treat water exiting the adjacent underground mine workings. The reclamation plan included liberal usage of CCB’s as structural fill and capping materials (Figure 2). The capping material (FSS) was a special concoction of fly ash, gypsiferous lime, and other ingredients that upon drying, form a very impermeable material with a high resistance to fracturing (Mullen et al, 1976). The entire area, whether capped by FSS or not, was covered by a layer of soil material before being subjected to re-vegetation.

Three highwall pit lakes were located in the vicinity of site MW8 (Figure 1). These ponds were filled with fly ash to provide structural fill and help treat acidic water that might still be seeping from the underground mine workings. FSS was then placed over the ash fill in an effort to restrict recharge of the relatively shallow water table.

The area around MW7 contains a large deposit of coarse refuse consisting of coal and black shale that contains a higher pyrite concentration (Figure 1). The groundwater in the refuse is very acidic so FSS was used to restrict recharge of the groundwater in the refuse. By restricting recharge, the FSS layer would serve to minimize outflow of acidic water from the buried refuse deposit.

A large highwall pit was also located in the vicinity where site MW9 is now situated. The water in the pit was drained and then a very thick deposit of fly ash was emplaced to smooth the local topography. Reclamation engineers felt that an FSS layer was not needed at the location because the unsaturated zone is thick enough to hold all incoming moisture in storage without producing recharge of the saturated zone at the base of the deposit.

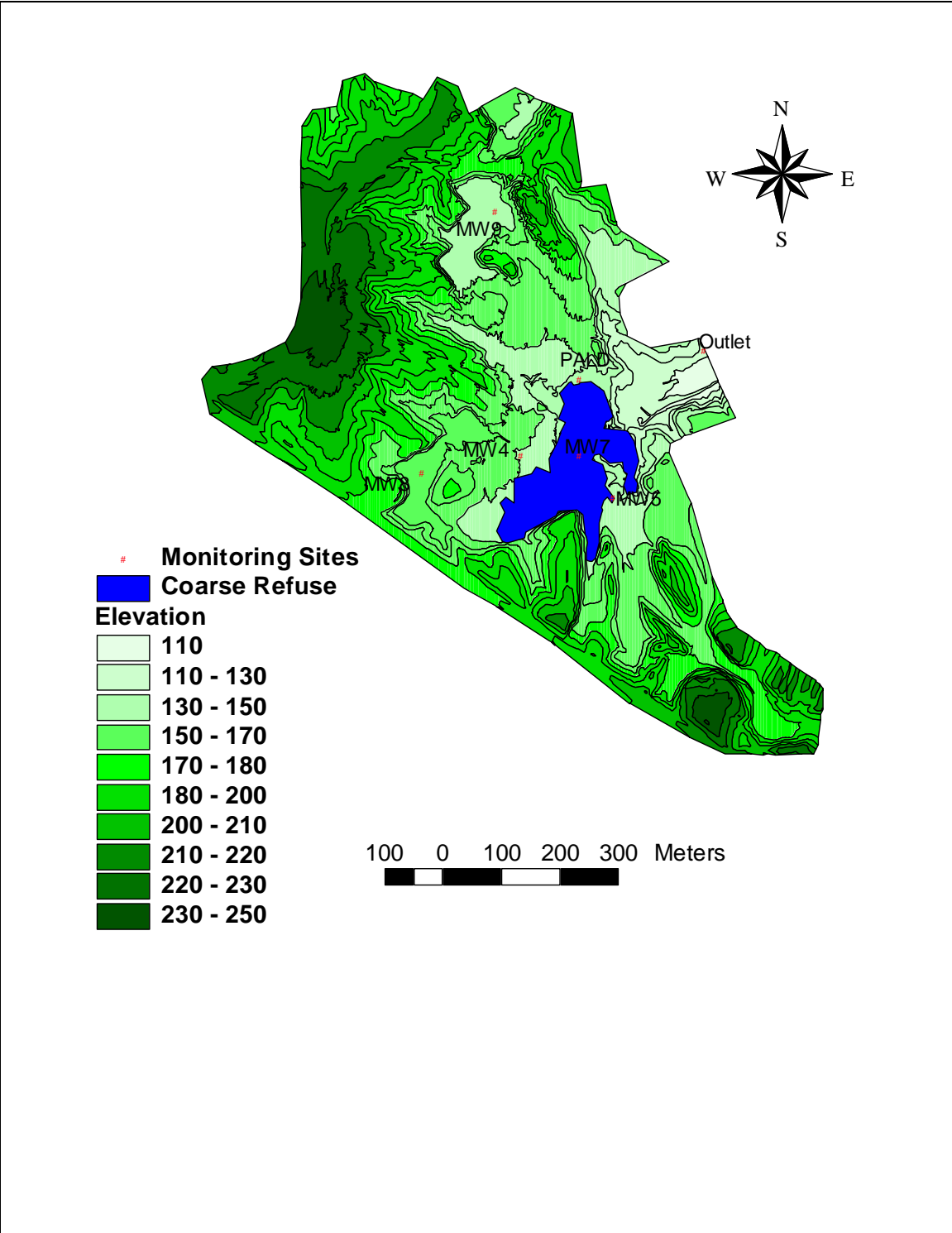


Figure 1. Map showing pre-reclamation topography, site locations, and coarse refuse deposit.

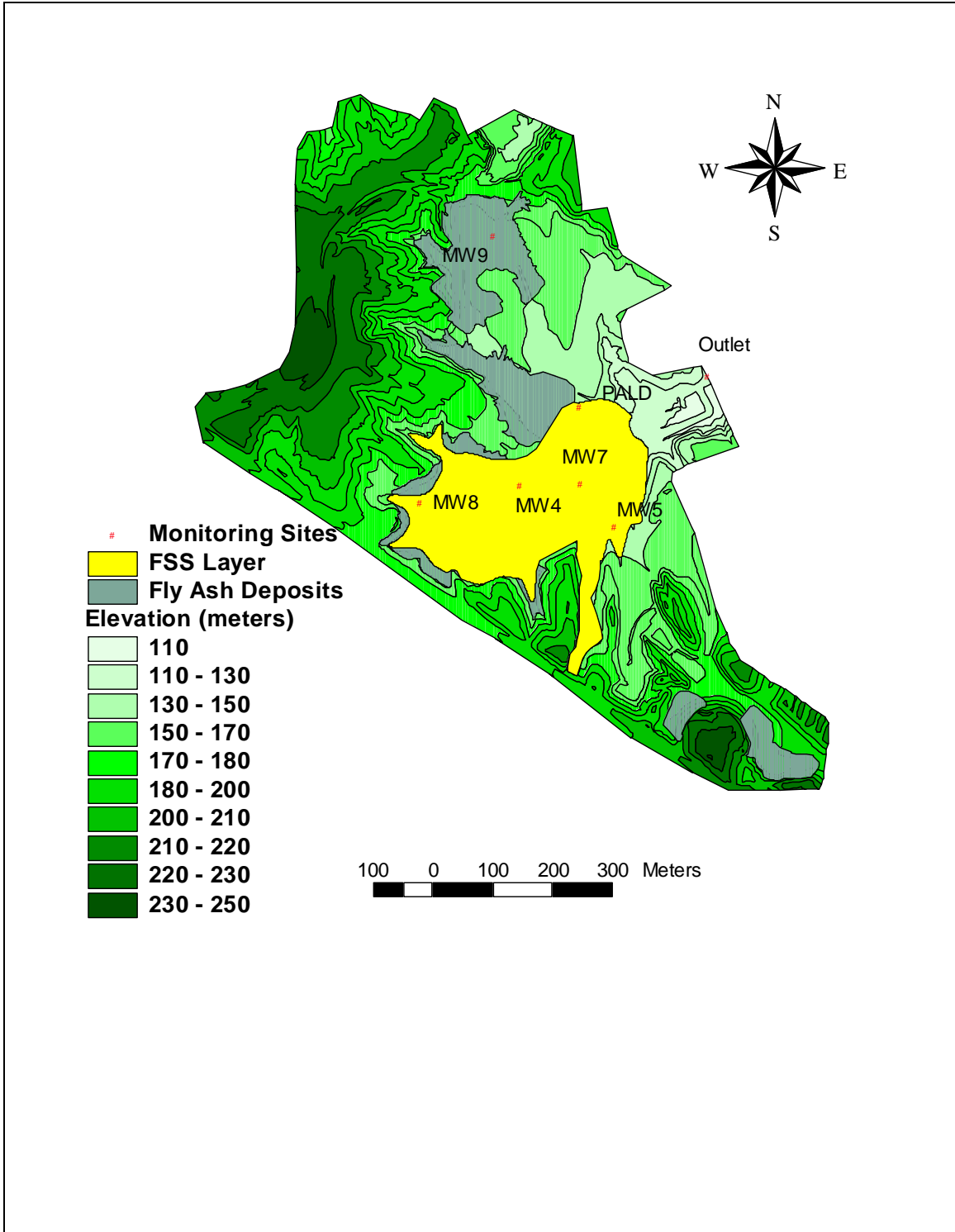
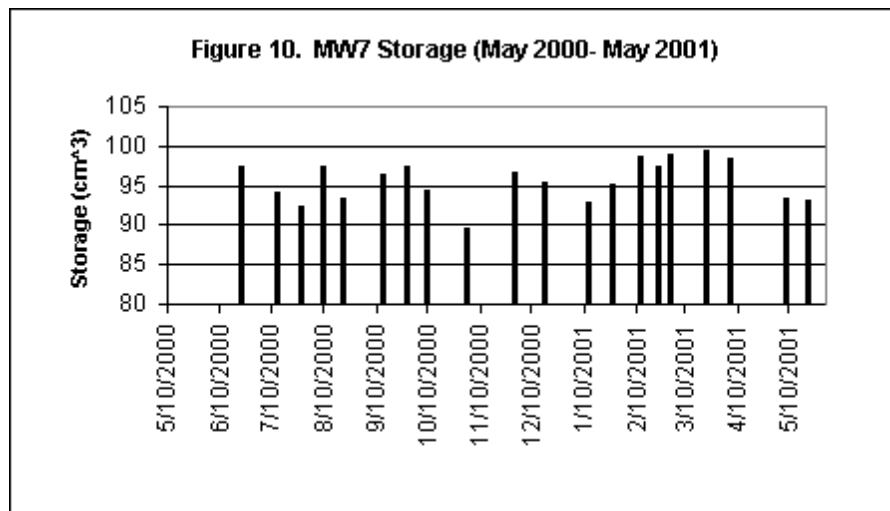
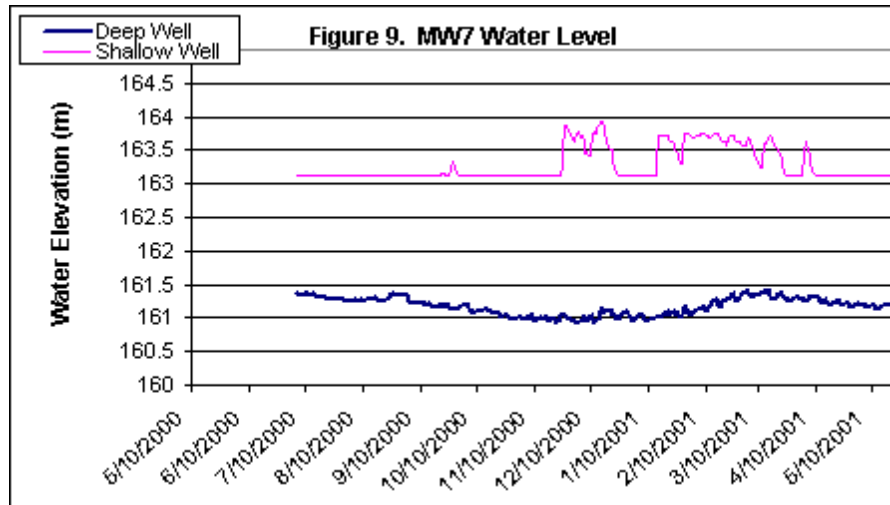


Figure 2. Map showing post-reclamation topography, site locations, FSS location, and fly ash locations.

## Water level and Storage

At monitoring site MW7 (Figure 2), there is approximately one meter of soil cover overlying a one-meter thick FSS layer. Under the FSS layer is a deposit of coarse pyretic refuse that is approximately 2 meters thick. The material underlying the pyretic refuse is unknown, but is most likely fine-grained spoil. Figures 9 and 10 display the water levels and storage for MW7. A shallow well is in soil cap material immediately above the FSS layer. The shallow well is dry most of the time, but a perched water table formed in late November at about the same time that a noticeable increase in storage was observed following a dry October where evaporation was the prevailing hydrologic activity. The perched water and storage data coincided closely throughout the winter months. Both showed a dry period in late December thru early January followed by a wet February and March. Note that the deep well (dark curve upper figure) does not show a substantial increase until late February and March indicating that it was not being immediately recharged by the same water affecting the shallow well and the overlying soil moisture.



## **Conclusion**

The FSS cap at MW7 is prohibiting the movement of soil moisture through underlying pyretic refuse and also limiting recharge to underlying groundwater. In doing so, the cap is restricting seepage of acidic water from the buried refuse. The thick layer of fly ash at MW9 appears to be limiting recharge of the underlying water table by holding soil moisture in storage. Some recharge was observed during the winter months, but it appears that lateral movement of water out of the old highwall pit is not yet occurring.

The results of this study illustrate some positive aspects of using coal combustion byproducts in reclamation. FSS acts as a recharge barrier so when applied over highly contaminated groundwater it prohibits outflow of acid mine drainage. There is also evidence that thick deposits of fly ash restrict recharge by holding moisture in storage, which is useful in areas where capping is not feasible.

Midwest website: <http://adamite.igs.indiana.edu/indsurv/research/index.htm>