Senate Concurrent Resolution -15

An Evaluation of the Underground Injection of Coal Slurry in West Virginia

Phase I: Environmental Investigation

West Virginia Department of Environmental Protection

west virginia department of environmental protection

"Promoting a Healthy Environment"

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1.0. Executive Summary

In February 2007, the West Virginia Legislature mandated that a comprehensive environmental study of the injection of coal preparation plant slurry into underground mines be conducted through the adoption of Senate Concurrent Resolution 15 (SCR-15). SCR-15 required that the study of the hydrologic impacts of slurry injection be completed within one year by the West Virginia Department of Environmental Protection (WVDEP), followed by a study of the health effects of slurry injection by the West Virginia Department of Health and Human Resources, Bureau of Public Health (WVDHHR). This report represents the results of the hydrologic review by the WVDEP. WVDEP enlisted the assistance of the Federal Office of Surface Mining Reclamation and Enforcement (OSMRE) in conducting this study. The WVDEP acknowledges the participation and assistance of the WVDHHR throughout this phase of the study.

A study of the effects of coal slurry injection on the environment is highly technical and complex. The one-year environmental review period mandated by SCR-15 was not sufficient to complete the study. In order to meet time limits, WVDEP determined that the team would need to forego seasonal sample collections that might require years to complete for a comprehensive hydrologic assessment. For example, the team members took a one-time sample, rather than drilling additional monitoring wells and monitoring rainfall and discharges over several years to obtain seasonal variation. Therefore, the findings of this report should be considered informational, rather than absolute.

The review team chose six underground injection control permits to evaluate. Four were reviewed as part of a hydrologic assessment and an additional two were evaluated for only slurry constituents. The team then gathered slurry, water, and coal samples to evaluate 175 parameters, most of which are not routinely tested as part of a mining operation.

Preparation plants use physical and chemical processes to remove impurities from coal. Slurry is the fine-grain wet portion of the impurities removed from the coal. Most modern plants use the addition of various chemicals to aid in this separation. Approximately eighty-five percent of the coal slurry produced in West Virginia is disposed in surface structures, such as slurry impoundments and slurry cells. This report investigates the fifteen percent of coal slurry produced by preparation plants in West Virginia that is injected underground.

Underground injection involves the placement of coal slurry in abandoned underground mine voids. Slurry is gravity fed into the underground mine via a network of slurry pipelines and injection wells. Under most conditions, the solid portion of slurry settles to the bottom of the mine void, while the liquid portion migrates.

No universal tracer was found to indicate the presence of coal slurry as distinguished from other mining activities on surface and groundwater. Slurry is similar to coal in its composition. Because manufacturers of the products often do not identify proprietary chemical compositions, there is insufficient information on the chemicals used in the coal preparation process. It is recommended that all chemicals used in the coal preparation process be fully detailed for operations that are permitted to inject slurry.

Despite the fact that the mines studied were below or partially below drainage, several of the mines had documented artesian flow – or internal pressure pushing slurry to the surface. A below-drainage mine is one where the coal seam is lower than the surface drainage feature. Many of these mine pools are pumped to control mine pool elevations. For these reasons, all mine pools that receive coal slurry must be closely monitored.

All of the deep mines evaluated in this study are below or partially below drainage. The majority of the mine workings are located below surface drainage with the exception of entries located at the up-dip end of the mines. Conceptually, waters associated with the deep mine workings below drainage are less likely to impact surrounding groundwater due to the low permeability of the strata surrounding the mine pools. Therefore, it is less likely for slurry and its constituents located in the deep mine pools to impact the surrounding groundwater. Based on available data, this study can neither confirm nor disprove this statement.

Most sites lacked adequate background data on mine pools and groundwater monitoring. All proposed slurry injection sites should be required to conduct detailed baseline monitoring. All existing slurry injection sites and sites permitted for injection in the future should be required to conduct detailed groundwater monitoring throughout the life of the permit.

Samples taken downgradient in a mine pool where slurry injection occurred showed no physical evidence of the migration of slurry solids. In addition, samples taken from two adjacent mine pools showed no physical evidence for the migration of slurry solids.

Two of the four sites showed the effects of injectate on the mine pools. Certain constituents, such as alkalinity, Total Dissolved Solids, sulfates, and some organics, had migrated from the slurry into the mine pool that received the injection. Migration of slurry chemical constituents from the mine pool to the surrounding surface water was not confirmed. It is recommended that all slurry injection sites conduct baseline sampling then monitor all water wells in use within one half mile of the mine pool that receives injectate throughout the injection process.

None of the four sites exhibited water quality impacts to surface waters due solely to slurry injection at the time of sampling.

Two public water supplies draw water from the same mine receiving slurry injection. The finished consumable water from both public water systems met EPA Primary Drinking Water Standards at the time of the sampling event.

In summary, no adverse effects to surrounding surface and groundwaters due to slurry injection were observed from the samples taken. Pending the full implementation of all recommendations proposed in this study, the WVDEP is imposing a moratorium on the approval of the injection of coal slurry into mine voids in which coal slurry injection has not previously been approved under the modern era program (since 1999).

2.0 Introduction

2.1. Legislative Resolution

In 2007, in response to concerns expressed by citizens and environmental organizations about potentially acute and chronic environmental impacts resulting from the underground injection of coal preparation plant slurry, the West Virginia Legislature mandated that a comprehensive study of the issue be conducted. The mandate, Senate Concurrent Resolution 15, or SCR-15, required:

1) An analysis of the chemical composition of coal slurry;
2) A hydrogeologic study of the migration of coal slurry into surface and/or groundwater;
3) An analysis of the effects of the coal slurry and its constituent contaminants on human health;
4) A study of the effects of coal slurry and its constituent contaminants on public health;
5) An environmental assessment of the effects on surface water and aquatic ecosystems;
6) Any other considerations that the Department of Environmental Protection and the Bureau for Public Health deem to be important.

A team comprised of personnel from the WVDEP, the WVDHHR, and OSMRE was selected to conduct the study, the first phase of which was completed in March 2009 and is here presented. The results of this phase, which assessed the chemical and environmental effects of underground slurry injection, will provide background data for the WVDHHR to complete the remainder of the requirements, specifically those involving human health.

Prior to SCR-15 being adopted by the West Virginia Legislature, WVDEP and OSMRE had already jointly agreed to conduct a study on coal slurry. This study was incorporated into the SCR-15 study.

2.2. Tasks and Objectives

The tasks of this first phase of the SCR-15 study, Items 1), 2), and 5), were addressed as follows:

1) An analysis of the chemical composition of coal slurry, including an inventory of organic and inorganic constituents was conducted at six sampling locations across the state. Solid and liquid components of the slurry were analyzed for more than 175 chemical constituents.

2) A hydrogeologic evaluation of the migration of coal slurry and its constituents into the surface and groundwater was conducted at four (4) mining sites.

5) An environmental assessment of the effects on surface water by direct and indirect migration of the injected slurry was performed. Additionally, a comparison of surface water quality upstream and downstream of the surface emplacement of coal slurry was conducted.

Chapter 3.0. Historic and Background Information

3.1. Regulatory History of Underground Injection Control (UIC) Program.

Pre-1983

Prior to 1983, the State's mining UIC program was administered by the United States Environmental Protection Agency (USEPA). West Virginia was granted primacy by the USEPA in 1983, because it met or exceeded the requirements set forth by the Federal government for the regulation of such activities. State primacy encompasses all types of injection wells, including mining, septic and industrial.

1983 - 1999

In West Virginia, the subsurface emplacement of fluids from coal mining operations during this period was regulated by the Groundwater Protection/UIC Unit of what is now the Division of Water and Waste Management of the West Virginia Department of Environmental Protection (WVDEP). After the State received primacy in 1983, the septic and industrial UIC programs became part of the Office of Water Resources, now the Division of Water and Waste Management, while responsibilities for this program were shifted to the NPDES program in the Office of Mining and Reclamation, now the Division of Mining and Reclamation.

Because the UIC program regulations were promulgated under Title 47 CSR 13, *Underground Injection Control*, by the authority of West Virginia Code Chapter 22, Article 11, *Water Pollution Control Act,* injection activities at mine sites were addressed in NPDES permits for mining operations. At that time, there were fewer than two dozen coal-related injection wells known in the entire State, although many more were later found to exist.

1999 - Present

At the beginning of the modern program, since field inspection of UIC permits for mine sites was under the purview of the Division of Mining and Reclamation, the UIC geologist worked closely with the mining inspectors throughout the coal fields to locate all injection wells and have them either properly closed or brought under a UIC permit.

In 1999, WVDEP determined that the mining UIC program should be included with other UIC programs, having separate, stand-alone permits, and managed by the (then) Office of Water Resources (OWR).

Applications for UIC permits, major modifications to existing permits, and permit re-issuances require the Material Safety Data Sheet (MSDS) for each proposed chemical to be assessed and a battery of analyses to be performed on the proposed injectate to confirm that the substance is not hazardous in accordance with the Federal Resource Conservation and Recovery Act (RCRA) and 40 CFR Part 261.

Monitoring

Once issued, mining UIC permits require regular monitoring to ensure that the injectate is meeting Federal Primary Safe Drinking Water Standards, also known as Maximum Contaminant Levels (MCLs). The MCL is the highest concentration of a contaminant that is allowed under Federal law. Most permits specify monthly sampling and quarterly reporting of approximately 18 parameters; some of these are not Primary Drinking Water Standards, but nevertheless merit watching, and so are listed as “Report Only” in the permit’s monitoring requirements and on the Discharge Monitoring Report (DMR). The DMR is the document that is submitted quarterly by the permittee to declare monthly monitoring results.

Records and Research

All DMRs, applications, and permit documents for any given site are permanently retained by WVDEP. This retention of records provides a valuable database for determining the extent and nature of underground injection occurring at mine sites in West Virginia. Unfortunately, information about such activities prior to 2000 is insufficient for research purposes, and records prior to 1983 are essentially non-existent. Many questions remain as to the locations, the quantity, and the quality of historical slurry injection within the State. For these reasons, this study focused only on UIC sites that have been permitted since 2000.

3.2. Regulatory Framework

As mentioned, above, the Groundwater Protection Unit’s Underground Injection Control (UIC) Program is responsible for regulating the injection of coal slurry into abandoned underground mines within the State. Regulations governing the program are set forth in Title 47, Series 13 of the Code of State Regulations (CSR) under the authority of the West Virginia Water Pollution Control Act, West Virginia Code Chapter 22, Article 11.

Coal slurry injection wells are classified by the State as Class 5 wells for regulatory purposes. Generally, Class 5 injection wells inject non-hazardous fluid into strata that contain underground sources of drinking water. Operators of these injection wells must be authorized either by a permit or a rule approved by the State. UIC permits for Class 5 injection wells are effective for a fixed term not to exceed five years as provided by CSR §47-13-13.13. Other types of injection wells that are regulated by the State include: Class 1 Hazardous Waste, Other Industrial or Municipal Disposal Wells; Class 2 Oil or Natural Gas Production, Enhanced Recovery, or Storage Wells; Class 3 Mineral Extraction Wells; and Class 4 Hazardous Waste Disposal Wells that cannot be classified as a Class 1 Well.

All injection wells within the State are regulated with the primary goal of protecting the underground sources of drinking water. The State’s UIC regulations at CSR §47-13-2.67

defines "underground source of drinking water" as an aquifer or its portion which supplies any public water system; or which contains a sufficient quantity of groundwater to supply a public water system; and currently supplies drinking water for human consumption; or contains fewer than 10,000 milligrams per liter of total dissolved solids; and which is not an exempted aquifer. An exempted aquifer would be one that currently does not serve as a drinking water source and it cannot now or in the future serve as a source of drinking water, given its quality, depth, or location as provided by CSR §47-13-3.1.

CSR §47-13-2.49 defines public water system to mean a system for the provision to the public of piped water for human consumption, if such system has at least 15 individuals. Such term includes any collection, treatment, storage, and distribution facilities under control of the operator of such system and used primarily in connection with such system, and any collection or pretreatment storage facilities not under such control which are used primarily in connection with such system.

The State's UIC regulations at CSR §47-13-13.1.b provide that no operator shall . . . conduct any other underground injection activity in a manner which causes or allows the movement of fluid containing any contaminant into underground sources of drinking water, if the presence of that contaminant may cause a violation of any primary drinking water regulation under 40 CFR Part 142, the National Primary Drinking Water Regulations, or promulgated pursuant to West Virginia Code §16-1-1 *et seq.* or may otherwise adversely affect the health of persons. If the regulatory authority learns that a Class 5 well may cause a violation of a primary drinking water rule under 40 CFR Part 142 or West Virginia Code §16-1-1 *et seq*. or may be adversely affecting the health of persons, it may take certain actions to prevent it pursuant to CSR §47-13-13.1.d and 13.1.e. In addition, if at any time, the regulatory authority gains knowledge of a Class 5 well which presents a significant risk to the health of persons, it must prescribe such action as necessary, including the immediate closure of the injection well, to remove such risk pursuant to CSR §47-13-12.3.

Under the Federal Safe Drinking Water Act and the amendments thereto, states must prepare and submit for EPA approval a State Drinking Water Source Assessment and Protection Program. Once approved, a state must conduct local assessments, including the identification of the groundwater protection areas. In addition, a state may identify other sensitive groundwater areas (well head protection zones) in the state that are critical to protecting underground sources of drinking water from contamination. These sensitive areas may identify highly productive aquifers that supply private wells; areas where water supply aquifers are recharged; etc. The Department of Health and Human Resources' Bureau of Public Health in West Virginia is responsible for preparing and implementing this program.

Under the UIC regulations at CSR §47-13-13.22, the WVDEP may identify and must protect, except where exempted, all aquifers or parts of an aquifer which meet the definition of an underground source of drinking water. In addition, the WVDEP may identify and describe all aquifers, or parts thereof, which the agency proposes to designate as exempted aquifers using the criteria in section 3. No designation of an exempted aquifer submitted as part of a UIC Program can be final until approved by the U. S. Environmental Protection Agency (EPA) as part of the approved State program. CSR §47-13-3.1 provides that an aquifer or a portion thereof which meets the criteria for an "underground source of drinking water" in section 2 may be determined to be an exempted aquifer if it meets the following criteria: it does not currently serve as a source of drinking water; and it cannot now and will not in the future serve as a source of drinking water because: it is a mineral, hydrocarbon or geothermal energy producing, or can be demonstrated by a permit applicant as part of a permit application for a Class 2 or 3 operation to contain minerals or hydrocarbons that, considering their quantity and location, are expected to be commercially producible; it is situated at a depth or location which makes recovery of water for drinking water purposes economically or technologically impractical; it is so contaminated that it would be economically or technologically impractical to render the water fit for human consumption; or it is located over a Class 3 well mining area subject to subsidence or catastrophic collapse; or the total dissolved solids content of the groundwater is more than 3,000 and less than 10,000 milligrams per liter and it is not reasonably expected to supply a public water system.

West Virginia's Groundwater Protection Act at §22-12-4 provides that the WVDEP has the authority to promulgate standards for groundwater. These standards must establish the maximum contaminant levels permitted for groundwater, but in no event shall the standards allow contaminant levels in groundwater to exceed the maximum contaminant levels adopted by EPA pursuant to the Federal Safe Drinking Water Act.

The Groundwater Protection Rule at CSR §47-58-1 *et seq.* was promulgated in response to this law. However, most of the requirements relate to industrial establishments, activities not included within the definition of an industrial establishment, or sewage treatment operations.

In addition, Groundwater Standards at CSR §46-12-1 *et seq*. were promulgated under the authority of the Groundwater Protection Act to establish minimum standards of purity and quality for groundwater located within the State. This rule contains specific groundwater quality standards; however, these standards do not apply to wells permitted pursuant to the UIC Program as provided by CSR §46-12- 3.4.b.

The criteria and standards applicable to Class 5 injection wells are set forth in the UIC regulations at CSR §47-13-12. Class 5 injection wells can be characterized as a catch all classification with limited standards. Unlike Class 1, 2, 3, or 4 injection wells, the permitting, monitoring and reporting requirements for Class 5 wells are limited. The UIC regulations at CSR §47-13-13.7, however, allow the WVDEP to impose conditions in permits on a case-by-case basis to assure compliance with the Federal Safe Drinking Water Act and the State Water Pollution Control Act and rules.

As provided by CSR §47-13-13.7.c, the State can require the same operating requirements for Class 5 wells that are required for Class 1 (hazardous waste) and Class 3 (mineral extraction) wells. This would require a Class 5 well to establish maximum injection volumes and/or pressure necessary to assure that fractures are not initiated in the confining zone, that injected fluids do not migrate into any underground source of drinking water, that formation fluids are not displaced into any underground source of drinking water, and to assure compliance with the operation requirements.

CSR §47-13-12.j. sets forth mandatory monitoring and record maintenance requirements for Class 5 and other injection wells. As provided by CSR §47-13-13.6.b, the permittee must retain all records concerning the nature and composition of injected fluids until 3 years after the completion of any plugging or abandonment procedures. CSR §47-13-13.7.e also allows monitoring and reporting requirements for Class 5 wells that are required for Class 1 and 3 wells. This would require the monitoring of the injection fluids, the injection well, and the underground sources of drinking water that could potentially be affected by the injection. The monitoring requirements could include testing of the injected fluids with sufficient frequency to yield representative data of its physical, chemical and other relevant characteristics; continuous recording devices to monitor injection pressure, flow rate and volume and annular pressure; demonstration of the mechanical integrity of the well at least every five years; sufficient type, number and location of wells to monitor the migration of fluids into and pressure in the underground sources of drinking water with parameters to be monitored and the frequency of monitoring, etc. Furthermore, CSR §47-13-13.7.f provides that any Class 1, 2, or 3 permit shall include, and any Class 5 permit *may* (emphasis added) include conditions to ensure that plugging and abandonment of the well will not allow the movement of fluids either into an underground source of drinking water or from one underground source of drinking water to another.

CSR §38-2-14.5.e.2 further provides that discharges into underground mine workings are prohibited, . . . unless the operator demonstrates that such activities will not cause, result in, or contribute to a violation of water quality standards and effluent limitations both on or outside the permit area; not be discharged without MSHA approval; minimize disturbance to the hydrologic balance on the permit area and prevent material damage outside the permit area. . .

In addition, West Virginia Code §22-3-24(b) provides that any operator must replace the water supply of an owner of interest in real property who obtains all or part of the owner's supply of water for domestic, agricultural, industrial or other legitimate use from an underground or surface source where such supply has been affected by contamination, diminution or interruption proximately caused by such surface mining operation, unless waived by said owner.

3.3. Slurry Scope

At this time, the majority of active preparation plants dispose of coal slurry in surface structures such as slurry impoundments and slurry cells. Calculations based on the total active slurry UIC data and all active preparation plants as listed by the 2008 *Coal Age* magazine indicate that approximately 15 percent of the slurry produced in the State is disposed of in underground mine works.

Data from the current UIC Program lists 13 approved UIC permits for the underground injection of coal slurry, as of March 2009. This is also the number of active sites in existence in March 2007 when this study first began. However, the 13 sites active in 2007 are not all the same as those that are active today. The 2009 sites are shown on Figure 3.3-1 as red triangles. This Figure also shows 18 sites where slurry has been injected, but no longer maintain an active permit to inject slurry at this time. These two groups include all known slurry injection activity back to 1999.

Historic records indicate that slurry injection had occurred as early as the 1960s. The records from this time period were not as well maintained as modern records. Data from these files were reviewed and used to create a database that is included in Appendix II-B. These sites are shown as small black triangles in Figure 3.3-1.

The old slurry records indicate that slurry injection was much more prevalent in West Virginia in the 1980s than it is today. In particular, after the Buffalo Creek slurry impoundment failure in Logan County, companies were encouraged to inject slurry underground. According to anecdotal evidence, for a short time, the majority of preparation plants in the State practiced underground injection for safety purposes. During the late 1970s and early 1980s, the database shows more than 60 different preparation plants across the State injected slurry underground. Much of this injection occurred prior to the State receiving primacy from the USEPA.

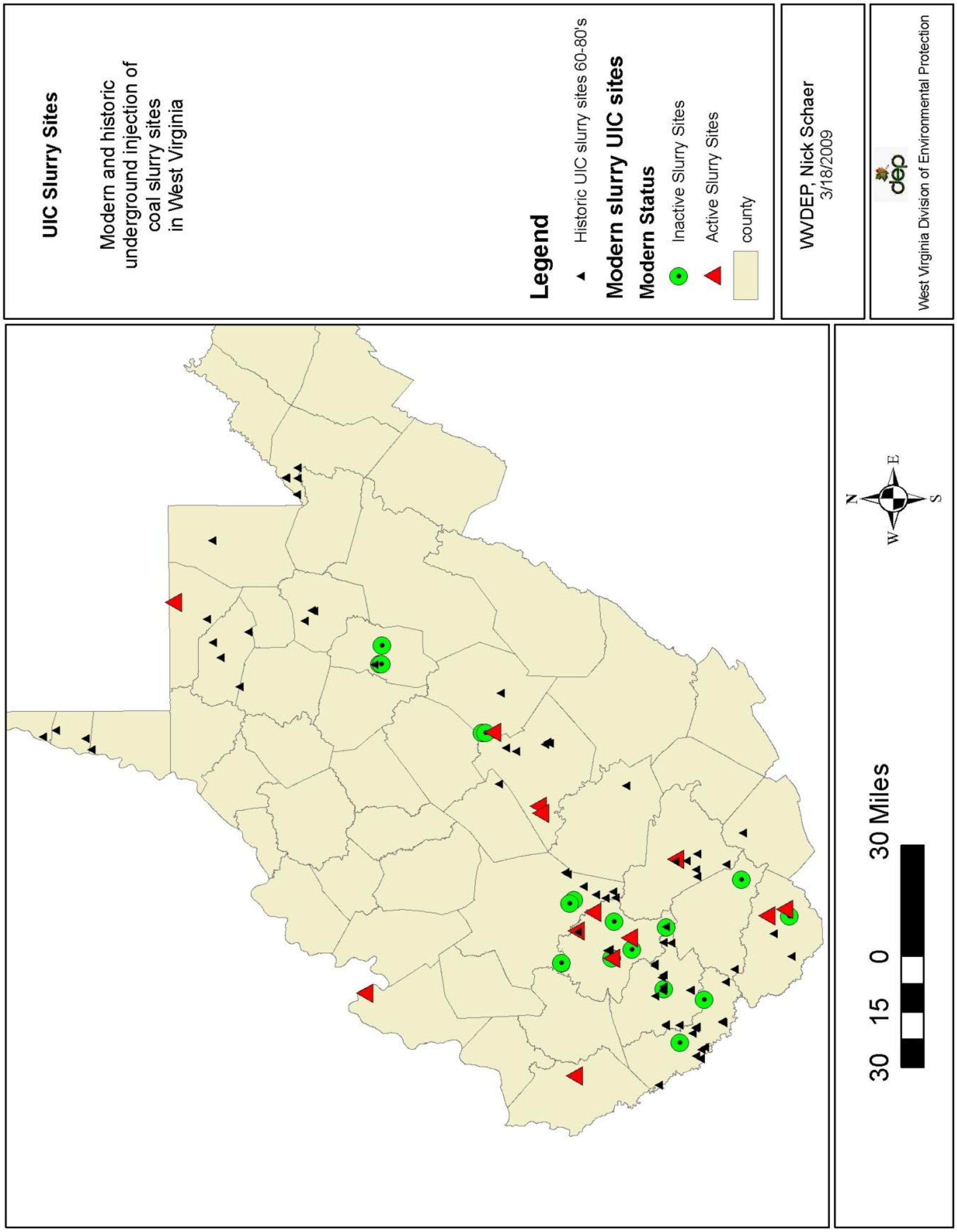

Figure 3.3-1: UIC Slurry Sites.

3.4. Inventory of Approved Chemicals for Injection

Under the UIC Program, chemicals used in the coal preparation process must be approved by the State. Appendix II-C contains a listing of 237 chemicals that have been accepted by the State for underground injection. This list was created by the UIC Program after reviewing the MSDSs for all chemicals that are commonly used in the coal preparation process that produces the injectate. Because these chemicals do not meet the definition of hazardous waste under the Resource Conservation and Recovery Act, they are allowed to be present in the injectate.

No substances can be used in the coal preparation process that produces the injectate other than those declared and approved in the UIC permit application. The use of any other substances without written approval from the WVDEP is a violation of the UIC permit.

Each UIC permit application states that a permit cannot be issued to an operation that uses diesel fuel, kerosene, or any other substance listed, or having a component(s) listed, as a hazardous waste by toxicity under RCRA.

3.5. Material Safety Data Sheet (MSDS):

In accordance with Occupational Safety and Health Administration's (OSHA) regulations in 29 CFR 1910.1200(g), chemical manufacturers and importers must obtain or develop an MSDS for each hazardous chemical they produce or import. In addition, employers must have an MSDS in the workplace for each hazardous chemical they use. OSHA allows for the use of a "generic" data sheet where the evidence supports the fact that a class or family of chemicals presents similar health hazards. However, any specific information that the chemical manufacturer has with regard to specific hazards must appear on the MSDS and label, as appropriate.

As mentioned, MSDSs must be developed for hazardous chemicals used in the workplace. Chemical manufacturers must either determine the hazards of the product as a whole or assume that the mixture presents the same health hazards as its components. In cases where a chemical mixture or compound has not been tested as a whole, the manufacturer's MSDS must list all chemical components that have been determined to be hazardous and which comprise one percent or greater of the mixture, or 0.1 percent or greater for components that are considered carcinogenic. The MSDS does not have to list the amount that the hazardous chemical occurs in the product.

All chemicals that are used in the coal preparation process must be evaluated by the manufacturer prior to being marketed and have an MSDS prepared for them. Information regarding each chemical is set forth on an MSDS. An MSDS is designed to provide both workers and emergency personnel with the proper procedures for handling or working with these chemicals. It includes information such as physical data (melting point, flash point, etc.), toxicity, health effects, first aid, storage, disposal, protective equipment required when using, and spill/leak procedures.

During the study, copies of all MSDSs were reviewed for each coal preparation plant that was injecting coal slurry underground. The MSDSs are included in the UIC permit file. During this evaluation, team members found that operators sometimes were not using the chemicals that were identified in their UIC permits. See Appendix II-D through H for copies of the MSDSs of the chemicals that were used at the four major study sites.

Chapter 4.0. Study Methodology

4.1. Criteria for Individual Sample Site Locations

Sample sites were selected by consensus of the SCR-15 study team with input from citizens and environmental groups concerned about the coal slurry issue. Team members analyzed pre-1999 UIC records retained at WVDEP. Those records were found to be incomplete, rendering baseline comparisons at those sites virtually impossible. Therefore, a hydrologic study of any of those locations would produce ambiguous results. Two historic injection sites are discussed below.

First, was Rawl Sales in Mingo County. A search of the WVDEP files produced no baseline hydrology data and very little information on the nature and location of injection activities at this site, which ceased injecting more than 20 years ago.

Second, the area around Prenter was considered. The only active slurry injection near this site is conducted by Independence Coal Company, more than three miles away from any residence in or near Prenter. Omar Coal Company conducted slurry injection slightly more than a mile from some Prenter residences, but this injection was conducted well before 1999.

4.1.1. Southern Minerals

The first site to be chosen was Southern Minerals in McDowell County, the oldest continually active injection site in the state. Underground injection has occurred there for well over 30 years, which means the mine pool has had more time to accrue impacts to its water quality. If any chemical reactions take place over a long period of time, they would most likely be found at Southern Minerals. More importantly, two large public water supplies draw from areas of the flooded mines near the injection points. If water quality were degraded by slurry injection, this is where the impact to human health could be the most direct and on the largest scale.

4.1.2. Loadout

The second site was chosen on the basis of optimum scientific suitability; this was Loadout, LLC in Boone County. Loadout was chosen because it is the only site in the state where no other mining activity occurred in the watershed prior to slurry injection. Therefore, pre-injection baseline surface and groundwater quality could be analyzed that showed no impacts from slurry or any other large scale mining. Furthermore, significant parts of the watershed are still un-affected by mining and could be used as a reasonable baseline comparison.

4.1.3. Panther

The Panther, LLC site in Kanawha County was chosen because several area residents and environmental groups had brought water quality concerns to the attention of the study team. However, after sampling had begun at Panther, it was discovered that no suitable groundwater monitoring was available. Because of this shortcoming, the SCR-15 group elected to study an additional hydrology site.

4.1.4. Power Mountain

The fourth site chosen was Power Mountain in Nicholas County. It, too, was recommended for study by citizens and environmental groups. Power Mountain had engaged in slurry injection for decades, nearly as long as Southern Minerals. Also, there are several domestic wells in the vicinity of Power Mountain and some of the well users had reported water quality problems to local environmental groups.

Study of the Power Mountain site is complicated; of all the sites considered for sampling, this area is the most heavily disturbed by mining activity, past and present. Because of the scale of surface mining, deep mining, refuse disposal, and slurry emplacement at Power Mountain, this site would be expected to exhibit the greatest overall mining water-quality footprint.

4.1.5. Slurry-Only Sites

Lastly, two slurry-only sample sites were chosen. The slurry only sample sites were chosen so the variability of slurry constituents from a broader set of locations could be assessed. One, Coresco, Inc. in Monongalia County, was selected because it was the only slurry injection site in the high-sulfur northern coal fields and, therefore, was essential for assessing variability of slurry across the state. Additionally, Coresco was the only preparation plant that used no chemicals in its process. The other slurry-only site was Marfork in Raleigh County, which did not use slurry injection.

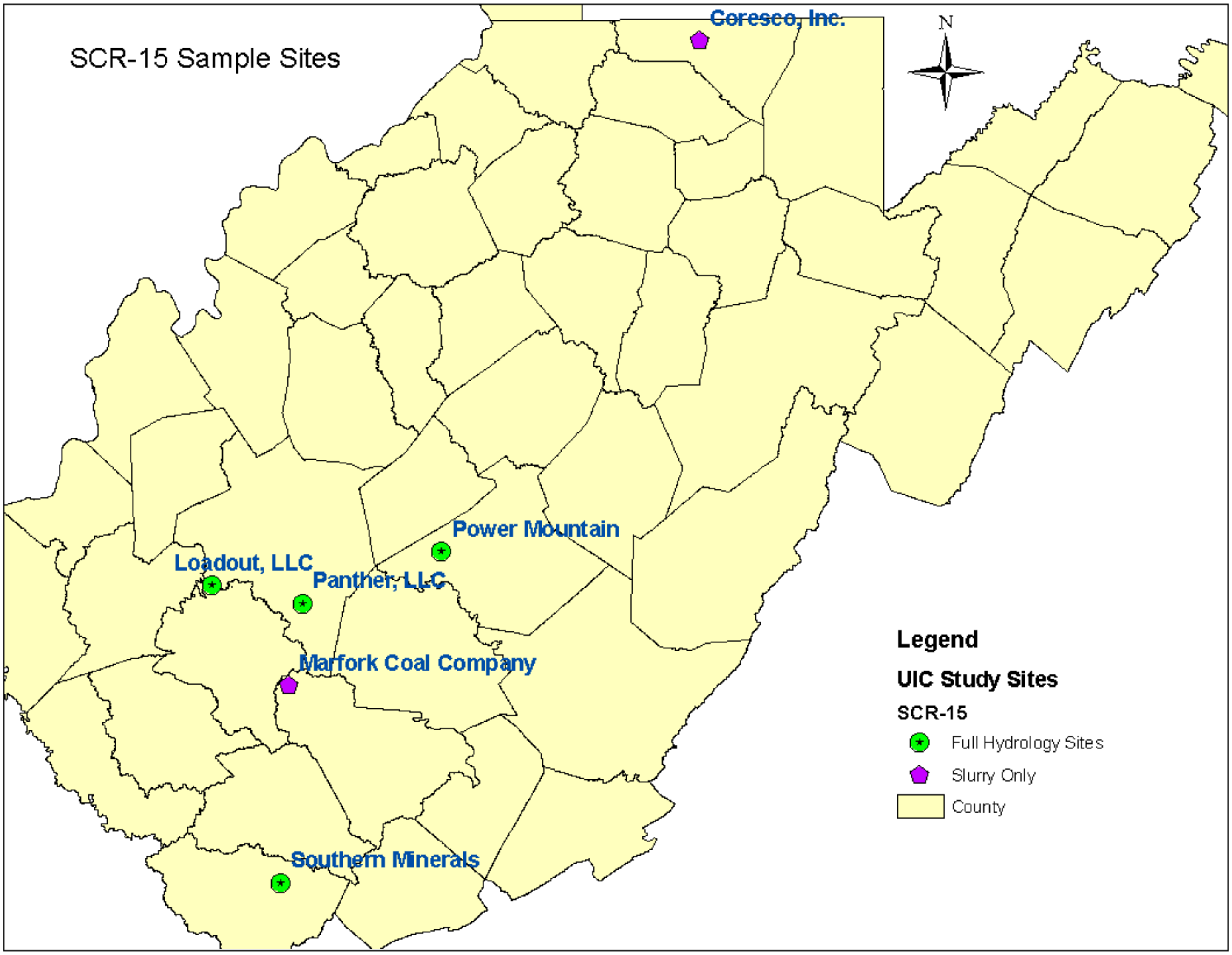

Figure 4.1-1: SCR-15 Sample Sites.

4.2. Methods and Laboratory Analysis

Parameter Selection

Prior to conducting field sampling activities, team members met and discussed the various parameters that would be evaluated at each site. A parameter listing for sampling coal, coal slurry, and surface and ground water was agreed upon by the team after several meetings in May 2007. The sample parameter listing is set forth in Appendix II-I. The listing contains more than 175 organic and inorganic parameters and the tests that the team recommended be evaluated for each site.

Both inorganic and organic parameters were analyzed for all samples collected at the sites. The requirement that both organic and inorganic constituents of the coal slurry be determined was outlined in the Senate Concurrent Resolution that mandated the study and determined its objectives. Additionally, the study team deemed these parameters necessary for the health and environmental assessment also required by the Resolution.

Most of the organic and inorganic parameters were chosen from an established list used for general health and environmental assessments. Many of these parameters have known health risks with established standards. Additionally, other parameters were chosen based on previous environmental and health studies related to coal slurry and chemicals used at coal preparation plants.

The team chose to test for iron, manganese, aluminum, calcium, magnesium and sulfate associated with mining activities, as these metals and ions are readily available in the coal and associated strata and are dissolved during the mining activities through exposure to air and water.

The listing is a result of numerous conversations with analytical chemists in regulatory authorities within West Virginia and in surrounding States. In addition, various publications and presentations were evaluated and several websites were consulted in developing the list. More information regarding this activity is set forth in Appendix II-I.

REI Consultants, Inc. (REIC)

WVDEP contracted with REIC in 2007 to analyze the water, slurry and coal samples that were collected for this study. The parameter listing discussed above was provided to REIC, and the laboratory further refined the listing. REIC is an approved State laboratory and followed EPA approved laboratory methods when conducting tests on all study samples. REIC used 29 different test methods to evaluate the coal, slurry and water samples provided by the team. Summaries of each of the approved methods used by REIC are set forth in Appendix II-J.

Laboratory Visit

Members of the coal slurry team met with REIC representatives and toured their laboratory in Beaver, West Virginia. The team discussed the various parameters and test methods that REIC had been using to evaluate the water and coal slurry samples to date.

4.3. Quality Control

Permit Review Information

A permit evaluation form was compiled by the team to evaluate and record basic permitting information regarding each study site. A copy of the form is included in Appendix II-L. Prior to conducting the site evaluations, team members reviewed the permit files for the four hydrologic assessment sites and completed the permit evaluation form. A copy of the form for each study site is included in Appendix II-M. This information was helpful in conducting the site evaluations and completing the report for each of the four hydrologic assessment sites. Team members also conducted more detailed reviews while completing the individual studies.

Sampling Protocol

Team members took samples at the six study sites for testing by REIC. The samples were collected between July 2007 and July 2008.

The sampling protocol set forth in Appendix II-N was followed for all water and coal slurry sampling. These included using latex gloves and plastic sheeting to prevent contamination of the samples and sampling equipment; collecting samples in clean and appropriate containers; using distilled water to rinse sampling and field instruments; using trip blanks; using chemical preservatives, when necessary, and keeping samples chilled to 4 C°; photographing the sampling sessions; and completing and filing the chain-of-custody for each sample. For a detailed description on sampling of the mine pools and groundwater refer to Appendix II-N.

Pre-site evaluations were conducted at each site to identify and verify access to sampling locations. Final sample collections were conducted within a week or so of those visits. Water and coal and/or slurry samples were collected at Southern Minerals, Panther LLC, Loadout LLC and Power Mountain. Only coal and slurry samples were collected at Coresco and Marfork.

Validation of Data

During the review, assigned team members took the laboratory results of the samples that were provided to REIC for testing and reformatted them into tables and categorized the data for each site.

The test results were divided into a solid and liquid phase for each site. The solid phase consists of metals analyses, general chemistry, volatile organic compounds, semi-volatile organic compounds, and miscellaneous analyses. The liquid phase consists of dissolved and total metals, general chemistry, volatile organic compounds, semi-volatile organic compounds, and miscellaneous analyses.

This data was compiled into tables for easy reference and further analysis by team members. All of the data tabulated by the team for each site are set forth in Appendix II-O. In addition, the actual laboratory results are set forth in Appendix II-P.

4.4. Study Constraints

Although considerable time and effort went into this study, several factors beyond the control of the team limited the overall timeliness and, to some extent, the ability to make conclusive findings as a result of this study. These factors include:

- The one-year environmental review period mandated by SCR-15 was not sufficient for a complete hydrologic assessment to consider seasonal variation and develop new monitoring wells necessary to model groundwater flow.

- Although slurry injection has been going on for years, a study of this kind has never been conducted before in this State, so a significant amount of time was spent trying to determine how to proceed and what parameters needed to be evaluated.

- There are currently 13 coal slurry injection operations within the State that have been approved under the UIC Program, so site selection for this study was limited to those operations.

- All study sites reflected alkaline mine pool chemistry. None of the sites evaluated for this study were injecting coal slurry into abandoned underground workings with acidic mine pools.

- All study sites had similar coal seam classification rankings with high fixed carbon, high volatile, and low sulfur characteristics.

- Most existing wells selected by the team for sampling were inaccessible due to various reasons, i.e. capped, not drilled, dry, etc. No wells had been installed by the operators to monitor the surrounding groundwater.

5.0. Environmental Assessment

The water quality and hydrologic analyses in the individual hydrologic reports provide an environmental impact assessment of the surface and ground water. The study group did not conduct sampling of streams at the study sites for benthic macroinvertibrates. While some may regard such sampling as a necessary component of the ecologic analysis of surface streams required by SCR-15, the study group chose not to perform benthic sampling because, as detailed in the hydrologic assessment reports and in section six, the sampling of surface streams near the underground injection of slurry showed no detectable water quality impact that could be directly traced to the underground injection of coal slurry. Even a stream that directly saw a slurry artesian event like Wilderness Fork, associated with Loadout LLC, showed no detectable impact from coal slurry by the time of the sampling conducted as part of the SCR-15 study. Also, every site reviewed in this study had nearby surface mine and refuse facilities. Generally, surface mining and coal refuse disposal activities have recognized impacts to stream benthic biology.

For the above reasons, benthic sampling would not be likely to reveal any data that would be identifiable as an impact solely from slurry injection, as opposed to impacts from other activities in the area that affect water quality. Accordingly, there was no logical reason for the study team to conduct benthic analyses.

6.0. Hydrologic Assessments

A comprehensive hydrologic assessment for each of the four sample sites is contained in Appendix I-A through D.

6.1. Southern Minerals Summary Findings

Hydrologic assessment for Southern Minerals study area lies completely within 73 square miles of Elkhorn Creek Watershed in McDowell County in Browns Creek District. The watershed receives an average of 48.49" of annual precipitation. Elkhorn Creek drains to the northwest and discharges into Tug Fork River. The abandoned mine seam voids that receive slurry injection are the Pocahontas No. 3 and No. 4 seams. The watershed is mostly forested, and has been extensively mined on the surface and underground. Remnant mining features, including reclaimed surface mines, gravity discharges from old mine portals and subsidence fractures are scattered throughout the watershed and convey a portion of surface runoff into underground mine workings. Generally, groundwater flow is to the northwest following the topography. Refer to the general mine flow and location map at the end of this section. Available mapping indicates that slurry injection was practiced from the mid-1970s to present.

The hydrologic assessment of the Southern Minerals, Inc. site indicates that neither the surface nor groundwater has elevated levels of metals, organic, or inorganic compound concentrations.

The higher concentrations of metals and organic compounds occurred in the solid phase of the coal slurry.

Samples from this site indicate that slurry constituents show little or no trend correlating with either depth or location. If such patterns of contaminant distribution exist, determining them would require more extensive sampling, both vertically and laterally, in the mine pool.

The goal of the SCR-15 study team was to determine whether the injection of coal slurry had adversely impacted groundwater and the receiving streams of the Elkhorn Creek Watershed. While some effects were detected, conclusions could not be drawn as to whether those effects were from present or past mining activity, slurry injection, or other human activities.

Two public water supplies draw their water from the same mine receiving slurry injection. The finished consumable water from both public water systems met EPA Primary Drinking Water Standards at the time of the sampling event.

6.2. Loadout, LLC Summary Findings

All slurry and refuse placement conducted by Loadout, LLC occurred within Fork Creek Watershed of the Big Coal River in Boone County. All slurry injection occurred between 1996 and 2006 in the abandoned Nellis Deep Mine in the Eagle Seam. The mine pool of the Nellis Deep Mine is maintained by active pumping. As detailed in the hydrogeology map at the end of this chapter, groundwater movement in Fork Creek is governed by the local dip to the Northwest.

UIC permit compliance reports for Loadout, LLC, for samples taken at the point of injection, often exceeded permit limits for chromium and Total Petroleum Hydrocarbons (TPH). However, elevated levels of these constituents were not found in any surface or ground water samples.

The discharge from the active slurry impoundment/cells at Loadout showed the strongest chemical signature for coal slurry. This water chemistry was significantly closer to that of raw slurry leachate than was any other sample from the site, including the mine pool that had directly received slurry. While the mine pool chemistry did show some elevated levels of alkalinity, dissolved solids, and strontium, it is not clear that its source was from the coal slurry or other mining related disturbances.

Surface water sampled immediately downstream of the location where a slurry artesian event occurred in 2005 indicated no residual detectable impact. Nevertheless, that artesian event could have been the source of an earlier possible contamination of a residential well. However, recent analysis of that well does not reveal any slurry effects.

Sampling from the adjacent down dip coal mine in the same seam as the mine pool that received injection showed no detectable migration of solid slurry or dissolved leachate from slurry.

6.3. Panther, LLC Summary Findings

A hydrologic investigation at the Panther, LLC underground No. 2 Gas Seam Mine was conducted to determine whether surface and groundwater of the Wet Branch Watershed, Kanawha County, has been affected by slurry injection. Authorized Eagle seam slurry injection into Mine No. 2 occurred from 2002 to 2004. Unauthorized No. 2 Gas Seam slurry injection into the Mine No. 2 occurred for approximately six months during 1996. Generally, groundwater flow is to the west-southwest following the topography. Refer to the general location map at the end of this section.

Data from the single SCR-15 sampling event at Panther shows that neither the surface water nor the groundwater exhibited elevated levels of metals. One citizen’s well water chemistry shows elevated concentrations of barium (level 0.48 mg/L, dissolved), and iron (level 10.5 mg/L, dissolved) compared to the other SCR-15 samples sites. This well water would be considered potable when compared to the standards that apply to public drinking water. No impacts from coal mining activities, including slurry injection, were detected in a residential well.

Elevated levels of metals and organic compounds were found in the coal slurry solids. One such metal, strontium, was consistently elevated at all sample locations.

Some organic compounds that were detected in the Eagle Seam slurry were also detected in the mine discharge. Certain organic compounds were found in the slurry liquid, but not in the slurry solids. Butanol, naphthalene and acetone were detected in the coal slurry liquid and at the mine dewatering borehole; butanol is a UIC-authorized chemical that is used at the Panther preparation plant. The data also shows the occurrence of naphthalene in the slurry solids. These three chemicals are presumed to originate from the Panther coal preparation process. The presence of butanol in both the slurry and the mine discharge indicates that some slurry constituents are migrating west-southwest downgradient from the injection holes, through the mine pool to the mine dewatering borehole. However, water quality data from below the mine discharge does not demonstrate that the receiving stream, Wet Branch, has been affected by slurry-influenced elevated metals or organic compounds.

The study data shows chromium concentrations at less than 1.0 mg/L in the slurry liquid phase and coal leachate, but at a greater concentration in the slurry solids. Selenium was detected only in the slurry solids. UIC compliance data showed three exceedences for total chromium and one exceedence for dissolved selenium. Three exceedences of the organic compounds Diesel Range Organics (DRO) and Oil Range Organics (ORO) had also occurred; however, there were no exceedences of Gasoline Range Organics (GRO). The source(s) of the DRO and ORO was determined to be the coal preparation process.

The results were inconclusive as to whether the injected coal slurry had adversely affected Wet Branch surface and ground water, since the organic compounds can occur either naturally or from pollutants in the environment. Using existing data, it is not possible to discriminate whether the source is naturally occurring, the chemicals used in the coal preparation process, or the coal seam proper. Relevant site-specific monitoring would have been necessary to determine whether any surface or ground water have been affected by coal slurry injection.

6.4. Power Mountain Summary Findings

The Power Mountain hydrologic site is located in Nicholas County and includes the Twentymile Creek and Peters Creek Watersheds. The site includes five abandoned deep mines, all located on the Eagle Coal Seam which received slurry injectate during the period of 1990 to the present. The general groundwater flow throughout the site is to the Northwest. Currently only one of the mines is receiving slurry injectate from the preparation plant. Pumping of the mine pool from this mine in addition to one other mine, is occurring so that the pool may be maintained at a prescribed elevation. A site location map is included at the end of this section.

A hydrologic study of the various mines at the Power Mountain site yielded insight into water quality impacts to mine pools from slurry injection. The team sampled the mine pool in the Flying Eagle deep mine upgradient and downgradient of the injection activities. The results showed increased concentrations of certain parameters downgradient. Total dissolved solids, alkalinity, and sulfates were significantly higher in the sample collected from the dewatering well compared with the sample from the upgradient monitoring well. Historical data on mine pool water quality for the Terry Eagle and William Eagle deep mines prior to, during, and after slurry injection reflect similar findings.

> The WVDEP-UIC compliance DMR data showed exceedences of UIC permit limits established for the coal slurry injectate. TPH (Total Petroleum Hydrocarbons) and Chromium are the most common parameters that exceeded the limits.

A comparison of the mine pools in adjacent deep mines where slurry did not occur supports the conclusion that injection activities impact mine pool water quality. Specifically, the water of the mine pool shows increased concentrations of total dissolved solids, alkalinity, and sulfates.

The water quality of a domestic well located within the study area was found to be affected by mining activities, which included slurry injection, although the specific type(s) of mining activity causing the impacts could not be determined. Although impacted by mining, this domestic well would still be considered potable when the concentrations are compared to the standards that would apply to public drinking water.

There are significant spatial and temporal water quality impacts within the watershed of the study area from various mining activities; therefore, distinguishing impacts on surface waters from slurry injection is not possible given the scope of this study.

6.5. General Hydrologic Findings

The following is a summary of the hydrologic assessments of the four study sites.

- None of the sites showed water quality impacts to surface waters due solely to slurry injection.

- Two of the four sites showed changes in water quality of the mine pool receiving injection. Certain constituents migrated from the slurry into the mine pool. Furthermore, migration of the constituents from the mine pool to the surrounding groundwater was difficult to determine due to a lack of background information prior to injection and appropriate monitoring of changes by the operator.

- One of the assessment sites was located in the vicinity of a public water system which received its water from the mine pool where injection occurred, but no impacts from slurry injection were detected.

- Based on the sample results, the inorganic and organic chemical composition of the coal slurry is similar to that of the coal seams. Accordingly, this similarity creates difficulty in isolating water quality impacts due solely to the injection of coal slurry in underground mines. In one site, the coal slurry showed organics that originated from the preparation process, but were not evident in the coal. Due to the complex nature of groundwater movement and the similar chemical make-up of coal slurry and the coal within the underground mine, differentiating impacts of injection activities from those of other mining activities is extremely difficult.

- Samples taken from the mine pools downgradient from the slurry injection sites showed no physical evidence of the migration of slurry solid materials out of the underground mine voids.

- Despite the fact that the mines studied were below or partially below drainage, several of the mines had documented artesian flow of slurry to the surface. A below drainage mine is one where the coal seam is lower than the surface drainage feature. Many of these mines pools are pumped to maintain mine pool elevations.

- Some Polycyclic Aromatic Hydrocarbons (PAH) compounds, which can occur naturally or as a result of pollutants in the environment, were found in the mine pools and the liquid phase of the slurry. These organic compounds are commonly part of a group of compounds associated with coal, fuels, gas, oils and tars. Discriminating between the naturally occurring, non-mining, mining, and slurry injection origins of chemicals is difficult.

- Many of the abandoned underground mines included in the study are located in areas adjacent to current mining activities. These coal mining activities have water quality impacts that would look similar to impacts from slurry injection. Therefore, it is difficult to differentiate causes of these impacts.

- No universal inorganic or organic tracer to indicate the presence of coal slurry was determined from this study. However, Stiff and Piper Diagrams were used to identify slurry association with surface and ground water resources. These diagrams are a graphic display of water chemistry data that can be used to visualize water types. Site-specific parameters have been noted for individual sites. Elevated levels of sulfate, alkalinity, strontium, sodium and specific conductivity concentrations have been found in association with coal slurry; however, these parameters can also be associated with mining impacted water.

- While several organic compounds were detected in the mine pools associated with slurry injection, there were no organic compounds found in surface and ground water samples taken during the site-specific investigations.

7.0. Coal Slurry Characterization

Information on coal slurry constituents is essential in understanding the potential impacts of coal slurry on the environment and to the public health. An accurate characterization of the slurry is necessary to determine the type and amount of constituents that may be released into the environment, in addition to its chemical stability under various conditions. Determining the water quality of the leachate and or liquid phase of the slurry once placed into the abandoned underground mine and the resultant water quality of the mine pool is essential in protecting the surrounding ground and surface waters.

A sampling program was designed and implemented to provide site specific and regional data on the coal slurry. The coal slurry samples represent the coal slurry produced at the preparation plant at the time of the sampling event and may not represent current or previous injectate. The program was designed to: a) provide essential data on the chemical composition of the solid and liquid phase of the slurry and the associated coal; b) provide comparisons and contrasts regarding coal quality, site locations and preparation plant processes; and c) determine if there exists a unique constituent that could be used to identify coal slurry impacts; i.e., a "tracer" to follow the migration of the slurry from the injection site into the surrounding hydrologic regime.

Six sample sets were collected at six different coal preparation plants located throughout the State. A sample of coal slurry and run-of-mine coal located at the preparation plant where injection activities occurred were collected and analyzed for a suite of organic and inorganic constituents. The liquid phase of the sample was separated at the lab through settling of the solids and decanting of the liquid. The solid and liquid portions (phases) of the slurry were then analyzed separately. To further understand the composition of the slurry, a solid coal and a simulated coal leachate was also analyzed. The coal was crushed to a size similar to that of the slurry, mixed with deionized water, and tumbled for a period of 24 hours to produce a simulated coal leachate.

The following table provides a description of the sampling points.

WEST VIRGINIA COALSLURRY INJECTION STUDY –
COAL SLURRY CHARACTERIZATION SAMPLING SITES

Preparation Plant / Site Location	Slurry and Coal Sample Designations	Presently Injecting	Coal Seam Represented by Samples
Southern Minerals (SM)	SM-Slurry	Yes	Fire Creek
Panther, LLC (PL)	PL-Slurry, PL-Slurry	No	Eagle
Loadout, LLC (LL)	LL- Slurry, LL-Coal	No	Eagle
Power Mountain (PM)	PM-Slurry, PM-Slurry	Yes	Several*
Coresco (CL)	CL-Slurry, CL-Coal	Yes	Redstone
Marfork (MF)	MF-Slurry, MF-Coal	No	No. 2 Gas

*Coalburg, Stockton, Five Block, Winifrede

Coal slurry was collected at each preparation plant thickener, and ranged from 10 to 50 percent solids. Both the liquid and the solid phase of the slurry was analyzed for approximately 175 constituents. The raw coal was collected from a coal stockpile at the preparation plant before cleaning. The coal should represent the material or particles that remain in the coal slurry after processing. However, due to the large and varied operations at some of the preparation plants, the coal may not represent the exact coal particles remaining in the slurry, nor does it necessarily represent the same coal seam where injection occurs. It does, however, represent coal from the surrounding area and provides data on the composition and relative constituents found in area coal. This is useful for comparisons with the constituents found in coal slurry.

The coal slurry characterization phase of this study focused on the chemical constituents composing coal slurry. Physical parameters (particle distribution, permeability, density, viscosity, etc.) were not tested on individual samples. General information on the coal slurry's physical characterization was taken from documents associated with the individual coal slurry injection sites and published information.

As noted earlier, the liquid and solid phases of the slurry were sampled separately. Summary and comparison tables have been completed, in addition to column plots, to help illustrate the data. An index of the tables and plots is shown below.

TABLE SC-A	Coal & Slurry Solid Phase Organic Chemistry (>ND)
TABLE SC-B	Coal & Slurry Liquid Phase Organic Chemistry (>ND)
TABLE SC-CI	Coal & Slurry Solid Phase Inorganic Chemistry – Metals
TABLE SC-CII	Coal & Slurry Solid Phase Inorganic Chemistry – General Chemistry
FIGURE SC-1	Metal Percentages in Solid Coal Slurry – Part 1
FIGURE SC-2	Metal Percentages in Solid Coal Slurry – Part 2
FIGURE SC-3	Metal Concentrations in Slurry Liquid – Part 1
FIGURE SC-4	Metal Concentrations in Slurry Liquid – Part 2
TABLE SC-DI	Coal & Slurry Liquid Phase Inorganic Chemistry - Metals
TABLE SC-DII	Coal & Slurry Liquid Phase Inorganic Chemistry – General Chemistry

The concentrations and constituents found in the solid phase were evaluated to determine the composition of the material; the evaluation of the solid phase does not take into consideration the mobility or availability of the constituents in the environment, whereas the liquid phase provides data on those constituents that have been dissolved in water and may be mobilized in the environment.

Organic Chemistry for Coal and Slurry Solid Phase – Table SC-A shows the organic compounds which were detected in the six sets of samples. The table illustrates the similarity of the coal seam and slurry in composition. The majority of the organic compounds detected were from a group of compounds called PAHs (Polycyclic Aromatic Hydrocarbons). These organic compounds are associated with coal, fuels, gas, oils and tars. They can occur naturally, or as a result of pollutants and are ubiquitous in the environment. As shown in the Table SC-A, most of the compounds detected in the coal are also detected in the slurry. Those compounds that were detected in the slurry samples, but not in the paired coal sample are acetone, chloromethane, ethylbenzene, n-propylbenzene, butylbenzene, naphthalene, n-nitrosodiphenylamine, and pyrene. For slurry samples that did not have a paired coal sample, the other coal samples were used for comparison purposes. Of these compounds, only butylbenzene was shown to be in the coal slurry at the Panther, LLC. This can be attributed to several factors which are outlined in the individual report for Panther, LLC in Appendix I-C. Unfortunately, the type of testing performed cannot identify the exact source of these compounds because a more comprehensive set of data is necessary to identify the sources. If future studies are performed, a review of organic compound ratios from potential sources and the samples in question may be useful.

Organic Chemistry of the Liquid Phase of the Slurry – Table SC-B shows the organic compounds that were detected in the liquid phase of the slurry and the simulated leachate of the coal for all sample sites. As illustrated in the referenced table, only three compounds were detected in the liquid phase of the slurry that were not detected in the coal leachate, specifically: naphthalene, phenanthrene and 2-butanone.

Naphthalene and phenanthrene are common PAHs and were detected in the liquid phase of the slurry at Loadout, LLC. The exact source of the compounds has not been determined, however, the compound 2-butanone which was measured in a slurry sample from the Panther, LLC site was determined to be associated with the coal preparation process. The organic compound found in the liquid phase of the slurry determined to be from the slurry process was 2-butanone, although an additional compound (1-butanol) classified as a Tentatively Identified Compound (TIC), which supports this conclusion, can be found in the individual Panther, LLC report set forth in Appendix I-C.

Note: REIC Labs, which provided the lab analyses for all samples taken in support of this assessement, confirmed that the concentrations reported for the semi-volatile organic compound, bis(2-ethylhexyl)phthalate were lab artifacts and not associated with the samples taken from the various sites. This means that the compound is present throughout the laboratory environment and can be detected in some samples.

The organic characterization data did not reveal a universal conservative (stable in the environment) tracer that could be used in future environmental assessments relative to slurry impacts.

Inorganic Chemistry of the Solid Phase of the Slurry – Tables SC-CI and SC-CII summarize the inorganic chemistry of the solid phase of the slurry and the coal for all samples. The main constituents of concern for human health and the environment are the heavy metals which have been converted into percentages and transferred onto two individual plots, Figures SC-1 and SC-2. The plots illustrate the relative concentrations of the metals within each sample and at the separate sites.

For all sample sites, iron, sodium, aluminum, and calcium made up the greatest portion of the slurry solids. Although the percentages varied for the individual sites, iron was the greatest percentage found at all sites, except Loadout, which had sodium in the greatest proportion. There were no concentrations of silver, cyanide, or thallium found in the samples, and most samples had no detectable concentrations of selenium and antimony, with the exception of Coresco and Southern Minerals.

All of the samples from all of the sites were alkaline with varying concentrations of chloride and sulfate values. The greatest sulfate concentration was found at Coresco and the lowest was at Southern Minerals. This may be a direct reflection of the sulfur content of the coal.

Inorganic Chemistry of the Liquid Phase of the Slurry – Tables SC-DI and SC-DII summarize the inorganic chemistry of the liquid phase of the slurry and coal. The dissolved metal concentration can come from a variety of sources. They may have been released from the slurry solids and/or the chemical additives used at the plant. They may also have been in the water used at the preparation plant. Dissolved metal concentrations account for the metals in solution and are appropriate when evaluating the liquid phase of the slurry. The dissolved constituents represent the most mobile in the environment depending on site specific conditions. Mine conditions, such as the amount and variability of saturation and chemical characteristics such as pH and redox (reduction and oxidation) conditions significantly affect the solubility of the constituents. In addition, other chemical conditions will affect the adsorption and precipitation of these constituents.

In all the liquid slurry samples from all the sites, sodium concentrations were the greatest; ranging from 58.8 mg/L to 272.0 mg/L. Calcium, magnesium and potassium were the next three highest ranking concentrations for all samples. Sulfate concentrations were highest in the slurry liquid phase for all samples at all sites, except for Panther where chloride was the most dominant constituent.

Relative to the heavy metals, no concentrations were reported for cadmium and mercury. Silver and thallium were only reported at the detection level for the samples at Power Mountain. It is interesting to note that neither of these metals had concentrations reported in the solid sample at Power Mountain. Of the other metals analyzed, aluminum, barium, manganese and molybdenum all had notable concentrations.

A review of the inorganic data did not reveal a universal conservative tracer that could be used in future studies. In fact, the predominant constituents found in the solid and the liquid phases are the same as those found in coal and coal mining impacted waters.

Using the Federal Primary Drinking Water Standards for comparison, three dissolved metal concentrations exceeded the standards in slurry liquid samples at selected sites. Antimony levels exceeded the standard of (0.006 mg/L) in the sample at Panther, Southern Minerals and Coresco (0.0104, 0.0220 and 0.0069), respectively. Arsenic levels exceeded the standard of (0.010 mg/L) in the sample at Panther (0.012mg/l), as did lead, which exceeded the standard of (0.015mg/l) at 0.0762 mg/L. Panther is not currently injecting.

TABLE SC-A Coal & Slurry Solid Phase Organic Chemistry (> Non-Detect)

Analyte	Unit	Loadlout, LLC		Panther		Southern Mineral		Power Mountain		Cresco		Marfork	
		Slurry Solid	Coal	Slurry Solid	Coal	Slurry Solid	Coal	Slurry Solid	Coal	Slurry Solid	Coal	Slurry Solid	Coal
TPH (Diesel Range)	mg/kg	282	746	144	NA	280	NA	222	927	712	1020	179	535
TPH (Oil Range)	mg/kg	469	525	159	NA	391	NA	382	782	765	740	258	640
Volatile Organic Compounds													
1,2,4-Trimethylbenzene(C9H12)	µg/kg	ND	64.1	216	NA	ND	NA	25.2	398	87.9	86.9	26.7	166
1,3,5-Trimethylbenzene(C9H12)	µg/kg	ND	60.1	76.8	NA	ND	NA	ND	183	35.4	78.6	22.6	94.3
Acetone (C3H7O)	µg/kg	267	ND	ND	NA	ND	NA	ND	ND	ND	398	ND	ND
Acrolein (C3H4O)		ND	ND	ND	NA	ND	NA	ND	ND	ND	356	ND	ND
Benzene(C6H6)	µg/kg	ND	16.6	166	NA	ND	NA	ND	330	ND	ND	ND	ND
Carbon disulfide (CS2)	µg/kg	ND	36.7	ND	NA	ND	NA	ND	ND	ND	ND	ND	ND
Chloromethane(CH3Cl)	µg/kg	ND	ND	ND	NA	ND	NA	ND	ND	ND	ND	ND	ND
Ethylbenzene(C8H10)	µg/kg	ND	24.9	122	NA	ND	NA	ND	139	20.2	ND	ND	24.5
Isopropylbenzene(C9H12)	µg/kg	ND	62.2	30.2	NA	ND	NA	29.9	132	107	162	34.4	100
m,p-Xylene(C8H10)	µg/kg	ND	92.6	585	NA	ND	NA	44.6	976	71.4	44.4	ND	163
Methylene chloride (CH2CL2)	µg/kg	ND	ND	ND	NA	ND	NA	ND	23.2	ND	ND	ND	ND
Naphthalene(C10H8)	µg/kg	ND	ND	259	NA	ND	NA	34.4	99.3	ND	ND	40.4	ND
n-Propylbenzene(C9H12)	µg/kg	ND	ND	45.5	NA	ND	NA	ND	61	22	ND	ND	23.7
o-Xylene(C8H10)	µg/kg	ND	53	284	NA	ND	NA	28.7	473	72.6	66.8	ND	114
Sec-Butylbenzene(C10H14)	µg/kg	ND	ND	8.5	NA	ND	NA	ND	ND	ND	ND	ND	ND
Toluene(C7H8)	µg/kg	27.6	205	1040	NA	ND	NA	51.6	8670	64.3	25.1	ND	178
SemiVolatile Organic Compounds													
2,4-Dimethylphenol(C8H10O)	mg/kg	0.482	1.24	0.167	NA	ND	NA	ND	0.466	ND	ND	ND	0.424
Acenaphthene((C12H10)	mg/kg	0.07	0.227	ND	NA	ND	NA	ND	0.072	ND	ND	ND	0.197
Benzo(a)anthracene(C18H12)	mg/kg	0.136	0.563	0.036	NA	ND	NA	ND	0.127	ND	ND	ND	ND
Benzo(a)pyrene(C20H12)	mg/kg	0.162	0.834	0.07	NA	0.167	NA	0.463	0.329	0.747	0.797	ND	0.231
Benzo(b)fluoranthene(C20H12)	mg/kg	0.176	0.859	0.082	NA	ND	NA	ND	0.261	ND	ND	0.087	0.227
Benzo(g,h,i)perylene(C22H12)	mg/kg	0.513	2.07	0.155	NA	0.092	NA	0.346	0.982	ND	ND	0.098	0.42
Benzo(k)fluoranthene(C20H12)	mg/kg	0.065	0.298	ND	NA	0.191	NA	ND	0.278	ND	ND	ND	0.213
Bis(2-ethylhexyl)phthalate (C24H38O4)	mg/kg	ND	0.239	ND	NA	ND	NA	ND	0.217	ND	ND	ND	0.227
Chrysene(C18H12)	mg/kg	0.198	0.76	0.206	NA	0.528	NA	0.248	1.16	0.73	0.873	0.32	1.1
Dibenzo(a,h)anthracene(C22H14)	mg/kg	0.042	0.251	0.032	NA	ND	NA	ND	0.183	ND	ND	ND	0.132
Fluoranthene(C16H10)	mg/kg	0.119	0.525	0.07	NA	0.078	NA	0.144	0.288	ND	ND	0.096	0.348
Fluorene(C13H10)	mg/kg	0.184	0.675	0.202	NA	0.327	NA	0.180	0.852	0.843	1.14	0.135	1.04
Indeno(1,2,3-cd)pyrene(C22H12)	mg/kg	0.074	0.371	ND	NA	ND	NA	ND	0.175	ND	ND	ND	0.08
m,p-Cresol(C7H8O)	mg/kg	0.21	0.428	0.089	NA	ND	NA	ND	0.175	ND	ND	ND	0.151
Naphthalene(C10H8)	mg/kg	2.69	9.61	1.5	NA	0.069	NA	1.41	7.54	4.1	5.24	0.234	4.8
Nitrobenzene(C6H5NO3)	mg/kg	ND	ND	ND	NA	ND	NA	ND	ND	ND	ND	ND	ND
N-Nitrosodiphenylamine	mg/kg	0.171	ND	ND	NA	ND	NA	ND	ND	ND	ND	ND	ND
o-Cresol(C7H8O)	mg/kg	0.207	0.434	ND	NA	ND	NA	ND	0.224	ND	ND	ND	0.229
Phenanthrene(C14H10)	mg/kg	0.947	3.77	0.903	NA	0.949	NA	1.09	4.99	4.22	6.2	0.604	4.76
Phenol(C7H6O)	mg/kg	0.068	0.087	0.045	NA	ND	NA	ND	0.075	ND	ND	ND	ND
Pyrene(C16H10)	mg/kg	0.225	0.966	0.095	NA	0.136	NA	0.169	0.447	ND	ND	0.121	0.462

ND - Non Detect
NA - Non Analyzed

TABLE SC-B Coal & Slurry Liquid Phase Organic Chemistry (> Non-Detect)

Analyte	Unit	Lab Results											
		Loadlout, LLC		Panther		Southern Mineral		Power Mountain		Coresco		Marfork	
		Slurry Liquid	Coal Leachate	Slurry Liquid	Coal Leachate	Slurry Liquid	Coal Leachate	Slurry Liquid	Coal Leachate	Slurry Liquid	Coal Leachate	Slurry Liquid	Coal Leachate
TPH (Diesel Range)	mg/l	16.6	ND	0.51	ND	ND	NA	0.26	ND	ND	ND	NA	ND
TPH (Oil Range)	mg/l	19.4	ND	ND	ND	ND	NA	ND	ND	ND	ND	NA	ND
Volatile Organic Compounds													
Acetone(C3H7O)	µg/l	7	14.8	16.7	9.9	ND	NA	ND	ND	ND	ND	NA	ND
Benzene(C6H6)	µg/l	ND	ND	1.8	1.6	ND	NA	ND	1.4	ND	ND	NA	ND
2-Butanone	µg/l	ND	ND	68.4	ND	ND	NA	ND	ND	ND	ND	NA	ND
Methylene Chloride	µg/l	1.4	1	ND	ND	ND	NA	ND	ND	ND	ND	NA	ND
Toluene(C7H8)	µg/l	0.6	0.7	2.8	2.1	ND	NA	ND	1.9	ND	ND	NA	0.2
0-Xylene(C8H10)	µg/l	ND	ND	0.6	0.3	ND	NA	ND	0.3	ND	ND	NA	ND
m,p-Xylene(C8H10)	µg/l	ND	ND	0.8	0.4	ND	NA	ND	0.4	ND	ND	NA	ND
SemiVolatile Organic Compounds													
Naphthalene(C10H8)	mg/l	0.0143	ND	ND	ND	ND	NA	ND	ND	ND	ND	NA	ND
Phenanthrene	mg/l	0.0061	ND	ND	ND	ND	NA	ND	ND	ND	ND	NA	ND
Bis(2-ethylhexyl)phthalate		ND	ND	ND	ND	ND	NA	ND	0.0091	ND	ND	NA	0.0108

ND - Non Detect
NA - Non Analyzed

TABLE SC-CI Coal Slurry Solid Phase Inorganic Chemistry													
Metals	Lab Results												
	Unit	Loadlout, LLC		Panther		Southern Minerals		Power Mountain		Coresco		Marfork	
		LL- Coal (Raw)	LL-Slurry Solid	Coal (Raw)	Slurry Solid	SM- Coal (Raw)	SM- Slurry Solid	PM- Coal (Raw)	PM- Slurry Solid	CL- Coal (Raw)	CL- Slurry Solid	MF- Coal (Raw)	Slurry
Aluminum	mg/kg	1170	36.1	NA	3600	NA	1910	8740	1040	1820	1420	8720	3130
Antimony	mg/kg	ND	ND	NA	ND	NA	0.55	ND	ND	ND	ND	ND	ND
Arsenic	mg/kg	1.56	ND	NA	ND	NA	1.2	4.34	2.11	10.6	4.63	159	ND
Barium	mg/kg	19.9	0.638	NA	52.3	NA	99.2	137	170	34.9	38.9	152	304
Beryllium	mg/kg	0.544	ND	NA	0.385	NA	0.425	1.29	0.289	1.4	0.525	NA	NA
Cadmium	mg/kg	0.0692	ND	NA	0.0809	NA	N/D	0.577	0.149	0.312	0.145	0.445	0.123
Calcium	mg/kg	453	84.1	NA	1220	NA	424	1640	371	2540	3940	951	719
Chromium	mg/kg	5.98	ND	NA	4.82	NA	2.77	14.3	4.33	10.7	7.47	13.9	5.55
Cobalt	mg/kg	3.80	ND	NA	2.31	NA	1.99	13.8	3.02	6.34	3.66	11.2	3.81
Copper	mg/kg	9.88	ND	NA	7.54	NA	4.59	25.7	6.16	10.5	7.98	27.4	10.8
Iron	mg/kg	1480	29.7	NA	6080	NA	2060	33800	9890	19900	8160	28200	7000
Lead	mg/kg	5.67	ND	NA	4.79	NA	2.95	16.7	4.89	8.06	4.09	16.2	5.86
Magnesium	mg/kg	382	26.2	NA	908	NA	620	3150	324	704	584	2680	1260
Manganese	mg/kg	13.5	0.498	NA	51.9	NA	22.5	570	34.3	85.7	48.7	183	72.9
Mercury	mg/kg	0.052	ND	NA	ND	NA	ND	0.044	0.112	0.158	0.034	0.254	ND
Molybdenum	mg/kg	0.610	ND	NA	ND	NA	0.395	0.56	0.408	0.765	0.876	1.62	ND
Nickel	mg/kg	6.80	ND	NA	5.06	NA	4.34	22.10	6.10	11.1	7.93	21.5	7.68
Potassium	mg/kg	451	43.3	NA	1210	NA	931	2160	422	555	381	2180	1280
Selenium	mg/kg	1.96	ND	NA	ND	NA	ND	ND	ND	ND	0.617	1.17	ND
Silicon	mg/kg	77.5	32.3	NA	46.3	NA	453	342	250	174	70.8	321	317
Silver	mg/kg	ND	ND	NA	ND	NA	N/D	ND	ND	ND	ND	ND	ND
Sodium	mg/kg	48.1	217	NA	754	NA	44.3	588	85.7	415	394	593	315
Strontium	mg/kg	13.4	1.57	NA	13.6	NA	16.8	68.9	14.4	84.6	84.0	61.4	34.6
Thallium	mg/kg	ND	ND	NA	ND	NA	ND	ND	ND	ND	ND	ND	ND
Vanadium	mg/kg	7.93	ND	NA	6.61	NA	3.14	13.2	25.6	16.5	11	16.8	8.22
Zinc	mg/kg	16.5	2.7	NA	17.4	NA	8.6	68.9	10.3	23.9	20.3	49.1	18.7

ND - Non Detect
NA - Non Analyzed

TABLE SCII Coal Slurry Solid Phase Inorganic Chemistry													
General Chemistry	Lab Results												
	Unit	Loadlout, LLC		Panther		Southern Mineral		Power Mountain		Coresco		Marfork	
		LL-Coal (Raw)	LL-Slurry Solid	Coal (Raw)	Slurry Solid	SM-Coal (Raw)	SM- Slurry Solid	PM- Coal (Raw)	PM- Slurry Solid	CL- Coal (Raw)	CL- Slurry Solid	MF- Coal (Raw)	MF- Slurry Solid
Nitrogen, Nitrate	mg/kg	ND	N/D	NA	ND	NA	ND	ND	4.10	3000	2390	ND	ND
Nitrogen, Nitrite	mg/kg	ND	N/D	NA	9.06	NA	ND	ND	ND	304	251	ND	ND
Chloride	mg/kg	306	118	NA	554	NA	ND	26.10	130.00	265	173	31	173
Cyanide	mg/kg	ND	ND	NA	ND	NA	ND	ND	ND	ND	ND	ND	ND
Fluoride	mg/kg	ND	N/D	NA	1.86	NA	ND	ND	5.10	35	90	2.54	ND
Sulfate	mg/kg	577	690	NA	144	NA	9.35	26.8	798.00	36100	18500	260	191
Nitrogen, Ammonia	mg/kg	31.9	33.6	NA	33.6	NA	ND	68.3	20	6.7	ND	57.1	25.8
Acidity, Total	mg/kg	ND	ND	NA	ND	NA	11.40	ND	ND	N/A	N/A	N/A	N/A
Alkalinity, Bicarbonate	mg/kg	652	1710	NA	ND	NA	449.00	787.0	352.0	1700	4820	ND	843
Alkalinity, Carbonate	mg/kg	7.7	86.1	NA	ND	NA	2.30	77.4	ND	358	521	ND	5.7
Alkalinity, Total	mg/kg	660	1790	NA	1390	NA	451.00	865.0	352.0	2060	5350	594	848
pH	SU	8.10	8.73	NA	9.44	NA	7.63	9.02	7.35	9.35	9.06	9.2	7.86

ND - Non Detect

NA - Non Analyzed

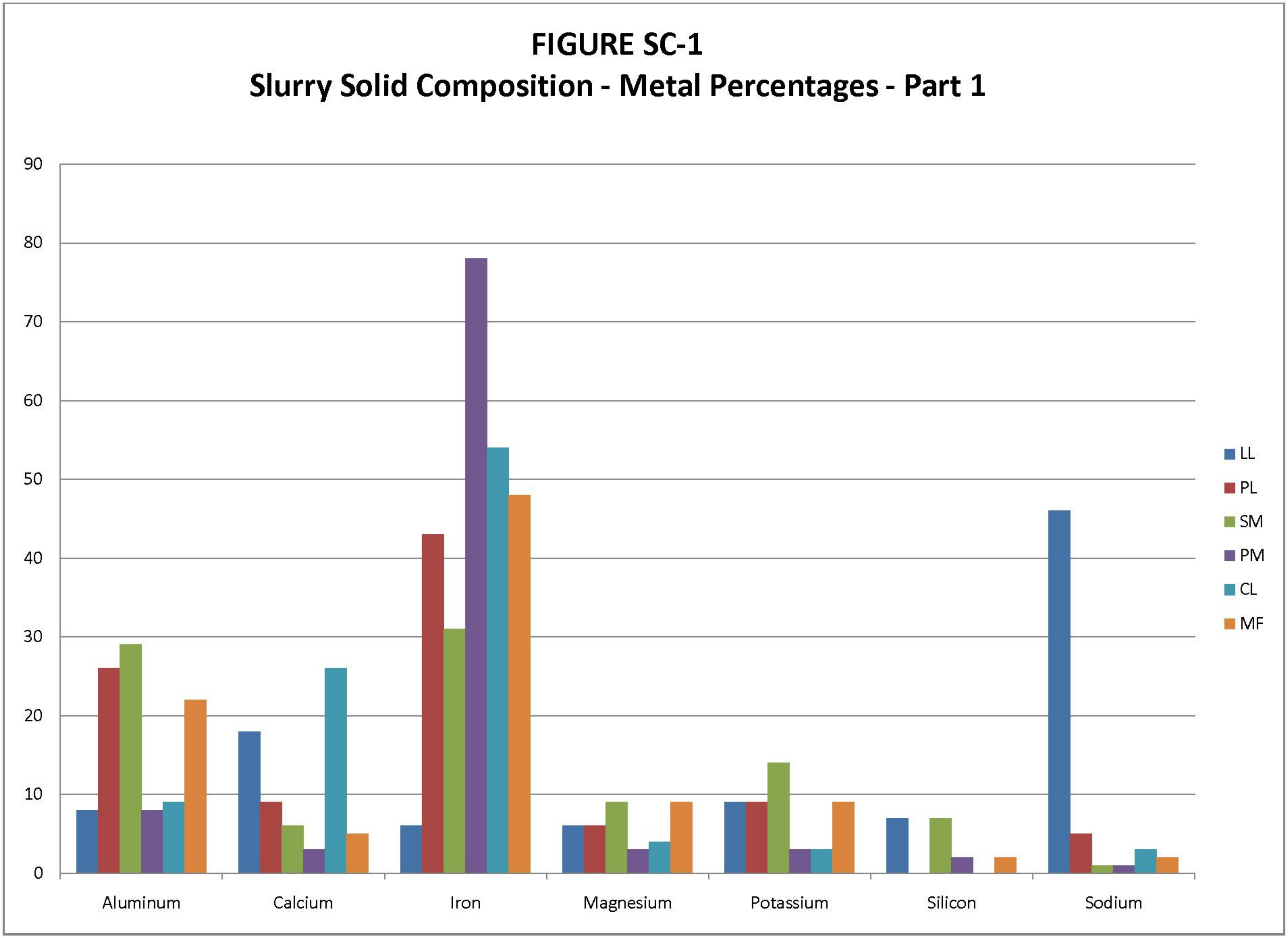
FIGURE SC-1
Slurry Solid Composition - Metal Percentages - Part 1
90
80
70
60
50
40
30
20
10
0
Aluminum
Calcium
Iron
Magnesium
Potassium
Silicon
Sodium
LL
PL
SM
PM
CL
MF

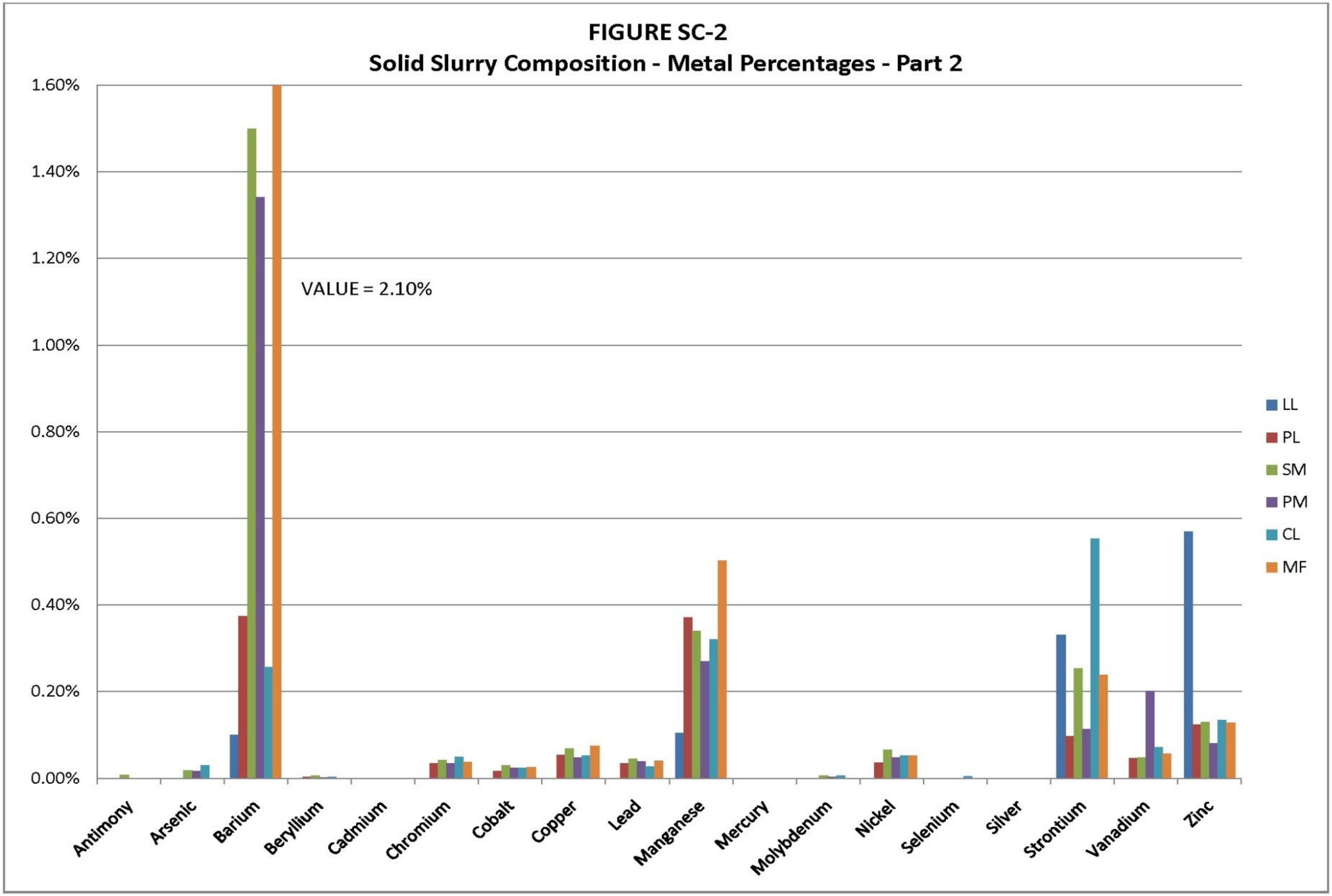
FIGURE SC-2
Solid Slurry Composition - Metal Percentages - Part 2
1.60%
1.40%
1.20%
1.00%
0.80%
0.60%
0.40%
0.20%
0.00%
VALUE = 2.10%
LL
PL
SM
PM
CL
MF
Antimony
Arsenic
Barium
Beryllium
Cadmium
Chromium
Cobalt
Copper
Lead
Manganese
Mercury
Molybdenum
Nickel
Selenium
Silver
Strontium
Vanadium
Zinc

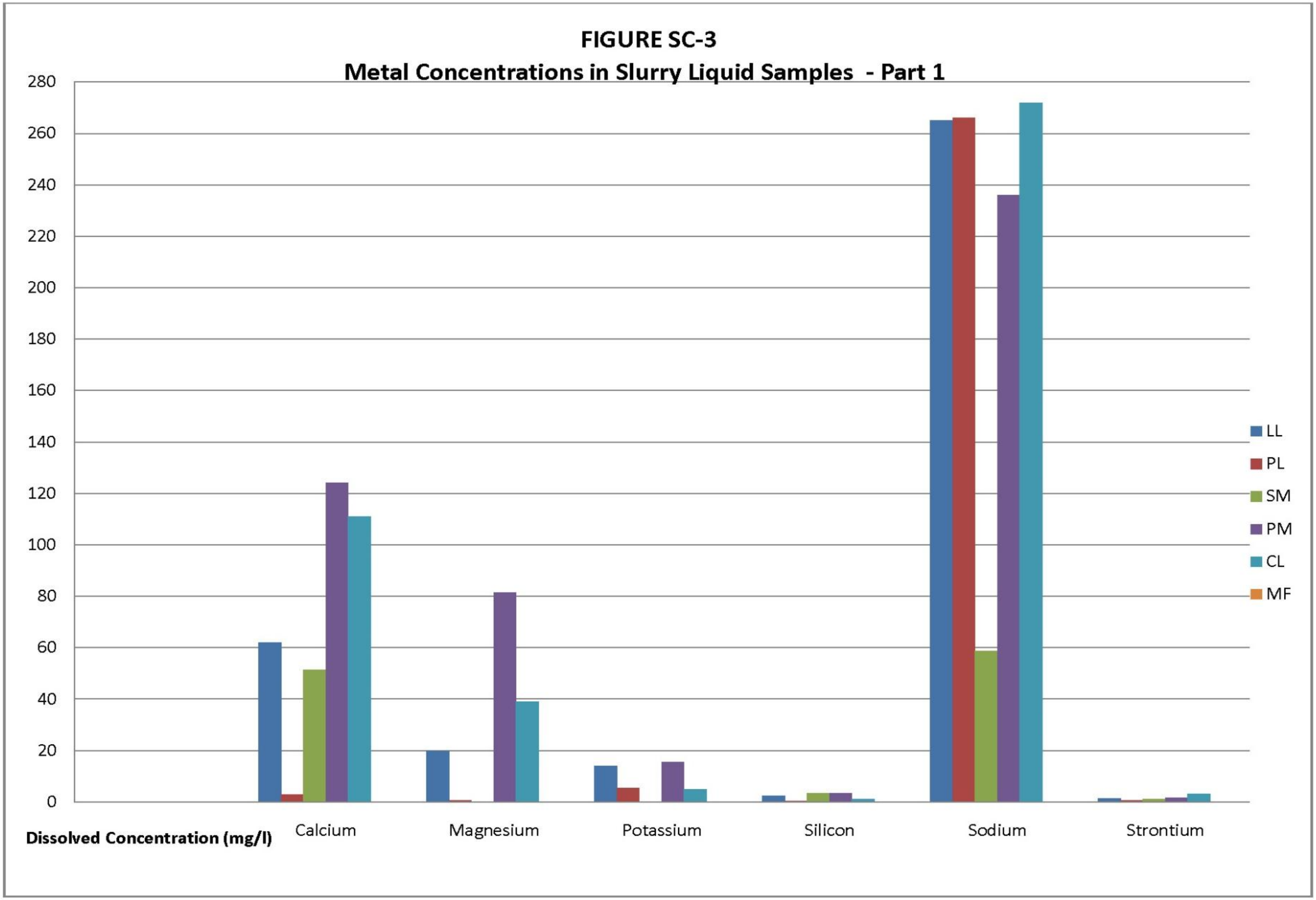
FIGURE SC-3
Metal Concentrations in Slurry Liquid Samples - Part 1
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
Dissolved Concentration (mg/l)
Calcium
Magnesium
Potassium
Silicon
Sodium
Strontium
LL
PL
SM
PM
CL
MF

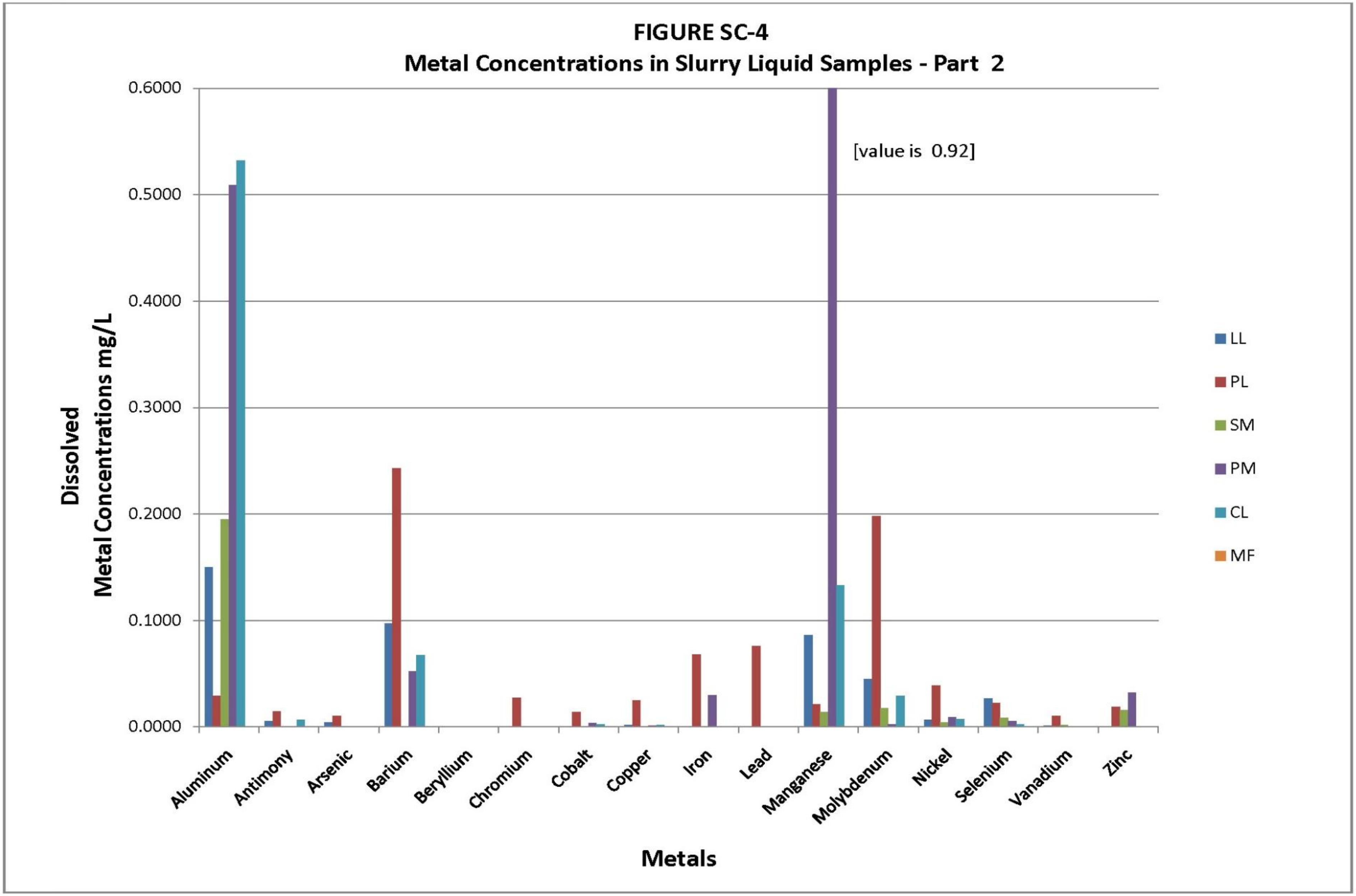
FIGURE SC-4
Metal Concentrations in Slurry Liquid Samples - Part 2
[value is 0.92]
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
Dissolved
Metal Concentrations mg/L
Aluminum
Antimony
Arsenic
Barium
Beryllium
Chromium
Cobalt
Copper
Iron
Lead
Manganese
Molybdenum
Nickel
Selenium
Vanadium
Zinc
Metals
LL
PL
SM
PM
CL
MF

TABLE SC-DI Coal Slurry Liquid Phase Inorganic Chemistry

Dissolved & Total Metals Analyses Results	Unit	Lab Results: Loadlout, LLC			Panther			Southern Mineral			Power Mountain			Coresco			Marfork		
		LL- Slurry Liquid		LL- Coal Leachate	PL- Slurry (Liquid)		PL- Coal Leachate	SM- Slurry Liquid		SM- Coal Leachate	PM- Slurry Liquid		PM- Coal Leachate	CL- Slurry Liquid		CL- Coal Leachate	MF- Slurry Liquid	MF- Coal Leachate	
		Dissolved	Total	Dissolved	Dissolved	Total	Dissolved	Dissolved	Total	NA	Dissolved	Total	Dissolved	Dissolved	Total	Dissolved	Dissolved/Total	Dissolved	Total
Aluminum	mg/L	0.1500	2.37	0.0540	0.029	0.046	0.398	0.1950	0.651	NA	0.509	0.564	0.214	0.532	0.644	0.356	NA	0.146	1.190
Antimony	mg/L	0.0057	0.0059	0.0019	0.0146	0.016	0.0012	0.0220	0.0215	NA	0.0004	0.0005	0.0018	0.0069	0.0071	0.0005	NA	0.0015	0.0011
Arsenic	mg/L	0.0042	0.0047	0.0041	0.0104	0.0113	0.012	0.0039	0.0043	NA	ND	ND	0.0141	ND	ND	0.0019	NA	0.0198	0.246
Barium	mg/L	0.0974	0.133	0.0055	0.243	0.269	0.0129	0.0809	0.114	NA	0.0523	0.0634	0.0079	0.0677	0.0713	0.0047	NA	0.0227	0.695
Beryllium	mg/L	ND	ND	ND	ND	ND	ND	0.0002	0.0004	NA	ND	ND	ND	ND	ND	ND	NA	ND	0.002
Cadmium	mg/L	ND	ND	ND	ND	0.0011	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND	NA	ND	ND
Calcium	mg/L	62.10	63.7	2.42	2.83	3.51	0.464	51.4000	51.7	NA	124.000	123.000	0.552	111	115	4.820	NA	0.2840	1.260
Chromium	mg/L	ND	ND	0.0013	0.0272	0.0342	ND	0.0013	0.0016	NA	ND	ND	ND	ND	ND	ND	NA	ND	0.0054
Cobalt	mg/L	ND	0.0016	ND	0.0142	0.0161	ND	0.0021	0.0024	NA	0.0037	0.0039	ND	0.0027	0.0029	ND	NA	ND	0.0067
Copper	mg/L	0.0016	0.0034	ND	0.0248	0.0278	ND	0.0012	0.0018	NA	0.0015	0.0016	ND	0.0021	0.0021	ND	NA	ND	0.0248
Iron	mg/L	ND	0.828	ND	0.068	0.089	ND	ND	0.91	NA	0.030	0.195	0.038	ND	0.174	0.022	NA	0.050	13.200
Lead	mg/L	ND	0.0016	ND	0.0762	0.0775	ND	ND	0.0008	NA	ND	0.0004	0.0004	ND	ND	ND	NA	0.0003	0.2170
Magnesium	mg/L	19.8	20.6	0.705	0.591	0.771	ND	20.8	21	NA	81.40	82.20	ND	38.90	40.00	0.29	NA	ND	2.21
Manganese	mg/L	0.0860	0.097	ND	0.021	0.028	ND	0.0141	0.0177	NA	0.921	0.921	ND	0.133	0.138	ND	NA	0.001	0.142
Mercury	mg/L	ND	ND	ND	ND	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND	NA	ND	ND
Molybdenum	mg/L	0.0447	0.0466	0.0090	0.198	0.217	ND	0.0176	0.0178	NA	0.0023	0.0024	0.0035	0.0290	0.0297	0.0020	NA	0.0029	0.0021
Nickel	mg/L	0.0067	0.0073	ND	0.0386	0.0432	ND	0.0043	0.0052	NA	0.0092	0.0096	ND	0.0073	0.0074	ND	NA	ND	0.0110
Potassium	mg/L	13.9	14.3	5.02	5.38	7.05	1.23	6.90	7.07	NA	15.50	15.50	0.380	5.01	5.16	1.080	NA	0.321	0.925
Selenium	mg/L	0.0268	0.0278	0.0195	0.0224	0.0255	0.0087	0.0082	0.0082	NA	0.0057	0.0059	0.0082	0.0024	0.0024	0.0019	NA	0.0043	0.0040
Silicon	mg/L	2.3	8.54	11.1	0.346	0.358	0.384	3.3	3.76	NA	3.27	5.31	7.59	1.14	3.91	0.43	NA	13.20	71.00
Silver	mg/L	ND	ND	0.0005	ND	ND	ND	ND	ND	NA	0.0006	0.0006	ND	ND	ND	ND	NA	ND	ND
Sodium	mg/L	265	267	4.88	266	341	10.1	58.8	55.5	NA	236.0	237.0	75.5	272.0	279.0	12.6	NA	48.1	6.7
Strontium	mg/L	1.44	1.4700	0.0159	0.571	0.632	0.0222	1.16	1.1700	NA	1.630	1.740	0.0043	3.19	3.270	0.16	NA	0.115	0.135
Thallium	mg/L	0.0003	0.0004	ND	ND	ND	ND	ND	0.0002	NA	0.0002	0.0003	ND	ND	0.0002	ND	NA	0.0002	0.0004
Vanadium	mg/L	0.0013	0.0025	0.0044	0.0103	0.0131	0.007	0.0018	0.0021	NA	ND	ND	0.0052	ND	ND	0.0015	NA	0.0031	ND
Zinc	mg/L	ND	0.008	0.008	0.019	0.014	ND	0.016	0.027	NA	0.032	0.041	ND	ND	ND	0.003	NA	ND	0.038

ND - Non Detect
NA - Non Analyzed

TABLE SC-DII Coal Slurry Liquid Phase Inorganic Chemistry

General Chemistry	Unit	Lab Results											
		Loadlout, LLC		Panther		Southern Mineral		Power Mountain		Coresco		Marfork	
		LL- Slurry Liquid	LL- Coal Leachate	PL- Slurry Liquid	PL- Coal Leachate	SM- Slurry Liquid	SM- Coal Leachate	PM- Slurry Liquid	PM- Coal Leachate	CL- Slurry Liquid	CL- Coal Leachate	MF- Slurry Liquid	MF- Coal Leachate
Nitrogen, Nitrate	mg/l	1.85	0.07	0.59	0.03	0.45	NA	3.45	ND	0.83	ND	NA	ND
Nitrogen, Nitrite	mg/l	0.35	0.17	ND	ND	2.32	NA	ND	0.14	0.16	ND	NA	0.10
Chloride	mg/l	84.80	1.45	423.00	7.12	0.18	NA	77.10	1.71	32.80	0.60	NA	1.43
Fluoride	mg/l	ND	0.55	1.53	0.51	8.39	NA	0.56	0.42	ND	ND	NA	0.31
Sulfate	mg/l	849.00	7.40	261.00	2.60	157.00	NA	853.00	3.44	1110.00	14.00	NA	4.55
Nitrogen, Ammonia	mg/l	1.27	0.34	1.96	0.44	0.18	NA	1.16	0.35	0.72	0.14	NA	0.10
Cyanide, Total	mg/l	ND	ND	ND	ND	ND	NA	ND	ND	ND	ND	NA	ND
Specific Conductivity	µmh/cm	1840	57.20	5000.00	170.00	702.00	NA	2110	100	2030	116	NA	86.7
Total Dissolved Solids	mg/l	933.00	21.00	2540.00	87.00	423.00	NA	1470	21	1340	51	NA	15.0
Total Suspended Solids	mg/l	191.00	1.00	74.00	6.00	5440.00	NA	9	1	22	1	NA	1
Acidity, Total	mg/l	6.90	ND	ND	ND	6.80	NA	8.7	ND	5.4	ND	NA	ND
Alkalinity, Bicarbonate	mg/l	102.00	25.50	412.00	42.00	180.00	NA	146.0	34.3	143.0	32.1	NA	23.2
Alkalinity, Carbonate	mg/l	ND	6.00	7.10	14.30	1.40	NA	ND	10.0	ND	6.8	NA	6.0
Alkalinity, Total	mg/l	103.00	32.70	420.00	58.20	181.00	NA	147.0	45.8	144.0	40.0	NA	30.6
pH	SU	7.88	9.40	8.26	9.56	7.93	NA	7.75	9.49	7.71	9.35	NA	9.44

ND - Non Detect
NA - Non Analyzed

8.0. Findings and Conclusions

Based on a review of the baseline data from the UIC and mining permits, there are insufficient surface and groundwater monitoring sample sites to determine effects from slurry injection on surface and ground water.

Most of the assessment sites lacked detailed information on mine pool conditions and adequate monitoring of the quantity and quality of the mine pool associated with the injection activities. Despite the fact that the mines studied were below or partially below drainage, several of the mines had documented artesian flow of slurry to the surface. A below drainage mine is one where the coal seam is lower than the surface drainage feature. Many of these mine pools are pumped to maintain mine pool elevations.

All of the deep mines evaluated in this study are below or partially below drainage. The majority of the mine workings are located below surface drainages with the exception of entries located at the up-dip end of the mines. Conceptually, waters associated with the deep mine workings below drainage are less likely to impact surrounding groundwater due to the low permeability of the strata surrounding the mine pools. Therefore, it is less likely for the slurry and its constituents located in the deep pools to impact the surrounding groundwater. However, this study does not provide evidence to confirm this statement nor does it disprove it.

Sample results indicate that the inorganic and organic chemical composition of the coal slurry is similar to that of the coal seams. This similarity creates difficulty in isolating water quality impacts due solely to the injection of coal slurry in underground mines. Due to the complex nature of groundwater movement and the similar chemical make-up of coal slurry and the coal within the underground mine, differentiating impacts of injection activities from those of other mining activities is extremely difficult, if not impossible. However, in one site, the coal slurry exhibited organics that appear to originate from the preparation process, but were not evident in the coal.

Some Polycyclic Aromatic Hydrocarbon (PAH) compounds, which can occur naturally or as a result of pollutants in the environment, were found in the mine pools and the liquid and solid phases of the slurry. These organic constituents are commonly part of a group of compounds associated with coal, fuels, gas, oils and tars. The PAH organic compounds can occur naturally, or as a result of pollutants in the environment. Differentiating among the naturally occurring, non-mining, mining, and slurry injection origins of chemicals is difficult.

Many of the abandoned underground mines included in the study are located in areas adjacent to mining activities. These coal mining activities have water quality impacts that would look similar to impacts from slurry injection. Therefore, it is difficult to differentiate causes of these impacts.

Stiff and Piper Diagrams were used to ascertain whether slurry was associated with surface and ground water resources. These diagrams are a graphic display of water chemistry data that can be used to visualize water types. Site-specific parameters have been noted for individual sites. Elevated levels of sulfate, alkalinity, strontium, sodium and specific conductivity concentrations have been found in association with coal slurry; however, these parameters can also be associated with other mining activities. No universal inorganic or organic tracer to indicate the presence of coal slurry was determined from this study.

None of the sites showed water quality impacts to surface waters due solely to slurry injection.

The Material Safety Data Sheets (MSDSs) do not provide adequate information on the composition of chemicals used at coal preparation plants. Therefore, sampling and analyzing for compounds associated with these chemicals is very difficult.

While several organic compounds were detected in the mine pools associated with slurry injection, there were no organic compounds found in surface and ground water samples taken during the site-specific investigations.

The WVDEP-UIC compliance DMR data showed exceedences of UIC permit limits established for the coal slurry injectate. TPH (Total Petroleum Hydrocarbons) and Chromium are the most common parameters that exceeded the limits.

Samples taken downgradient in the mine pool where slurry injection occurred showed no physical evidence of the migration of slurry solids. In addition, samples taken from two adjacent mine pools showed no physical evidence of migration of slurry solids.

Two of the four sites showed effects to the mine pool receiving injection. Certain constituents migrated from the slurry into the mine pool. Due to a lack of adequate baseline and compliance monitoring by the operator, migration of the constituents from the mine pool to the surrounding groundwater was difficult to determine.

Two public water supplies draw their water from the same mine receiving slurry injection. The finished consumable water from both public water systems met EPA Primary Drinking Water Standards at the time of the sampling event.

Using the Federal Primary Drinking Water Standards for comparison reasons, three dissolved metal concentrations exceeded the standards in slurry liquid samples at selected sites. Antimony levels exceeded the standard of (0.006 mg/L) in the sample at Panther, LLC, Southern Minerals and Coresco (0.0104 mg/L, 0.0220 mg/L, and 0.0069 mg/L, respectively). Arsenic levels exceeded the standard of (0.010 mg/L) in the sample at Panther, LLC (0.012 mg/L); in addition, the lead level exceeded the standard of (0.015 mg/L) at 0.0762 mg/L. Panther, LLC no longer injects coal slurry.

The Federal Safe Drinking Water Act applies only to public water systems. Private water supplies are not subject to the primary or secondary standards established under the Federal Safe Drinking Water Act.

Due to insufficient groundwater characterization and monitoring by the operators, definitive conclusions could not be drawn on the extent of the effects of slurry injection on the surrounding groundwater regime.

Operators did not conclusively demonstrate that, when slurry is injected into abandoned underground mines, it remains contained and the surrounding hydrologic regime is not adversely affected.

All slurry injection study sites that were investigated had at least one slurry spill during their lifetime that affected surrounding surface waters.

Many of the private, individual water wells within the vicinity of slurry injection sites were not monitored by operators during the slurry injection activities.

One operator, who injected slurry within the vicinity of a public water system, monitored that system during slurry injection activities to ensure that slurry was not adversely affecting that public water system.

9.0 Recommendations

1. Effective immediately, the WVDEP will impose a moratorium on the approval of injection of coal slurry into mine voids in which coal slurry injection has not previously been approved under the modern era program.

2. The UIC program needs to work much more closely with the DMR and NPDES permitting programs. Better coordination is needed between the UIC program and the DMR inspection program in order to provide better oversight of coal slurry injection activities and their impacts. The coal slurry UIC program should be moved into the purview of the WVDEP's mining program to assure this coordination and oversight takes place.

3. During injection activities, site-specific and hydrologically pertinent groundwater monitoring should be required for all UIC permits, and surface water monitoring. At a minimum, sampling should include TPH (Total Petroleum Hydrocarbons), GRO (Gasoline Range Organics), DRO (Diesel Range Organics), and ORO (Oil/Grease Range Organics), heavy metals, standard baseline/compliance general chemistry parameters, and additional organic parameters, if necessary. This recommendation should be implemented through an administrative order for existing permits and as a standard permit condition for future permits.

4. All mine pools receiving slurry injection must be monitored using monitoring wells at multiple locations for the life of the injection permit. This recommendation should be implemented through an administrative order for existing permits and as a standard permit condition for future permits.

5. All new slurry injection permits should complete all SCMRA and NPDES modules related to slurry injection. The addition of slurry injection is a major modification and an updated PHC report and CHIA report should be completed.

6. All new permits should conduct a full baseline survey for organic constituents and heavy metals for all nearby surface and groundwater resources. This survey should provide data sufficient to show seasonal variation as detailed in SCMRA. In addition, a well survey of all well users within ½ mile of the extent of the mine void receiving injection should also be required.

7. Pre-injection mine pool water quality should be determined and evaluated prior to UIC approval. Specifically, probable interactions between the mine pool and coal slurry should be taken into account.

8. All UIC-related sampling at surface and ground water monitoring sites should be detailed in both SCMRA and UIC permits.

9. All collected and detailed water sample data associated with underground injection should be entered into the West Virginia EQUIS database.

10. All underground injection compliance sampling data should be reviewed and exceedences identified through QA/QC quality checking software. WVDEP should regularly monitor the non-compliance reports that are submitted by slurry injection operators and take appropriate enforcement action for self-reported violations.

11. The WVDEP-UIC program should continue to ban the use of diesel fuel in the coal preparation process that produces slurry that is to be injected underground.

12. The WVDEP should maintain a public GIS layer of all UIC injection sites and all associated mine pools.

13. The WVDEP should compile a historic database of all known coal slurry injection sites that have been approved in the past.

14. Incident to the transfer of responsibility for the slurry injection program to its mining program, the WVDEP should train all mining inspectors to regularly check all chemicals used at underground injection sites to verify compliance with the UIC permit. In particular, training on how to identify and prevent the use of diesel should be emphasized.

ACRONYMS & SYMBOLS

ANSI/ASQ	**American National Standards Institute/American Standard of Quality**
ASCII	**American Standard Code Information Exchange**
ASTM	**ASTM International, formerly American Society for Testing and Materials**
ATSDR	**Agency for Toxic Substances and Disease Registry**
AFCEE	**Air Force Center for Environmental Excellence**
BFB	**bromofluorobenzene**
BOD	**biochemical oxygen demand**
BPH	**Bureau of Public Health (DHHR)**
BTEX	**benzene, toulene, ethylbenzene, and xylene**
CCL	**contaminant candidate list**
CCR	**consumer confidence rule**
CFR	**Code of Federal Regulations**
CO	**carbon monoxide**
COD	**chemical oxygen demand**
CSR	**Code of State Regulations**
CWA	**Federal Clean Water Act**
DBCP	**1,2 dibromo-3-chloropropane**
DCE	**dichloroethene**

DEP	**West Virginia Department of Environmental Protection**
DHHR	**West Virginia Department of Health and Human Resources**
DMR	**discharge monitoring report; Division of Mining and Reclamation**
DNR	**West Virginia Division of Natural Resources**
DQO	**data quality objective**
DWEL	**drinking water equivalent level**
DWWM	**Division of Water and Waste Management**
EDTA	**ethylenediaminetetraacetic acid**
EPA	**U.S. Environmental Protection Agency**
ERIS	**Environmental Institute of the States**
ETV	**environmental technology verification**
FC	**fecal coliform**
GC/ECD	**gas chromatograph/electron capture detector**
GPD	**gallons per day**
GPM	**gallons per minute**
GPP	**groundwater protection plan**
GRO	**gasoline range organics**
GW	**groundwater**
HA	**health advisory**
HAA5	**five haloacetic acids**
HMX	**oxyhydro 1,3,5,7-tetranitro- 1,3,5,7 –triazine**

ID	**inside diameter**
ITRC	**Interstate Technology and Regulatory Council**
LDPE	**low-density polyethylene**
MCL	**maximum contaminant level**
MCLG	**maximum contaminant level goal**
MDL	**method detection limits**
MEE	**methane, ethane, and ethene**
MEK	**2-butanone**
mg/L	**milligrams per liter**
MIBK	**4-methyl-2-pentanone**
MTBE	**methyl tert-butyl ether**
MSDS	**Material Safety Data Sheet**
MSHA	**Mine Safety and Health Administration (U.S. Department of Labor)**
msl	**mean sea level**
nd	**nondetect**
NPDES	**National Pollutant Discharge Elimination System**
NPDWR	**national primary drinking water regulation**
OD	**outside diameter**
ORO	**oil range organics**
OSM	**Federal Office of Surface Mining Reclamation and Enforcement**
PAH	**polycyclic aromatic hydrocarbon**

PCB	**polychlorinated biphenyl**
PCE	**perchloroethene**
PDB	**polyethylene diffusion bag**
pH	**relative acidity or alkalinity of a substance on a logarithmic scale**
POC	**point of contact**
PP	**polypropylene**
PPB	**parts per billion**
PPM	**parts per million**
PQL	**practical quantitation limit**
PSD	**public service district**
PsMS	**polysulfone membrane sampler**
PVC	**polyvinyl chloride**
QA	**quality assurance**
QAPP	**quality assurance project plan**
QC	**quality control**
RCRA	**Federal Resource Conservation and Recovery Act**
RDX	**2,3,5 –trinitro-1,3,5 triazine**
RPP	**rigid, porous polyethylene**
SCMRA	**West Virginia Surface Coal Mining and Reclamation Act**
SCR	**Senate Concurrent Resolution**
SDWA	**Federal Safe Drinking Water Act of 1974**

SDWIS	**safe drinking water information system**
SMA	**surface mining application**
SMCRA	**Federal Surface Mining Control and Reclamation Act of 1977**
SOP	**standard operating procedure**
SOW	**statement of work**
SS	**suspended solids**
SVOC	**semivolatile organic compound**
SWAPP	**source water assessment protection plan**
SWTR	**surface water treatment rule**
TAME	**tertiary amyl methyl ether**
TBA	**tert-butyl alcohol**
TCA	**trichloroethane**
TCE	**trichloroethene**
TDS	**total dissolved solids**
TIC	**tentatively identified compound**
TNB	**trinitrobenzene**
TNT	**trinitrotoluene**
TOC	**total organic carbon**
TPH	**total petroleum hydrocarbons**
TSS	**total suspended solids**
TT	**treatment technique**

TTHM	**total trihalomethanes**
UCL	**upper control limit**
USACE	**U.S. Army Corps of Engineers**
USDW	**underground source of drinking water**
USGS	**U.S. Geologic Survey**
UIC	**underground injection control**
UV	**ultraviolet**
VOA	**volatile organic analysis**
VOC	**volatile organic compound**
WVGES	**West Virginia Geologic and Economic Survey**

SYMBOLS

µg	**microgram**
µg/kg	**micrograms per kilogram**
µg/g	**micrograms per gram**
µg/L	**micrograms per liter**
µg/mL	**micrograms per milliliter**
µL	**microliter**
µm	**micrometer**

mg/kg	**milligrams per kilogram**
mg/L	**milligrams per liter**
ng	**nanogram**
ng/L	**nanograms per liter**
ng/mL	**nanograms per milliliter**
nm	**nanometer**
oz	**ounce**
ppm	**parts per million**
ppmv	**parts per million by volume**
ppb	**parts per billion**
ppbv	**parts per billion by volume**

Glossary

Acrylamide: a chemical compound used to synthesize polyacrylamide, which is used as a water soluble thickener.

Aliquot: a sample of specified volume used in the makeup of a composite sample.

Aquifer: a geological formation, or group of formations, or part of a formation that is capable of yielding a usable amount of water to a well or spring.

BTEX: Benzene, Toluene, Ethylbenzene, and Xylene, which are selected volatile organic compounds associated with petroleum and gas sources.

Class 5 Injection Well: a well that injects non-hazardous fluids into strata that may contain underground sources of drinking water, and which does not meet the definition of Class 1, 2, 3, or 4 wells according to Title 47 CSR13, *Underground Injection Control*.

Coal Preparation: physical and mechanical processes applied to coal to make it suitable for a particular use.

Coal Rank: classification of coal according to degree of metamorphism or progressive alteration in the natural series from lignite to anthracite.

Coal seam: a bed or stratum of coal.

Coliform Bacteria: bacilli common to the intestines of humans and other vertebrates.

Composite Sample: a representative mixture of several different samples from the same source (aliquots), from which the laboratory sample is taken.

Compound: a substance formed from chemically combined elements.

Conductivity: Specific Conductance, Electrical Conductivity, or EC. The measurement of a fluid's ability to conduct an electrical current.

Contaminant: any man-induced physical, chemical, biological, or radiological substance or matter in water.

CWA: Clean Water Act of 1972 (replaced the Federal Water Pollution Control Act of 1948)

DEP: the West Virginia Department of Environmental Protection.

DHHR: West Virginia Department of Health and Human Resources, Bureau of Public Health.

DRO: Diesel Range Organics.

Element: a substance composed of only one type of atom.

EPA (USEPA): the United States Environmental Protection Agency.

Fault: a surface or zone of rock fracture along which there has been displacement.

Fecal Coliform (FC): see Coliform bacteria.

Fluid: any material or substance that flows or moves, whether in a semisolid, liquid, sludge, gas, or other state.

Formation: a body of rock characterized by a degree of homogeneity that is mostly, but not necessarily, tabular, and is traceable in the subsurface or mappable on the surface.

GRO: Gasoline Range Organics.

GPD: Gallons per Day.

GPM: Gallons per Minute.

Groundwater: water below the land surface in a zone of saturation.

Hydrocarbon: any compound that contains only hydrogen and carbon atoms.

Hydrology/Hydrogeology: The study of water and the study of the interaction of geological materials and processes with water.

Injection Well: a well through which fluids, including slurry, are discharged to the subsurface.

Inorganic: a chemical compound that does not contain carbon atoms.

Lithology: the description of rocks on the basis of their physical and chemical characteristics.

MCL: Maximum Contaminant Level. The highest concentration of a contaminant that is allowed in drinking water under Federal (and State) law. Also called a Primary Drinking Water Standard. MCLs are enforceable standards. MCLs are set as close to MCGLs as feasible using the best available treatment technology and taking cost into consideration.

MDL: Method Detection Limit or Minimum Detection Limit. The minimum concentration of a substance that can be measured and reported with confidence by a given analytical method.

MCLG: Maximum Contaminant Level Goal. The level of a contaminant in drinking water below which there is no known or expected risk to health. These are non- enforceable public health goals.

Metal: an element that conducts heat and electricity.

Mg/L: Milligrams per Liter. A measurement of the concentration of a substance in water, equivalent to Parts per Million (PPM).

MSDS: Material Safety Data Sheet. The information sheet for a particular substance, provided by the manufacturer, that lists (among other things) physical and chemical properties, hazards, fire and explosion data, protective equipment required, and recommended cleanup and disposal procedures.

ND: Not Detected or Non-Detect. Indicates that a substance was not detected at or above the MDL of a given analytical method.

NPDES: the National Pollutant Discharge Elimination System of 1972; in West Virginia, also referred to as "Article 11" (of Chapter 22).

Nonmetal: an element that does not exhibit the properties of a metal.

Nuclide: a type of atom that is characterized by the properties of its nucleus, e.g., the number of protons, neutrons, and energy state.

ORO: Oil Range Organics.

Organic: any chemical compound that contains one or more carbon atoms.

OSM: Federal Office of Surface Mining Reclamation and Enforcement, U.S. Department of the Interior.

PAH: Polycyclic Aromatic Hydrocarbon.

Petroleum Hydrocarbon: a hydrocarbon that is derived from crude oil or any fraction of crude oil.

pH: the relative acidity or alkalinity of a substance, 1 being the most acidic, 14 being the most alkaline, and 7 being neutral.

Pollutant: A substance or energy, usually a waste that contaminates air, soil, or water.

PPB: Parts per Billion

PPM: Parts per Million.

PQL: Practical Quantitation Limit. The lowest level of concentration of a substance that is achievable among laboratories within specified limits by routine laboratory operation. It is usually about 3 to 5 times the calculated Method Detection Limit with a reasonably good certainty that the reported value is reliable.

Primary Drinking Water Standard: see MCL.

Radionuclide: a nuclide that exhibits radioactivity.

SDWA: the Federal Safe Drinking Water Act of 1974.

Secondary Drinking Water Standards: EPA's non-enforceable guidelines regulating non-toxic contaminants that may cause cosmetic or aesthetic defects, such as taste, color, or odor, in drinking water.

Site: the land or water where any facility or activity is physically located or conducted, including any adjacent land used in connection with the facility or activity.

SCMRA: West Virginia Surface Coal Mining and Reclamation Act; also referred to as "Article 3" (of Chapter 22).

SMCRA: Federal Surface Mining Control and Reclamation Act of 1977.

Stratum (plural **Strata**): a single sedimentary bed or layer, regardless of thickness, that consists of generally the same kind of rock material.

Semi-Volatile Organic Compound (SVOC): an organic compound having a moderately high vapor pressure and low water solubility, which evaporates slowly to the atmosphere.

TDS: Total Dissolved Solids, the total dissolved (filterable) solids as determined by use of a method specified in 40 CFR Part 136.

TICS: Tentatively identified compounds.

TPH: Total Petroleum Hydrocarbons; includes DRO, GRO, and ORO, plus others.

TT: Treatment technique. A required process intended to reduce the level of a contaminant in drinking water.

μg/L: Micrograms per Liter. A measurement of the concentration of a substance in water, equivalent to Parts per Billion (PPB).

Underground Injection: the subsurface emplacement of fluids through a well.

USDW: Underground Source of Drinking Water, i.e., an aquifer or its portion that supplies water for human consumption.

VOC: Volatile Organic Compound, i.e., an organic compound having a high vapor pressure and low water solubility, which evaporates rapidly to the atmosphere.

Well: (for the purpose of the West Virginia Underground Injection Control Program) a bored, drilled, or driven shaft, or dug hole, whose depth is greater than the largest surface dimension.

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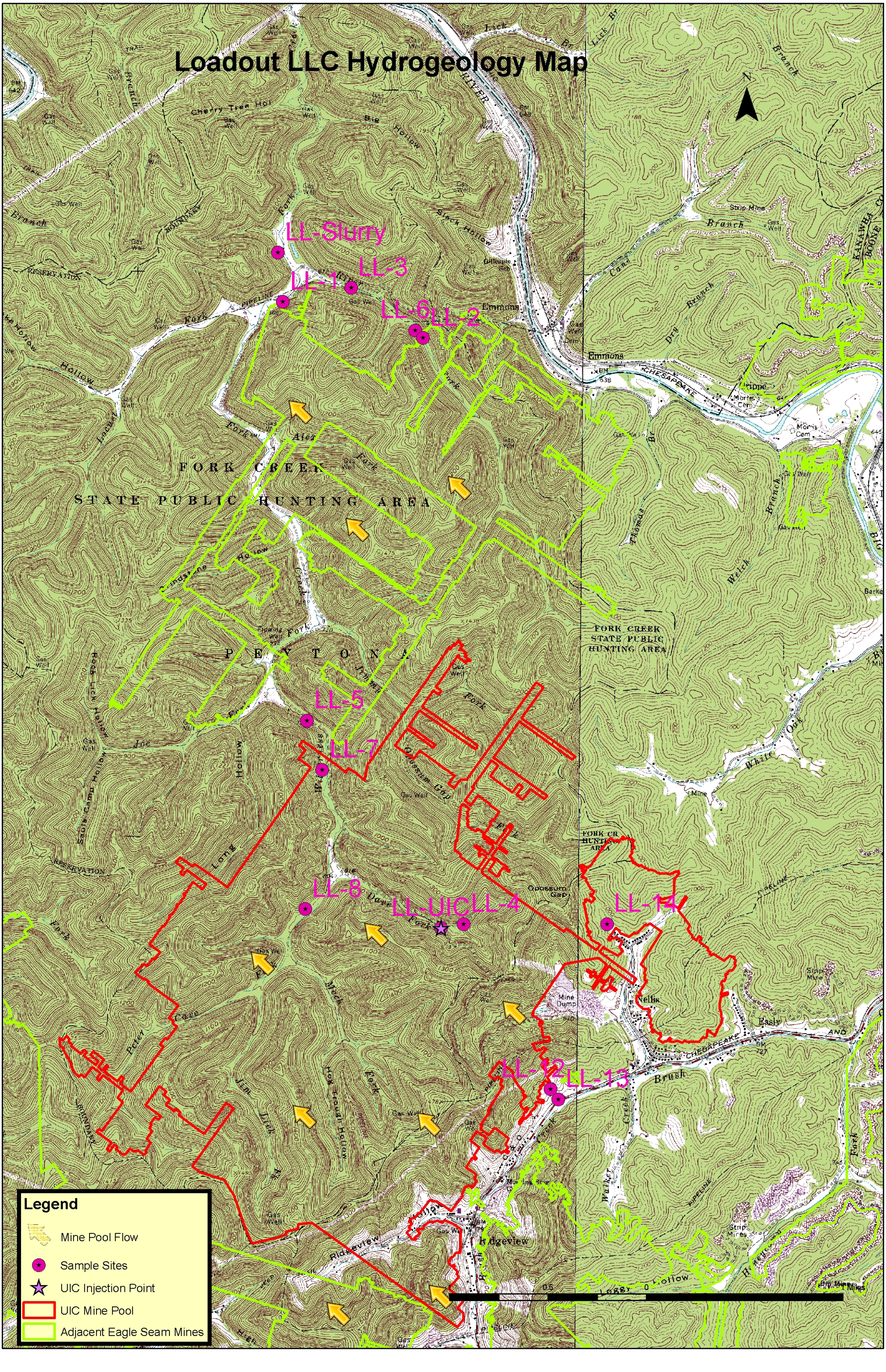
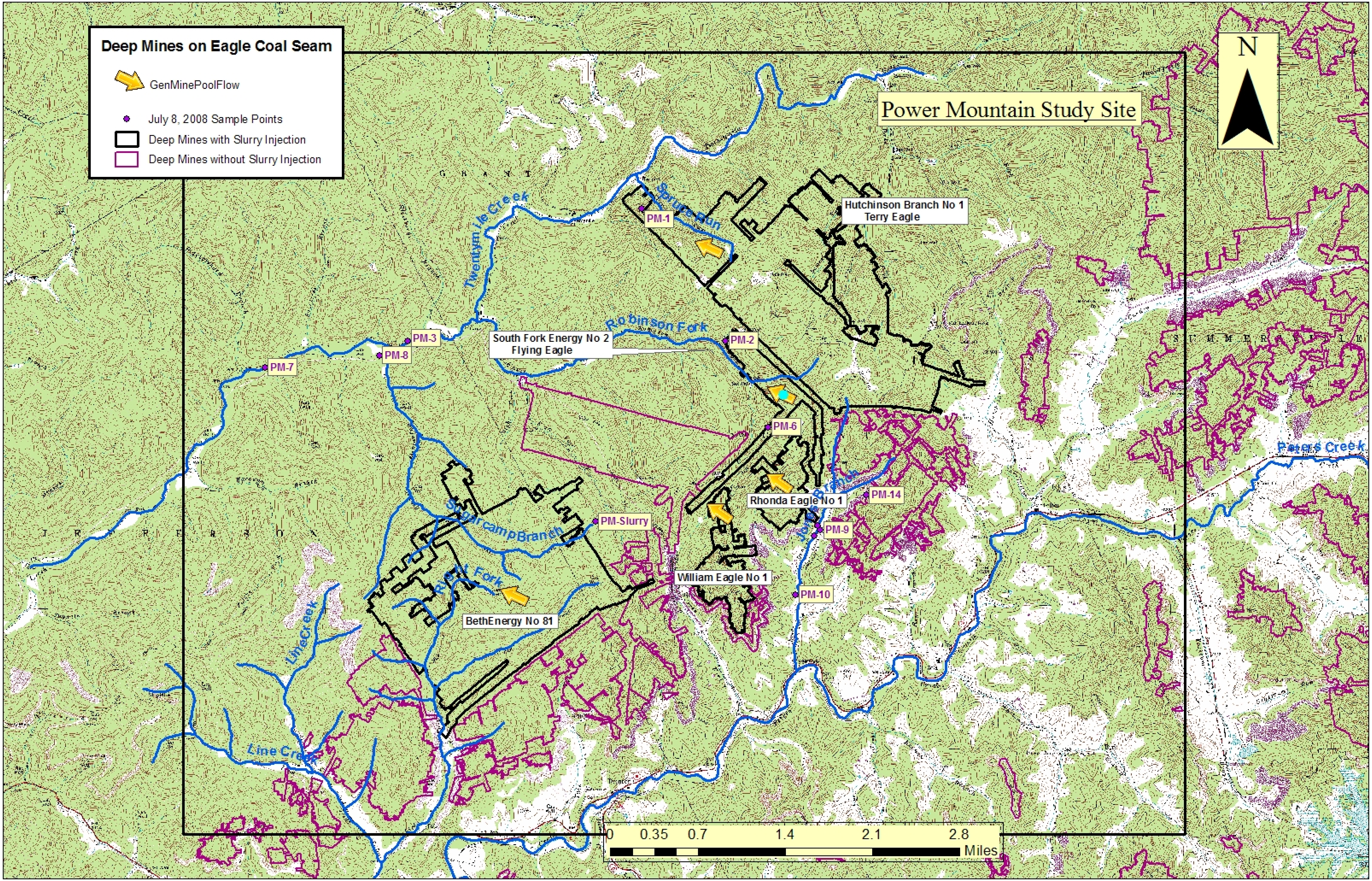


Loadout LLC Hydrogeology Map
LL-Slurry
LL-1
LL-3
LL-6
LL-2
LL-5
LL-7
LL-8
LL-UIC
LL-4
LL-14
LL-12
LL-13
FORK CREEK
STATE PUBLIC HUNTING AREA
PEYTONA
Emmons
Nellis
Bridgeview
Legend
Mine Pool Flow
Sample Sites
UIC Injection Point
UIC Mine Pool
Adjacent Eagle Seam Mines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GenMinePoolFlow
July 8, 2008 Sample Points
Deep Mines with Slurry Injection
Deep Mines without Slurry Injection
Power Mountain Study Site
N
Hutchinson Branch No 1
Terry Eagle
South Fork Energy No 2
Flying Eagle
Rhonda Eagle No 1
William Eagle No 1
BethEnergy No 81
PM-1
PM-2
PM-3
PM-6
PM-7
PM-8
PM-9
PM-10
PM-14
PM-Slurry
Spruce Run
Twentymile Creek
Robinson Fork
Peters Creek
Line Creek
Sugarcamp Branch
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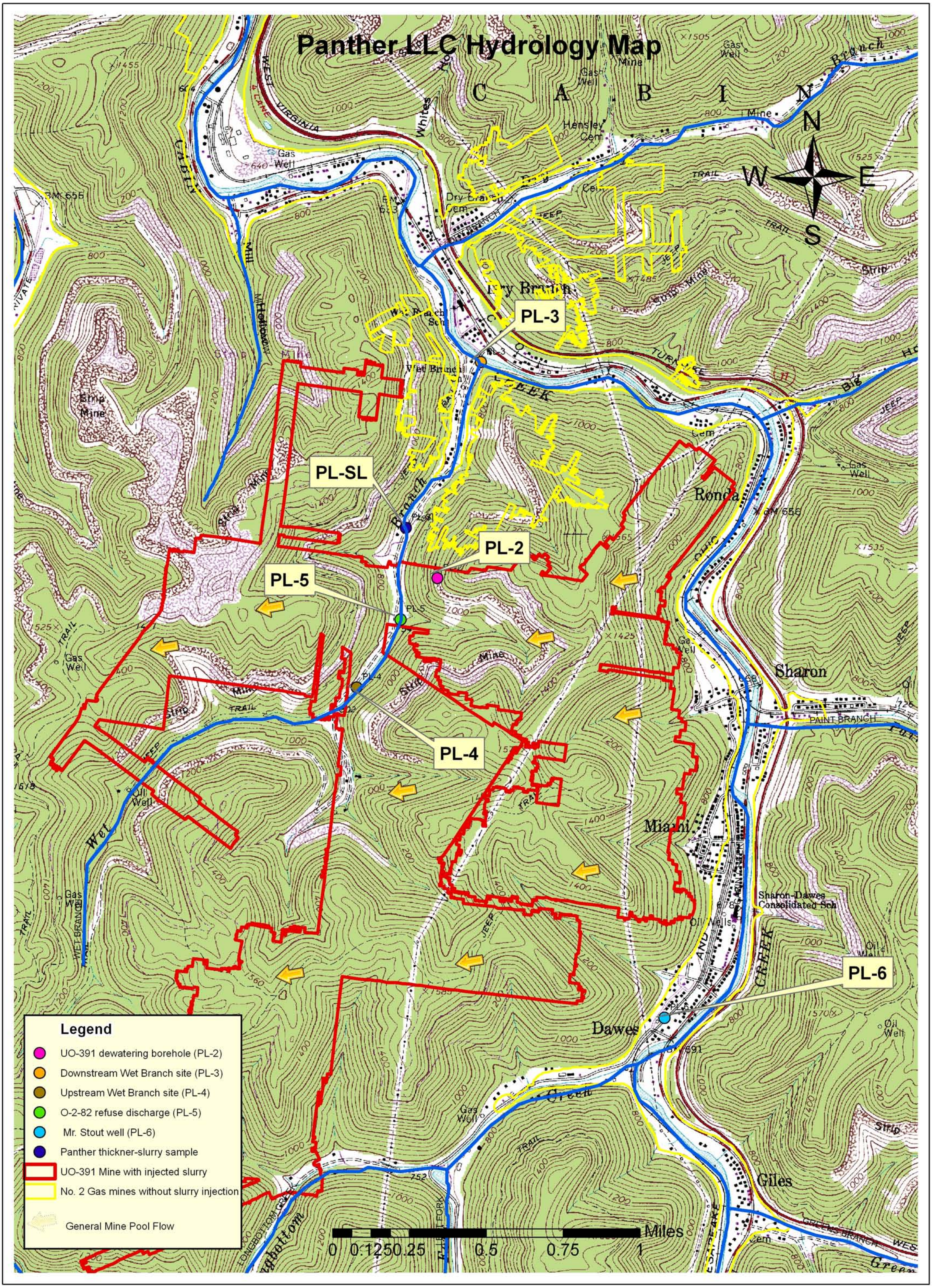
Miles



Panther LLC Hydrology Map
PL-3
PL-SL
PL-2
PL-5
PL-4
PL-6
Legend
UO-391 dewatering borehole (PL-2)
Downstream Wet Branch site (PL-3)
Upstream Wet Branch site (PL-4)
O-2-82 refuse discharge (PL-5)
Mr. Stout well (PL-6)
Panther thickner-slurry sample
UO-391 Mine with injected slurry
No. 2 Gas mines without slurry injection
General Mine Pool Flow
0 0.1250.25 0.5 0.75 1
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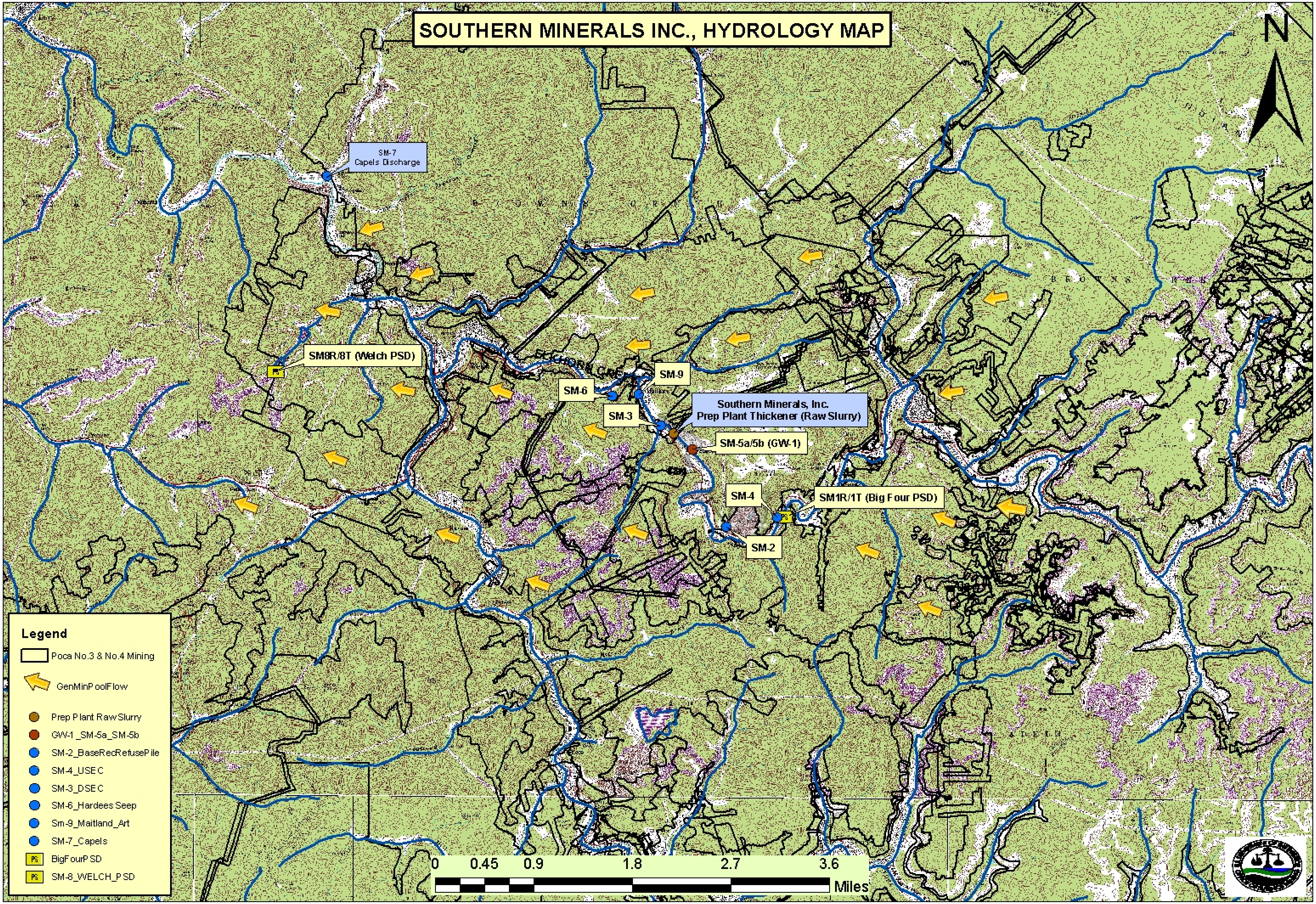
S
E
W
Sharon
Miami
Dawes
Giles
Ronda
Sharon-Dawes Consolidated Sch
PAINT BRANCH


SOUTHERN MINERALS INC., HYDROLOGY MAP
N
SM-7
Capels Discharge
SM8R/8T (Welch PSD)
SM-6
SM-9
SM-3
Southern Minerals, Inc.
Prep Plant Thickener (Raw Slurry)
SM-5a/5b (GW-1)
SM-4
SM1R/1T (Big Four PSD)
SM-2
Legend
Poca No.3 & No.4 Mining
GenMinPoolFlow
Prep Plant Raw Slurry
GW-1 _SM-5a_SM-5b
SM-2_BaseRecRefusePile
SM-4_USEC
SM-3_DSEC
SM-6_Hardees Seep
Sm-9_Maitland_Art
SM-7_Capels
BigFourPSD
SM-8_WELCH_PSD
0 0.45 0.9 1.8 2.7 3.6
Miles