Coal Combustion By-Product Tools and Mine Pools: Environmental and Geotechnical Engineering Comments from Maryland

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ABSTRACT

This report presents an overview of fifteen years of environmental observations of the legacy of three hundred and fifty years of mining in Maryland. Abandoned mines are observed not to be dead or static micro-ecosystems. The continuing environmental impacts of long abandoned mines are subject to sometimes insidious and sometimes sudden disastrous changes. Most of these changes are predictable by careful scientific observations. Each mine is unique and subject to some degree of improvement from an environmental point of view through restoration by astute application of modern geotechnical engineering. Long considered to be too costly to fix, many abandoned mines are written off as environmental derelicts of our past environmental insensitivity. The economic feasibility of restoring such mines using pozzolanic coal combustion products to create stabilized or solidified material meeting the requirements of the Environmental Protection Agency is discussed with a focus on the two most intensely mined coal basins in Maryland.

INTRODUCTION

In 1994 the Maryland Power Plant Research Program (PPRP) shifted its focus regarding research on ash management practices at Maryland power plants from one of monitoring disposal to one of promoting beneficial use. Prior monitoring clearly indicated that what had passed as ash management amounted to dumping the highest volume solid waste, fly ash, in its raw state on the power plant's "back forty". Such practice was not and never would be an acceptable environmental practice. Changing the name of the ash piles to storage sites did not alter the fact that their runoff polluted nearby streams with sediment and heavy metals. Further change of name to structural fill did not alter the fact that their leachate polluted ground water in the area with heavy metals.

Even the conventional methods of managing solid waste were deemed not appropriate for massive quantities of fly ash, a material that had close parallels in nature to loess and glacial flour in terms of physical properties. Thus, if placed in a containment, such materials are subject to uncontrolled movement if the containment is broken. Liners may actually make matters worse in the long term by generating differential pressures as ground water levels change or the integrity of the liners are breached by future activities of man.

Instead, the new focus of PPRP's research efforts was based on the closest parallel fly ash has in nature in terms of both its chemical and physical properties: **Volcanic ash**, the natural pozzolan**.** Maryland had a Pozzolan Management Statute in place requiring that pozzolan be used in accordance with sound engineering practices. There had been such limited use of pozzolan in Maryland that a core issue was to define what constituted sound engineering practice in its use. Pulverized coal fly ash produced at our power plants is actually a superior pozzolan in that the particle size distribution of the mix of glass cenospheres in the fly ash and free lime accelerators readily available in Maryland produces a very flowable self compacting material that cures into a solid monolith with favorable leaching characteristics in the same time frame that concrete cures. Hydraulic conductivities lower than those observed for unfractured shale and clays were observed for such stabilized or solidified coal combustion by-products (CCBs).

The above observation suggested beneficial use research efforts in three areas. In each case our CCBs would end up as stabilized or solidified material that is benign to the environment. The three elements of PPRP's CCBs beneficial use research program are:

1. Augment the efforts of our power plant operators to move CCBs to Maryland's large cement manufacturing and cement products and building products industries.
2. Promote displacement of expensive Portland cement and chemical grouts with CCBs and high free lime content waste products of industry in the most massive

geotechnical engineering applications of the conventional products: Admixture stabilization, in situ stabilization, grouting, and construction of cut offs.

3. Promote a whole new industry of mine restoration in Maryland and the Appalachian Highlands to consume the excess of Class F fly ash that would still be available.

The following is a candid report on success and failure in PPRP's beneficial use research efforts.

CONTEXT OF MARYLAND POWER PLANT RESEARCH PROGRAM RESEARCH IN THE BENEFICIAL USE OF CCBs

PPRP was established in 1971 essentially as a technical program to assist the Maryland Public Service Commission in licensing power plants. PPRP's primary role is to conduct joint reviews of applications to build or modify grid connected power plants in Maryland. It is funded by a small environmental surcharge on electricity sold in Maryland. Within severe budget limitations PPRP conducts research on persistent environmental issues associated with Maryland power plants. One of those issues is CCBs, particularly fly ash because of the large volume produced.

In the early 1990s PPRP was processing an application to the Maryland Public Service Commission from AES Warrior Run, Inc. (AES) to construct a coal fired fluidized bed power plant near Cumberland, Maryland. Based on earlier observations of ash management practices in Maryland PPRP recommended the license for the new plant contain a condition that its ash management plan provide for no ash storage (even temporary) at the plant site and no land filling of its ash. All ash was to be returned directly from the plant's silos to the coal mines from which its fuel was derived and put to constructive use. Such constructive use was to be incorporated into the reclamation plans for the mines supplying coal to the plant and monitored under permits issued for these mines like any other mine permitted under the Surface Mining Control and Reclamation Act (SMCRA). After a directed study of coals used and ash produced at existing fluidized bed power plants and coals proposed to fuel the Maryland plant AES submitted such a plan on June 10, 1994. The plan (AES, 1994) was approved for the plant's construction and operation and there have been no significant environmental incidents relative to the plant's ash management in a decade of operation. In a companion study (PPRP, 1994) PPRP identified technology developments and environmental and transportation issues that would guide research on returning ash to mines for mine restoration.

The Class F fly ash produced at our larger power plants in the Baltimore/Washington area presented far more significant problems. Both the coal fly ash and the wastes (both liquid and solid) that could be stabilized are highly variable. It is therefore necessary to do laboratory tests of all combinations before recommending larger scale applications or recommending final procedures. Results at full scale stabilization sites must also be verified by laboratory test results. Budget constraints do not permit a significant portion of PPRP's beneficial use program to be carried out at commercial laboratories. PPRP has therefore established a soils and material science laboratory at Frostburg State University (FSU). This laboratory is operated under contract by the Western Maryland Resource Conservation and Development Council, Inc. (RC&D), a not-for-profit organization sponsored by the U.S. Department of Agriculture. FSU has also established a capability to reliably duplicate various leaching tests including the Toxicity Characteristic Leaching Procedure (TCLP) tests at a small percentage of the cost of doing these tests in commercial laboratories. This permits PPRP to comply with ASTM E 2060-00 in zeroing in on acceptable results before submitting only final recommended combinations or procedures to commercial laboratories for certified results.

ACKNOWLEDGEMENTS

PPRP is and will remain highly dependent on its partners to carry out larger demonstration projects. We gratefully acknowledge the support we have received from the Department of Energy, the Office of Surface Mining, the U.S. Fish and Wild Life Service, the Fish and Wild Life Foundation, Carmeuse of North America, our power plants and numerous western Maryland industrial entities.

In addition to monetary support and in kind services in the field from the above organizations PPRP is grateful for the dedication with which Environmental Resources Management, Inc. (ERM), iLF Consultants Inc. (iLF), and Hemmings & Associates (H&A) have supported our projects for more than a decade.

Special and grateful mention is also made of the work of the National Research Council's Committee on Mine Placement of Coal Combustion Waste. PPRP and ERM made presentations to the Committee's meeting in Evansville, Indiana, to stress two important points: 1) To take advantage of the pozzolanic properties of fly ash and only use it in mines as stabilized or solidified material and 2) Individual mine site characterization was very important to avoid undesirable consequences. We were disappointed at the indifference with which our presentations and the early results of our Winding Ridge experiment were received. The Committee Chairman noted our concern and personally apologized to me saying we were dealing with the issue with such a firm hand that our approach might not yet be appreciated. In the end we failed to make our first point. The Committee's final report (National Research Council, 2006) does not even include the word pozzolan in its glossary and makes just limited mention of cementation. On our second point however the Committee has provided valuable work. Their final report is an important collection of incidents where mine placement of CCBs produced undesirable consequences. In addition, their report contains very helpful summaries of data, comparisons of regulations, and a synthesis of issues relative to mine placement of CCBs.

ELEMENTS OF THE MARYLAND POWER PLANT RESEARCH PROGRAM RESEARCH IN THE BENEFICIAL USE OF CCBs

ELEMENT 1: USE OF CCBs IN THE CEMENT MANUFACTURING AND CEMENT PRODUCTS AND BUILDING PRODUCTS INDUSTRIES.

Promotion of use of CCBs by our industries was quickly recognized as a marketing activity severely constrained by the cost of transportation. PPRP created a special brokerage that maintained expertise in materials handling and transportation with an assignment to augment the efforts of our power plant operators and their brokers. In anticipation that our largest power plants would have to install scrubbers the brokerage pursued selling gypsum from a nearby out-of-state power plant as a surrogate for Maryland produced gypsum and has succeeded in moving 500,000 tons of gypsum to the cement industry. This proved of great importance as Maryland scrubbers are coming on line just as the normal sales of gypsum to wallboard plants is weak due to the housing industry slump. The movement of Maryland produced fly ash to our cement industry and nearby cement plants has been greatly improved. The special brokerage continues to daily work out obstacles that come up in the regular movement of CCBs to industry. The construction of barge facilities at our largest coal fired power plants to import coal opens up a broader geographic market for Maryland produced CCBs via marine transportation.

ELEMENT 2: DISPLACEMENT OF PORTLAND CEMENT AND CHEMICAL GROUTS IN MORE MASSIVE GEOTECHNICAL ENGINEERING APPLICATIONS.

Admixture Stabilization is the modern geotechnical engineering term for old fashion soil cement technology. (Portland Cement Association, 1956) PPRP partnered with Carmeuse of North America to investigate use of lime or lime kiln dust with fly ash as a substitute for expensive Portland cement to stabilize problem soils. We were successful in getting the Maryland Highway Administration to consider this as an alternative to removal and replacement of problem soil in the rebuilding of I-95 in Maryland. The Federal Highway Administration has also provided matching funds to augment our research on various applications of CCBs in a broader research program at the University of Maryland College Park.

A second important admixture stabilization application of fly ash in Maryland is to stabilize dredged material. Our laboratory work shows that a ten-to-one mix of dredged material with a ten-to-one mix of fly ash and free lime will produce a final solid monolith with such favorable leaching characteristics that the method can be used to make even contaminated dredged material suitable for innovative reuse. Maryland will produce about 20 million tons of dredged material from the harbors and channels of the Chesapeake Bay each year. This application could consume all of Maryland's excess annual production of fly ash and result in mining some of our legacy piles of fly ash. The Maryland Port Administration is advertising an open ended Request for Proposals seeking treatment of 5000 cubic yards of dredged material now in the Cox Creek dredged material containment facility near Constellation Energy's Brandon

Shores Power Plant. Carmeuse has investigated this opportunity at length with PPRP and is seeking a construction company partner to respond to the Port Administration's Request for Proposals.

In-Situ Stabilization entered the lexicon of geotechnical engineering in the 1970s and 1980s as a method of improving the engineering properties of soil at depth by injecting and mixing Portland cement or other stabilizing agents with native soils or fill with special machinery. (Coduto, 1998, p.678) PPRP has taken a special interest in the method to stabilize structural fills of fly ash that are leaching at unacceptable levels into nearby groundwater. The problem is to get near uniform mixing of a slurry of lime and water with the fly ash to depths over 100 feet. Modeling the various machines available for in situ mixing to obtain reliable reproducible results at laboratory scale has proved to be challenging. There are numerous other applications for in situ stabilization in which fly ash and lime kiln dust might be the stabilizing agent making it cheaper. At lower cost it could be more widely used to environmental advantage.

Grouting as discussed here refers to the geotechnical engineering applications of injecting special liquids or slurries into the ground for special engineering purposes such as reducing the hydraulic conductivity of a region. (Coduto, 1998, p.676) Traditional grouts are either cementitious (employing Portland cement that hydrates after injection) or chemical (solidify with time or other factors once injected). PPRP's research in this area is aimed at doing demonstrations using coal combustion by-product (CCB) grouts in lieu of traditional grouts in environmentally beneficially applications that would otherwise not be completed due to the high cost of traditional grouts. Demonstrations have been completed in two of the four principal grouting methods discussed below. Clearly a precise knowledge of site conditions in the region to be grouted is paramount regardless of the grout material used.

- **Intrusion Grouting** commanded PPRP's attention as the potential highest volume user of CCB grout of the four grouting methods. Also Maryland had an outstanding candidate for intrusion grouting to reduce the hydraulic conductivity in the region around two abandoned mine shafts at Kempton, Maryland. Two 420 foot mine shafts had been sunk there between 1911 and 1914 to serve Kempton Mine No. 42. One, the Manshaft, was used to harvest ground water for the Town of Kempton during the 46 year period the mine was pumped down from 1914 to 1950. Historical records reported production of 144,000 gallons of water per day from a water ring in Manshaft at the 178 foot level. It was likely the other shaft produced a similar amount. When the mine was closed in 1950 and was allowed to flood the water level did not return to the original regional water table elevation of 1980 feet but stopped at 1951 feet due to discharges from Mine 42 a mile away at this elevation. This resulted in large cones of depression around the mine shafts at Kempton next to the North Branch of the Potomac River. This causes a major losing reach in the North Branch and placed great stress on sensitive wetlands in the area during droughts. PPRP first requested approval to backfill the two shafts with CCB grout as a fail-save method of preventing their eventual collapse and eliminating the cones of depression under the river and the wetlands. Our regulatory authority would not approve of this option. They did approve of intrusion grouting around the Manshaft which might reduce its cone of depression and reduce some of the acid mine drainage flowing from the mine. It was quickly noticed in drilling the field of grouting holes around the Manshaft that communication between drill holes up and down dip were nearly that of open channels. Fist-size rocks were blown from drill holes up to 40 feet from drill holes under pressure. This suggested a formation of unidirectional transmissivity, too fractured or too badly eroded by piping to hold grout up and down dip from the shaft. Never-the-less we went ahead with grouting using the thickest grout of 100% CCBs we could mix and move through grout pipes. Monitoring the site proves that we have reduced the hydraulic conductivity of the formation around the shaft. A full report on this project is in preparation.

- **Permeation Grouting** is traditionally done with expensive liquid chemicals to get the chemical into small void spaces either under pressure or due to their expansive properties where it cures to a solid achieving the desired change in hydraulic conductivity. PPRP's research proposed to determine if some applications of chemical grouting could be displaced by extra thin fly ash grout and achieve acceptable results. The U.S. Bureau of Mines had experimented with chemical grouting to seal a stream in Maryland that was lost to mine subsidence. The experiment failed due to continued subsidence. The Bureau personnel involved were transferred to DOE when the Bureau was disestablished but were interested in trying their experiment again where subsidence would not be an issue. The opportunity for parallel chemical and fly ash grout experiments was present at a valuable trout stream, Hoyes Run, and the Keystone Quarry in Garrett County, Maryland in 2002. After years of pumping down the quarry solution channels and cavities had developed in the limestone formation between the streambed and the quarry. Erratic flow in these channels caused the entire flow of the stream to be lost to the quarry during annual periods of low flow. After geophysical surveys DOE reasoned that these cavities and channels had at least partially filled with porous stream debris and sediment and could be closed by chemical grout. PPRP had entered into a Cooperative Research and Development Agreement with DOE and it was agreed DOE would attempt chemical grouting of the solution channels with entries in the streambed and in the stream bank adjacent to the quarry. PPRP would attempt fly ash grouting of channels with entries in the stream bank away from the quarry. As the DOE chemical grouting contractor went about his work an undesirable consequence confronted us. The expansive power of the chemical grout was so great it lifted the bedrock in the stream bank and streambed opening partings in the bedrock making stream flow losses even greater until the entire stream was lost. Chemical grouting was terminated and the entire problem was left for PPRP to try to fix with CCB grout. We now had a problem best described as **channel grouting** since most of the channels were now gulping water in a loud and hungry manner with the sound of water moving several feet down in the channels. Each channel entry was carefully marked as the stream flow diminished with the season. We did not want to attempt injecting CCB grout in the flowing stream as pH spikes would be lethal to marine life.

Late in the season when all the stream flow was being taken by the two uppermost solution channels CCB grout was injected into each marked channel entry that was now dry. Some took a few cubic feet of grout and some gulped grout like they had gulped water taking several cubic yards until they stopped gulping and filled to the level of the streambed. Channel entries in the streambed were filled first to allow the time for their surfaces to cure before water would flow over them. Entries on the stream bank were then filled. Finally the two entries taking all the stream flow were sand bagged off and the stream flowed through the entire former loss zone with no apparent loss of flow. These last two entries gulped several yards of CCB grout before filling to the level of the stream bed. The next morning the sand bags were removed leaving a very natural appearing streambed with no loss zone. A final report with details of this work is in preparation.

- **Compaction Grouting** or displacement grouting as it is sometimes called involves injection of a very stiff grout under high pressure into the ground to form inclusions that compact the adjacent fill or soil. It is most frequently used to arrest active subsidence or correct settlement by raising structures back to acceptable levels. Obviously its use frequently involves major liability issues. For this reason PPRP has found it difficult to find a partner to develop a demonstration experiment using CCB grout for this purpose. A private property owner adjacent to the FSU campus has built student housing on land with an uncertain mining history and is experiencing major subsidence problems. He has resolved the liability issue for the present by agreeing to pay for exploratory drilling on his property. Our detailed mapping of coal seams and abandoned coal mines show his property mostly over an important coal seam. Initial drilling reveals his housing is built on a thin layer of gravel over highly variegated groups of fill materials in what may have been an early surface mine or near surface mine. Our laboratory work suggests that CCBs may offer the flexibility to create the variety of grouts that may be needed to fix the settlement issues this property owner is experiencing at a price he can justify but could not justify using traditional Portland cement grout. Our assessment of the appropriateness and risk of compaction grouting at his location is on going.
- **Jet Grouting** is a kin to in situ stabilization discussed above. (Coduto, 1998, p.677). It may be viewed as inserting an auger into the ground and distributing grout via a hollow auger stem and channels in the final auger flight as the auger is withdrawn. PPRP has not found an opportunity to demonstrate such grouting at large scale using CCB grout. Our laboratory work does suggest that the improved flowability of fly ash grout will permit design of machinery to go deeper which may be important in its many applications.

Construction of Cutoffs is likely to be very important during the planned construction of mass transportation facilities. (Coduto, 1998, p.274) Cutoffs could also become very important to the ash community to manage water movement at the many contaminated sites we have created with improper ash storage and disposal. In all four forms (**diaphragm walls, slurry trenches, secant drilled shaft walls, and tremie seals)** cutoffs use particularly massive amounts of Portland cement. Our laboratory work suggests their material cost could be cut in half by substituting CCBs and high lime content waste products for Portland cement in their construction. Actual cost will be site sensitive because so much of the cost regardless of product used is associated with transportation.

The cost issue is complicated by a very important infrastructure problem. Much of the ready-mix industry is not set up to receive and mix fly ash and other CCBs whether to make flowable fills, CCB grouts, or other CCB substitutes for concrete. PPRP is fortunate that Cumberland Concrete in Cumberland, Maryland has seen fit to dedicate two silos at a no longer used batch plant to stock high lime content bed drain ash and bag house ash from the Warrior Run Power Plant near Cumberland to make custom mixes for PPRP demonstration projects. Resolution of this infrastructure problem is important to every power plant to maximize direct movement of fly ash to the ready-mix industry.

ELEMENT 3: MINE RESTORATION

Maryland will produce at least 2 million tons per year of Class F fly ash for the remaining economic life (35 to 50 years) of its pulverized coal fueled power plants. Even with outstanding success in Elements 1 and 2 of our beneficial use research there will be at least a million tons per year left over for other uses. Such uses would have to be massive to consume this much material for up to 50 years. One end use that could use this much material and would be highly beneficial to Maryland was identified: **Mine Restoration**. Maryland has a long history of mining going back to mining iron ore in colonial times followed by clay mining to support pottery and brick industries, sand and gravel mining, limestone and building stone mining, and intense coal mining starting in the early 1800’s. Two potentially practical approaches to mine restoration were examined:

1. Use fly ash stabilized or solidified by addition of free lime from high lime content waste products of our cement, lime, and limestone industries. Our laboratory work showed that a ten-to-one mix of fly ash with the free lime content would provide a reliable engineering material comparable to flowable fills already in use or could be mixed in place using conventional soil cement technology.
2. Use the above mix in a one-to-ten ratio to stabilize or solidify dredged material for use in mine restoration. Maryland will produce about 20 million tons per year of highly variable dredged material each year. The Maryland General Assembly has requested the Maryland Port Administration to examine alternatives for innovative reuse of dredged material. PPRP represents the Maryland Department of Natural Resources on a State Committee for this purpose. Our laboratory work suggests several advantages to using fly ash in this manner. The numerous large pit mines available that could be served by low cost marine and pipeline or conveyor transportation are sufficient to use the quantities of material involved for more than 50 years.

Studies to advance these approaches to mine restoration have been tailored to fit within the small budget PPRP could dedicate to a massive use of fly ash. Initial findings revealed numerous problems and limited incentives for a meaningful mine restoration program to be undertaken in Maryland:

- The State's inventories of abandoned mines were very inaccurate.
- The precise location of many underground mines was unknown.
- The characteristics of abandoned mines, particularly as related to their hydro-geology, biochemical, and environmental interactions, were poorly understood.
- Any mine restoration activity must be especially sensitive to impact on water quality and potential for causing mine blowouts.
- The long term impact of acid mine drainage and attempts to treat it are especially poorly understood. Acid mine drainage by itself produces large amounts of sediment which destroys habitat for benthic marine life which is the start of the food chain for fish. Our attempts at in stream treatment with limestone drum plants and lime dosers and dumping limestone in streams just increases the amount of sediment in our streams. Major hydraulic events move the sediment downstream to our reservoirs where it destroys reservoir capacity intended for flood control and water storage.
- A major Works Project Administration Mine Sealing Program in the 1930s had failed to reduce acid mine drainage.
- The Maryland Abandoned Mine Reclamation Plan (Maryland Department of Natural Resources, 1982) prepared by the Maryland Bureau of Mines (then a part of the Department of Natural Resources) and approved by the Office of Surface Mining in 1982 gave Maryland primacy over its Abandoned Mine Land activities but was of limited scope because of limitations in SMCRA.
- There was no State or Federal program or source of funds for restoration of underground mines. SMCRA was limited to dealing with priority health and safety problems.
- PPRP would be requested to review and make recommendations on an AES request to license a fluidize bed coal fired power plant at Cumberland, Maryland, that would produce up to 400,000 tons per year of self cementing CCBs.
- Maryland shares two large underground mine complexes (Kempton/Coketon and Crellin) with West Virginia. Any restoration of these complexes would require interstate coordination.
- A very insidious problem developed as our environmental ethic grew. Mining became unpopular. Our mines and mining legacy were put in the closet to be hidden behind fences and visual barriers like automobile junk yards. The bureaucracies responsible for them were stripped of resources to the point they could not even enforce patching the fences. So a big pit exists in downtown Baltimore with dozens of holes in the fence and a dangerous lake next to high walls inside, a recipe for drowning children. In another case a commuter driving his usual route to work dies as he drives into a sinkhole that formed over night in karst topography next to a limestone quarry. In the Georges Creek Coal Basin an old coal mine blows out and kills all the fish in Georges Creek for four miles. On that

same hill a high wall in a surface mine collapses and kills two miners. The Federal investigation blames it on subsidence in an old deep mine.

Based on these observations PPRP conviction to continue the mine restoration research begun in 1994 remains stronger than ever even with mounting problems for Maryland electric power industry and demands on our budget. We encourage others to join us since ash characteristics are unique to every coal burned and every power plant that burns coal. In the same way site characteristics for every mine to be restored are unique to every mine. Each of us must do our own homework. We are pleased to outline what we have done in our small program in Maryland hoping it will motivate programs in other states. PPRP looks most of all for a persistent program of mine restoration at the Federal level particularly as it relates to abandoned deep mines in the eastern United States.

1. The **Winding Ridge Project** (Rafalko, 2000) consisted of bulk filling the small Frazee Mine with a self cementing mixture of CCBs and mine water and monitoring its environmental performance for ten years. A ten year report (Lee, Rafalko and Giacinto, 2008) on the project has recently been issued. For PPRP it became proof of concept that such backfilling could be completed with conventional construction equipment at reasonable cost and result in greatly reduced acid production in mine tunnels subject to the passage of water. Aside from serving as a proof of concept, the Frazee Mine represents one small mine that has been "fixed" in that what was once produced a continuous large black scar on the wall of Bear Creek Canyon does so no more.
2. A **Geographic Information Service** was created and is operated by contract in the Department of Geography at FSU to collect, organize, and geo-reference historical mine information and retain same in a data base of core logs, overburden analysis and other information useful to characterizing mines for restoration. Special studies and staff support to PPRP have been provided since 1998. Some details of their work are presented in the Poster Session of this Conference.
3. A **Soils and Material Science Laboratory** was created at FSU and operates by contract under the RC&D to do the extensive testing required to evaluate the numerous combinations of CCBs and materials that may be stabilized or solidified. **Characterization of CCBs** is a never ending task as sources of coal shift at our numerous power plants.
4. A **Library Project** was created at the Ort Library at FSU to encourage collection, preservation, cataloguing, and interpretation of Maryland's coal mining industry maps and historical records. A Reference Guide for the one hundred years from 1876 to 1977 has been published. (Keller, 2008). We continue a heavy focus on the more difficult pre-1876 period, especially for the heavily mined Georges Creek Basin. New information is constantly uncovered that improves our understanding of abandoned mines and their environmental threat in Maryland.
5. **Phase I of the Siege of Acre Project** was completed to prepare for grouting the only uniquely Maryland acid producing segment of the Kempton/Coketon Mine Complex. This Phase of the Project was funded primarily by the DOE Combustion By-Products Recycling Consortium. It was concerned with finding

and monitoring acid production in three tunnels 180 feet below the surface and 4000 feet from the last two known points on both the surface and in the mine. Our success there in being able to sample a small stream of acid mine water (pH 2.2) at a depth of 180 feet was very encouraging. Robin Lee, who presented the Barton Award winning paper on our Winding Ridge Project at the World of Coal Ash Conference in 2007 as Robin Guynn, is presenting a paper on the Siege of Acre Project at this Conference.

6. PPRP has contracted with Garrett College to **Monitor the Wetlands on the North Branch of the Potomac River and Laurel Run** with a view of understanding the impact of the large Kempton/Coketon Mine Complex has on the Nation's River and have a baseline to see what changes occur if this Complex can ever be even partially restored. (Skylstad, 2001).
7. A study of the **Works Project Administration Mine Sealing Program** of the 1930s reveals that its failure resulted from failure to research the historical methods of ventilating mines by "natural means". (Murphy, 1905, p.44) One of these methods was to drill holes to the surface every 100 feet or so. These holes became lost in the forest above the mines but continued to supply air for the production of acid mine drainage even when water seals were constructed at the mine entries. In a similar way previously unexplained shifts in the hydraulics of abandoned deep mines and mine blow outs may be explained by their nexus to new surface mines through old mine drainage and ventilation schemes.
8. A **Heliocopter Electromagnetic Survey** of the Kempton/Coketon Mine Complex proved very useful in locating the true sources of acid production within 100 feet of the surface.
9. **Weathering Blocks** of various combinations of CCBs were prepared and have been kept under simulated mine conditions with low pH water running over them for four years. Details on this experiment are presented in Robin Lee's paper at this conference. After two years we began to notice some biochemical reaction on these blocks. We have given our biology support contractor an assignment to investigate this issue and recently added a biologist to our staff. We want to again emphasize that the National Research Council's report *MANAGING COAL COMBUSTION RESIDUE IN MINES* provides an excellent discussion of the need for site characterization of each mine to be restored including biochemical characterization.
10. **Mine Characterization** also proves to be a never-ending-task as the inventory grows with each investigation. We have divided Maryland into three Mine Districts for the sake of general characterization of mines for restoration with CCBs. See Figure 1.
    - The Coastal Geophysical Plain Province is referred to as the Coastal District, any CCBs put in mines here will be in contact or potential contact with ground water.
    - The Piedmont, Blue Ridge, and Valley and Ridge Provinces are designated as the Karst District. Uncertain hydrogeology in this District requires that contact with ground water be assumed.
    - The Appalachian Plateaus Province is designated as the Coal District. Mines in this District are dominated by abandoned underground coal

mines with acid mine drainage problems. The most complex of the five Coal Basins in this District is the Georges Creek Basin with the oldest and most poorly mapped mines. (Clark, 1905). This Basin is now a multi-story collection of abandoned partially gobbed voids covering about 100 square miles. The void spaces are known to be connected in many cases by unmapped or poorly mapped ventilation and drainage systems. (Swartz and Baker, 1920).

It can be seen from this general characterization of our mines that it is difficult to make a case for placing any CCBs in our mines except as stabilized or solidified material. Aside from this general characterization each mine site is unique and its geology, hydrogeology, and biochemical characteristics must be examined very carefully before attempting restoration. In this respect mine restoration with CCBs is no different than bridge, dam, tunnel, or any other civil engineering construction activity.

11. The **Cost** of mine restoration will be very site sensitive because of transportation costs and in the case of underground mines because of engineering investigation, access, and drilling costs. PPRP had ERM and iLF examine cost issues using modern materials handling equipment for handling massive quantities of materials with fugitive dust problems and material safety handling issues similar to Portland cement and conventional gypsum. We have not yet published their reports to us but are confident in making these general statements:
    - For abandoned pit mines in our Coastal District the cost of direct movement of fly ash to the mines by marine transport and conveyor, pipeline, or rail and converting the fly ash to stabilized or solidified material using conventional soil cement technology and high lime content waste products will be less than current and planned methods of disposal of fly ash. The volume of mines in the Coastal District to be restored is sufficient to consume all the fly ash that will be produced at our pulverized coal fired power plants in their remaining economic lifetimes.
    - Mines in the Karst District will have to be examined on a case by case basis to determine if restoration is justified. In general real estate in this District is not of sufficient value to justify restoration. The one big safety issue, sinkholes forming at the perimeter of mines in karst topography, could be addressed with CCB grout at lower cost than conventional methods but the amount of CCBs used would not be significant.
    - Abandoned underground mine restoration in our Coal District offers a special budget challenge because there is no Industry, State, or Federal program to address the problem. PPRP had iLF attempt to bring the cost issue into focus by comparing the on site costs of conventional mine back filling with light density grout injection with similar back filling with CCB grout. For large projects (greater than 250,000 tons) the cost using light density grout leveled out at just under $48 per cubic yard. For similar large projects the cost using CCBs leveled out at under $18 per cubic yard with 80% of the cost being in on site labor, an important socio-economic consideration.

SUMMARY

Maryland is fortunate to have a large cement manufacturing and cement products industry that will consume at least 50% of the CCBs our power plant produce in the long term. The amount of CCBs that can be use in concrete mixes and as alternatives to Portland cement can be further increased by demonstrations that lead to changes in the infrastructure of the ready mix industry to store and use CCBs on a regular basis. There is a major opportunity to use CCBs with high free lime content waste products of our limestone industry for low cost and low risk mine restoration in areas served by marine transportation. Restoration of Maryland's numerous abandoned underground coal mines presents a far more complex set of issues. The benefits could be great but the costs and risks are uncertain. The Winding Ridge Project suggests that a technology exists for massive restoration of abandoned underground coal mines with CCBs. The ash management plan made part of the license for the AES Warrior Run Power Plant suggests a strategy that would eliminate the ponds, lagoons, and other temporary storage measures that recently gave notoriety to ash management. The issue is of such magnitude in the Appalachian Basin that PPRP proposes a consortium of the electric power industry, the water resources industries, and the mining industries to develop the resources to make massive mine restoration a new industry in the Appalachian Basin.

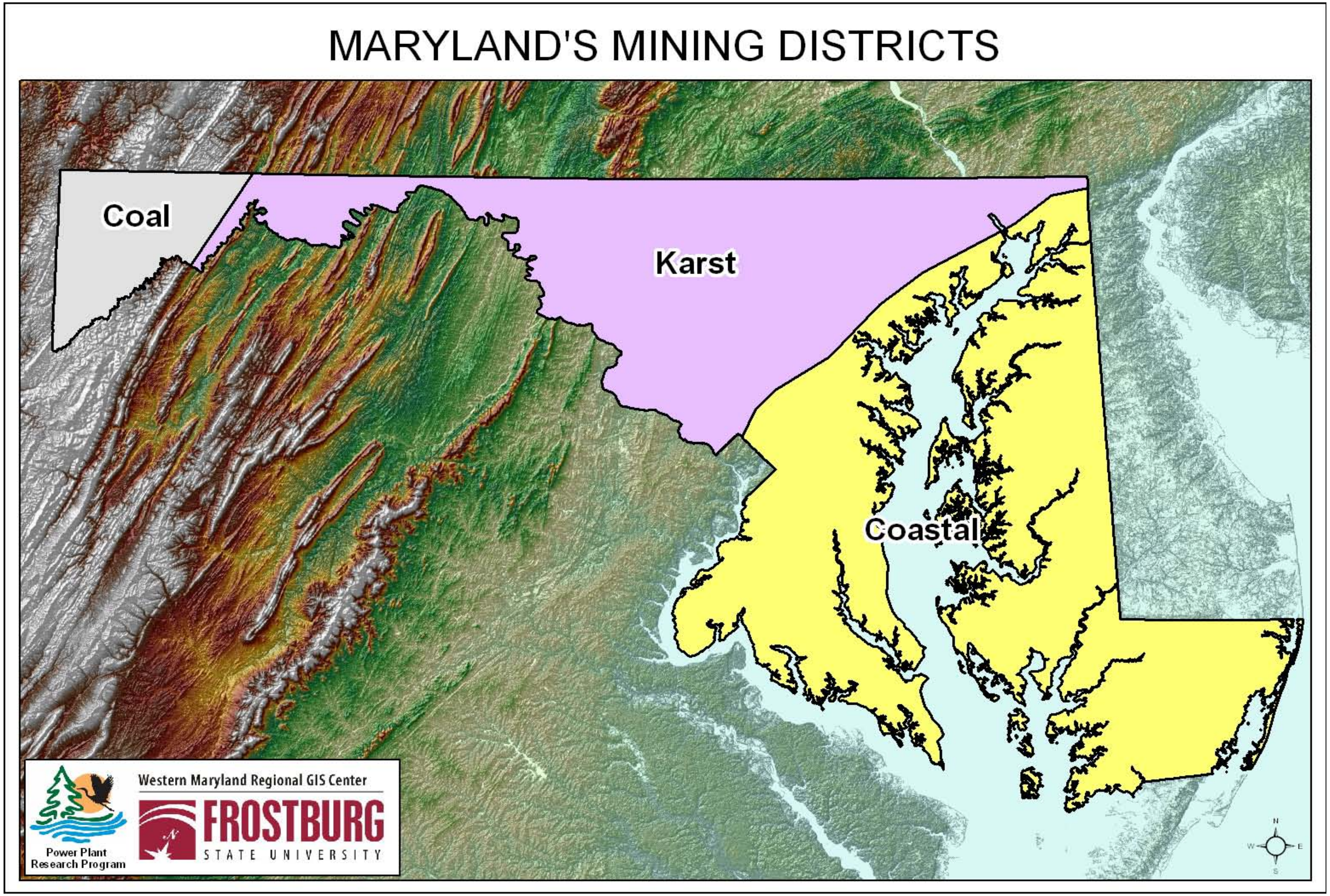
MARYLAND'S MINING DISTRICTS
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Figure 1

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