

APPENDIX 4 SELENIUM

A4.1 Abstract

Although the Mingo Logan mining company asserts that their plans will not release excess selenium, the arguments are not well supported by evidence or previous mining in the area. There is abundant selenium in the coal deposits. Conditions that make selenium bioavailable occur at mine sites in adjacent mines operated by the same company. The documentation does not demonstrate that the company can effectively distinguish material requiring isolation from water from those that have low selenium and might be used in valley fill. Furthermore, they do not provide convincing evidence that water will not interact with these exposed deposits or that the selenium will be removed when the coal is removed. Thus, EPA contends that there is a strong likelihood that toxic levels of selenium will be released if the Spruce 1 mine continues as planned.

A4.2 Fate of Selenium in the Environment

Selenium naturally exists in different oxidation states including oxyanions [selenate (SeO_4^{2-}) and selenite (SeO_3^{2-})], reduced selenium [selenide (Se^{2-})] and elemental selenium (Se). Selenate and selenite oxyanions, common in oxidizing environments such as the potentially exposed mine materials in valley fill areas, are the most mobile and toxic of the selenium species. The presence of aluminum (Al) and/or iron (Fe) oxides in the solid phase may result in substantially higher Se sorption as selenide (Se^{2-}) oxidizes to selenite (Se^{4+}) which could then sorb to $\text{FeO}(\text{OH})$. However, given the potentially alkaline nature of the mine materials from the proposed Spruce No. 1 mine, specific adsorption of

selenium species onto geologic (or valley-filled materials) materials is not likely to play an important role in reducing Se mobility. This is because any near-field Se plume in the valley-filled materials will be sufficiently alkaline to greatly reduce the number of anion exchange sites for the Se oxyanions. Oxidation of the selenite to the highly mobile selenate could then take place. Also, given the depositional history and nature of formation of the rocks above and below the coal layers in West Virginia coal formations, significant concentrations of sulfates are expected in these valley-filled materials. Some of the sulfates will form as the metal sulfides in the valley-filled materials are exposed to the environment. Sulfates are known to compete with Se oxyanions for mineral adsorption sites making the Se oxyanions more available for leaching to surface waters and other environments.

While Se oxyanions have been reported to have lower potential for bioaccumulation in fish and other aquatic organisms, a reducing environment that may be induced in streams could reduce the oxyanions to forms that could easily bioaccumulate in aquatic species. A more desired outcome will be to decrease Se mobility in the valley-filled materials which will require a reducing environment. It is well known that reduction of Se is largely controlled by microbial processes (Février et al., 2007). In the valley-filled materials, we expect the subsurface to be physically complex and redox environments (at the microscale), and associated metabolic processes, to be heterogeneously distributed in both space and time. In particular, within the deeper deposits, oxygen is less available resulting in a chemically reducing environment.

A4.3 Predicting Fate of Se in Valley-filled Materials

In the absence of mechanistic physical, chemical, and microbiological models, the Agency can only use empirical models of Se partitioning between subsurface compartments as a basis to predict how Se will behave in these valley-filled materials. The K_d parameter for Se (and indeed for other toxic metals that may be present in the valley-filled materials) is an important parameter to estimate the potential for the adsorption of dissolved contaminants in contact with soil. K_d (L/kg) is typically defined as the ratio of the contaminant concentration associated with the solids (mg/kg) to the contaminant concentration in the surrounding aqueous solution (mg/L) when the system is at equilibrium. It is recognized that generic or default K_d values in the literature can result in significant errors when used to evaluate contaminant migration or site-remediation options. Hence site-specific K_d values derived using site-specific data are preferable. However, in the absence of such data, relevant published values may be used. Consequently, a literature survey for partition coefficients of Se was conducted. The following criteria and guidelines developed in the U.S. Environmental Protection Agency (USEPA) document (USEPA, 2005) were used to evaluate the published K_d values.

- a) Use “whole” natural media for determination of K_d in natural media systems (meaning the rejection of K_d values from studies using pure mineral phases or treated soils).

- b) Use low total metal concentrations (i.e., if K_d were determined at sites with multiple total metal concentrations, K_d values corresponding to the lowest metal

concentrations where K_d is less likely to depend on metal concentrations where chosen).

- c) Use pH values in the natural range of 4-10 (given the expected pH values of soils and rock formations that will be valley-filled).
- d) Partition coefficients with no organic chelates (e.g., EDTA) in the extractant.
- e) Where multiple K_d values are presented for a system due to experimental variation of pH or other parameters, choose K_d values corresponding to the conditions most closely approximating the geologic conditions of the materials that may be valley-filled.

The effective range of Se- K_d values in the ambient vadose zone of sediments is 0 to 0.78 L/kg (Kaplan & Serne, 1995). A K_d of zero means Se is entirely associated with the solution phase with a very high potential of being released into surface and/or ground waters. Using a conservative estimate of 2 mg/kg (or 2,000 $\mu\text{g}/\text{kg}$) in the valley-filled materials and the maximum estimated K_d of 0.78 L/kg, at equilibrium; we would expect 0.88 mg/kg (or 880 $\mu\text{g}/\text{kg}$) to remain adsorbed on the solid phase and 1.12 mg/L (or 1,120 $\mu\text{g}/\text{L}$) to be released into the soil solution. If we assume $1\mu\text{g} = 1\text{ mL}$ (which is reasonable for dilute systems), then 1,120 $\mu\text{g}/\text{mL}$ in solution is equivalent to 1,120 parts per million (ppm). This is 224 times the 5 ppm criterion for Se in receiving streams. How much of this will end up in receiving streams or groundwater will require further modeling.

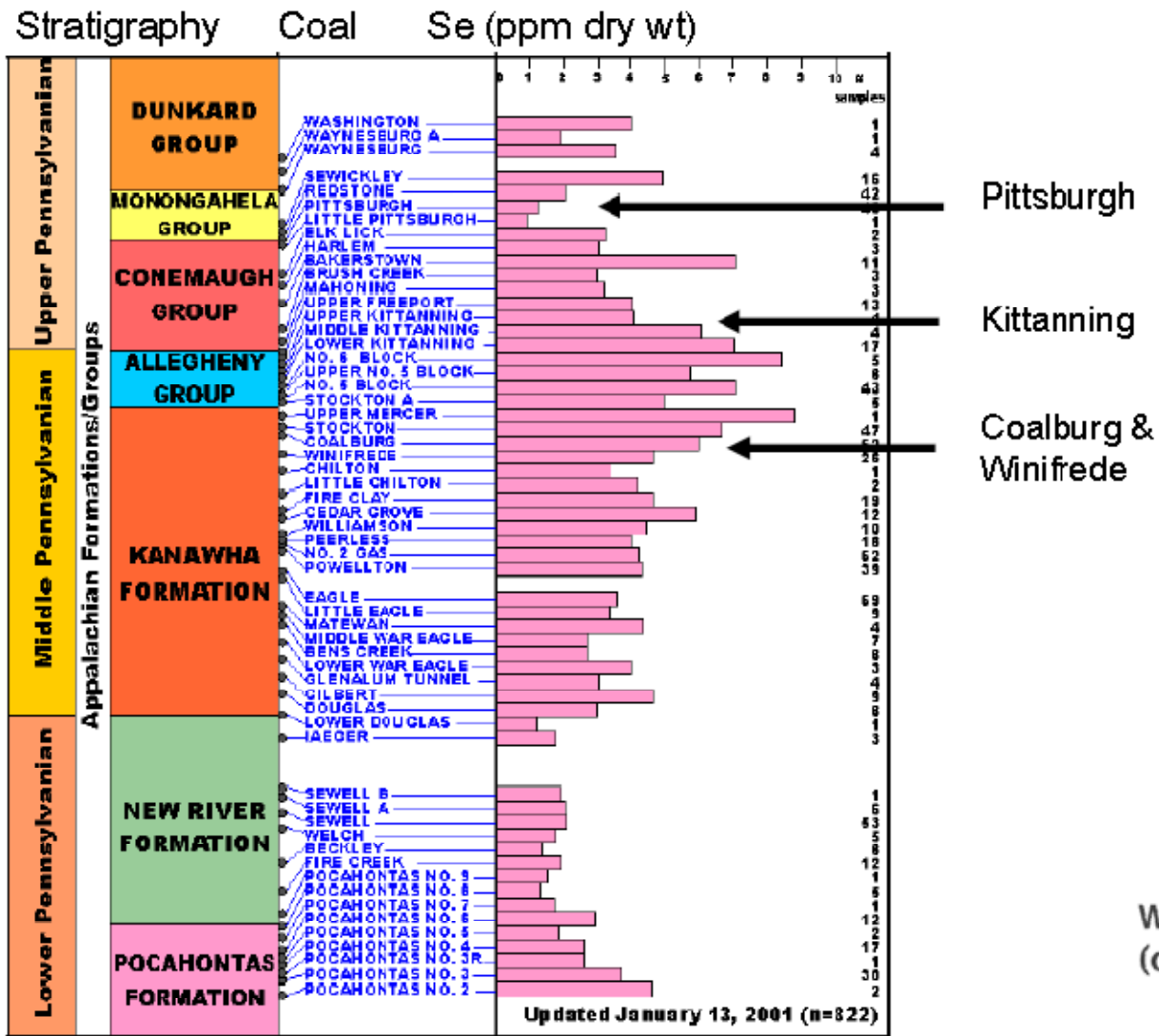
However, in the absence of data, we should take the conservative approach and assume that this leachable mass will end up in streams and/or groundwater. This may be a realistic assumption given that the 2 mg/kg used in this example is half of the mean Se concentration reported for WV coals (see next section). Some horizons above and below the coal beds have also been reported to have more than 2 mg/kg. As indicated previously, soil microbial activity may increase the Se K_d . This will happen if mobile Se oxyanions are reduced to species that would readily adsorb on the solid phase and decrease the mobility of Se. It is, however, unclear whether the conditions at the proposed valley-filled materials will be conducive to microbial growth.

Evidence is lacking that might demonstrate that Se in the materials to be deposited in the Spruce Mine valley-fills will be immobile and poses no environmental threat. This would require the development of comprehensive and predictive models that quantify the anticipated dynamics of the biogeochemical systems including variations in the redox processes operating at the microscale in the proposed valley-filled materials.

A4.4 Differences in Geologic Environment

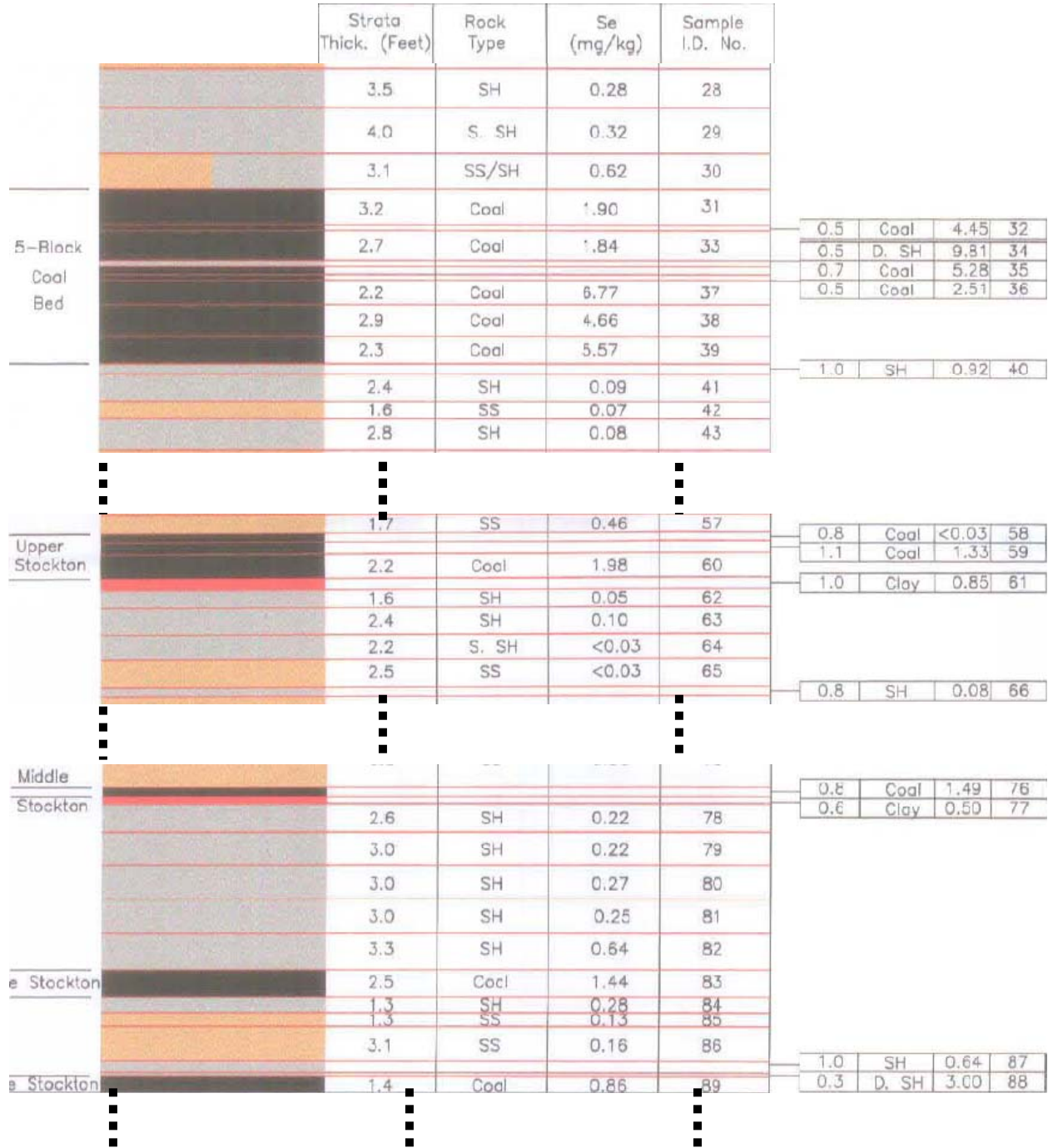
The selenium content of West Virginia (WV) coals has been thoroughly examined and these data are available at the West Virginia Geological and Economic Survey (WVGES) website (<http://www.wvgs.wvnet.edu/www/datastat/te/index.htm>) and are summarized in **Figure 1**. From a total of 845 samples, Se concentrations are reported to range from non-detects to 21.3 mg/kg with a mean concentration of 4.2 mg/kg and standard deviation of 2.83 mg/kg.

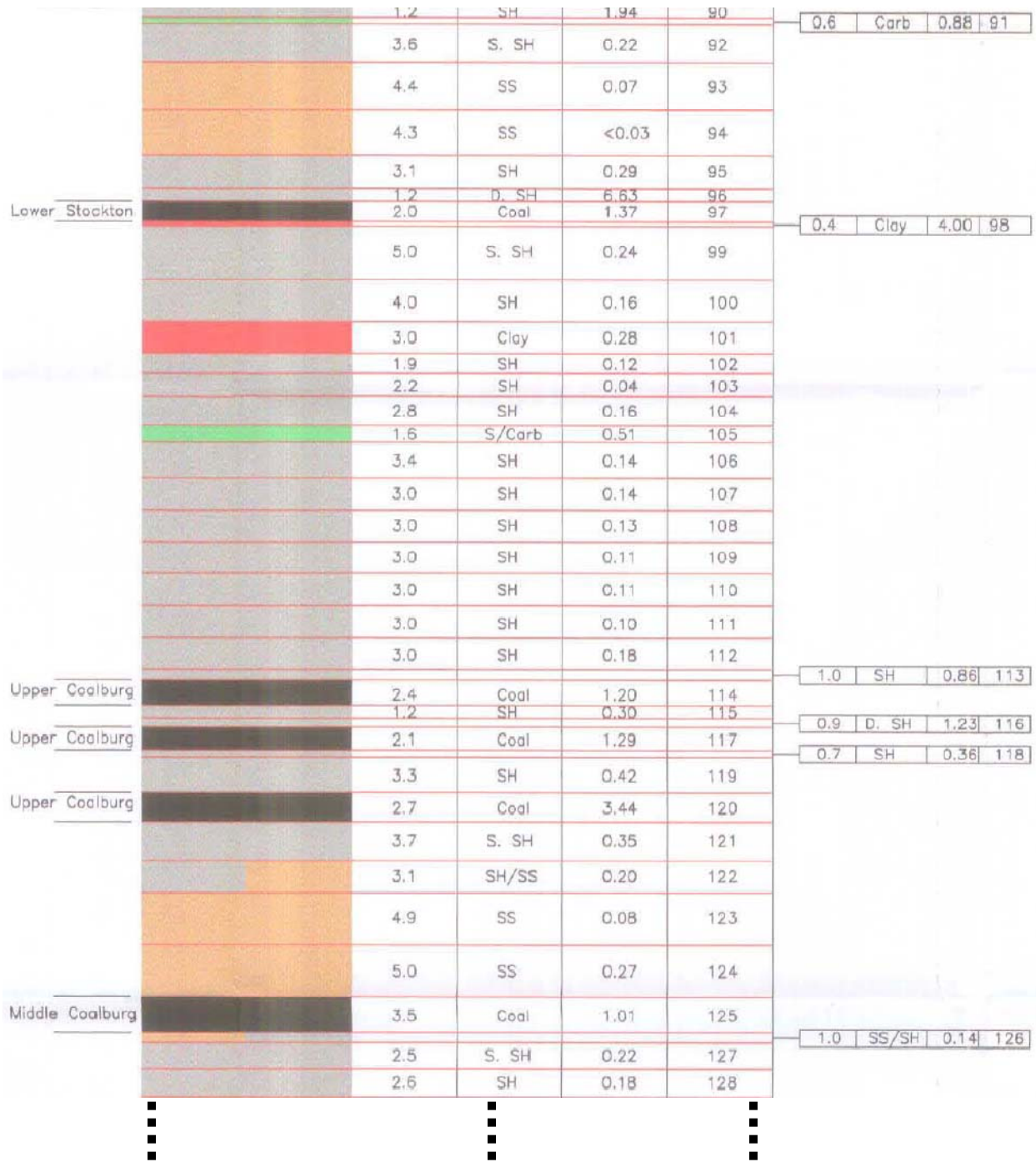
Figure 1: Selenium by coal bed in West Virginia coals

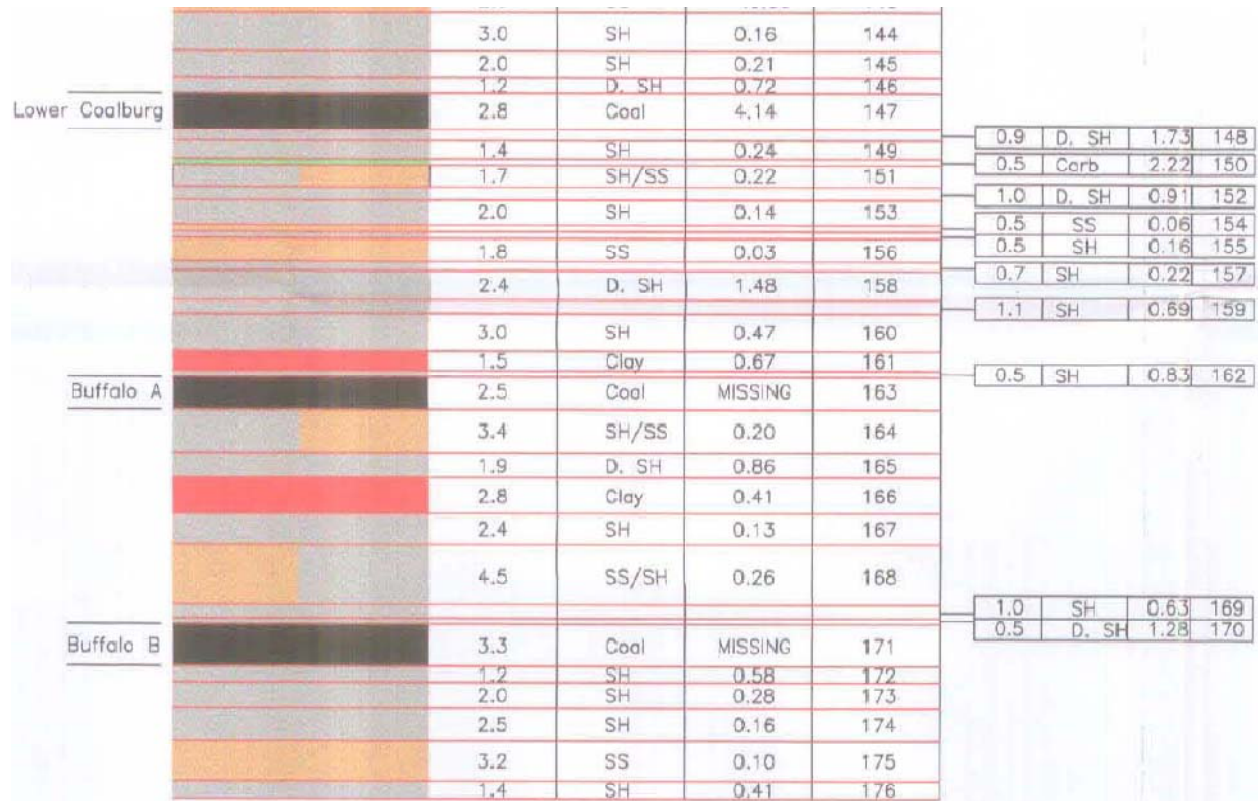


From the analysis of Se in the different coal beds, coals containing the highest selenium contents are in a region of south central WV which includes the region of the proposed Spruce No 1 mine. In addition, the coal beds of the Allegheny and Upper Kanawha Formations exhibit high Se contents compared to coal beds both lower and higher in the geologic sequence. Formation cores analyzed by USGS (Paybins et al., 2000; Sandra et al., 2005) show similar trends. The coal beds to be targeted by the proposed Spruce No 1 mine include 5-Block of the Allegheny Group and down to the Upper Stockton coal bed in the eastern portion of the project area. In the western portion of the project area, they plan to extract coal through the Middle Coalburg coal bed. These coal beds are enriched in Se as evidenced by Se distribution data in the Spruce No. 1 column (DT0417) provided by the applicant for the NPDES permit application (Figure 2). Due to space limitations, the profile has been modified to show only coal beds encountered during drilling and the rocks above and below the coal beds that may be removed and deposited in valley fills during mining. The complete profile with associated Se for each formation (coal and non-coal formations) is provided. Similar Se distributions in Coalburg coal and Winifrede coal at the Bull Creek Mine (Figure 3) were also reported by Vesper & Rhoads (2008).

Figure 2: Geologic column DT0417







Legend

 Sandstone

 Coal

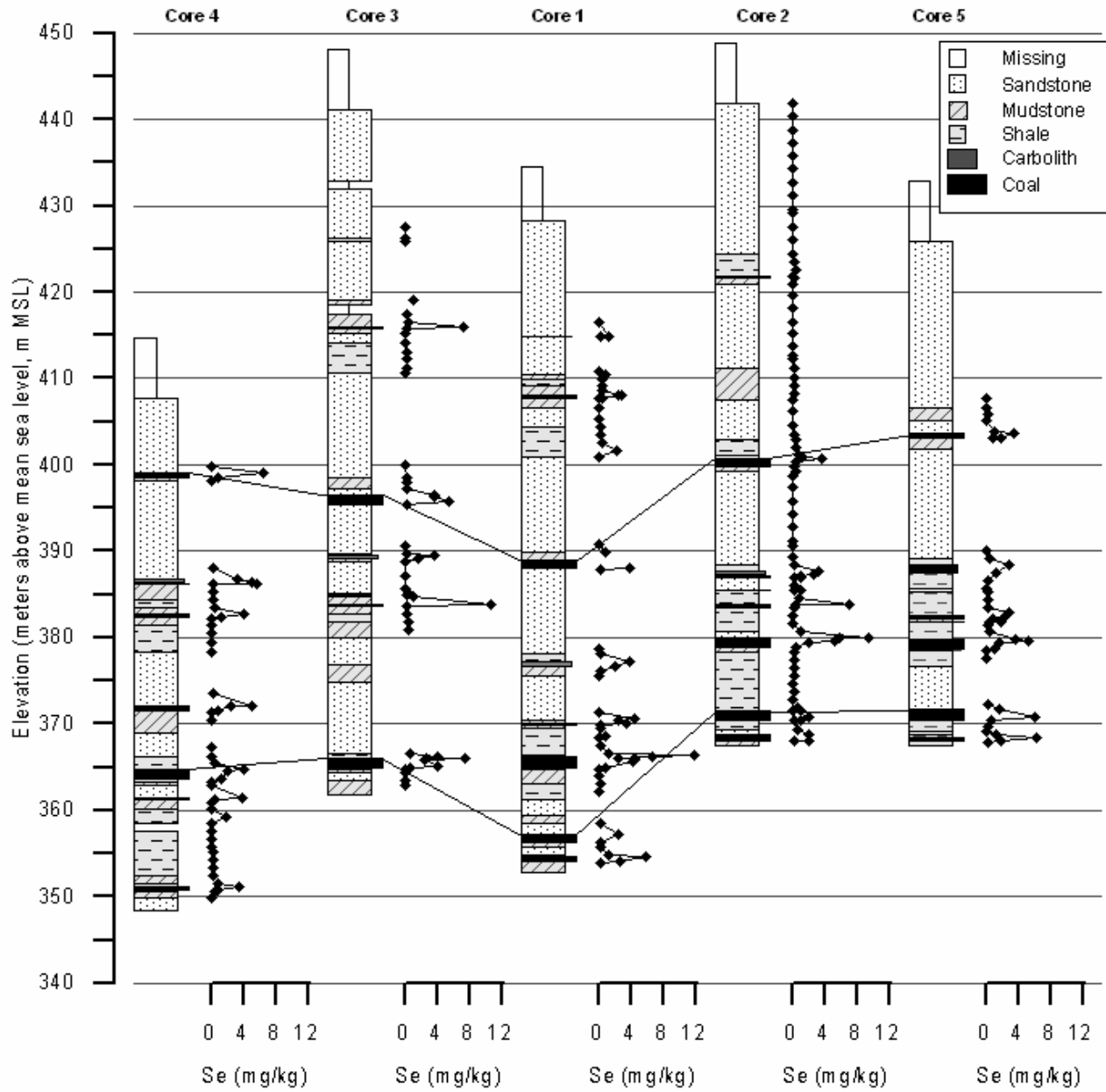
 Carb

 Clay

 Shale

■ Continuation of
■ Sandstone layer

Figure 3: Se distribution in Coalburg coal (upper line) and Winifrede (lower line) coal, both of the Kanawa Formation (Boone County) at the Bull Creek Mine (Vesper, 2008)

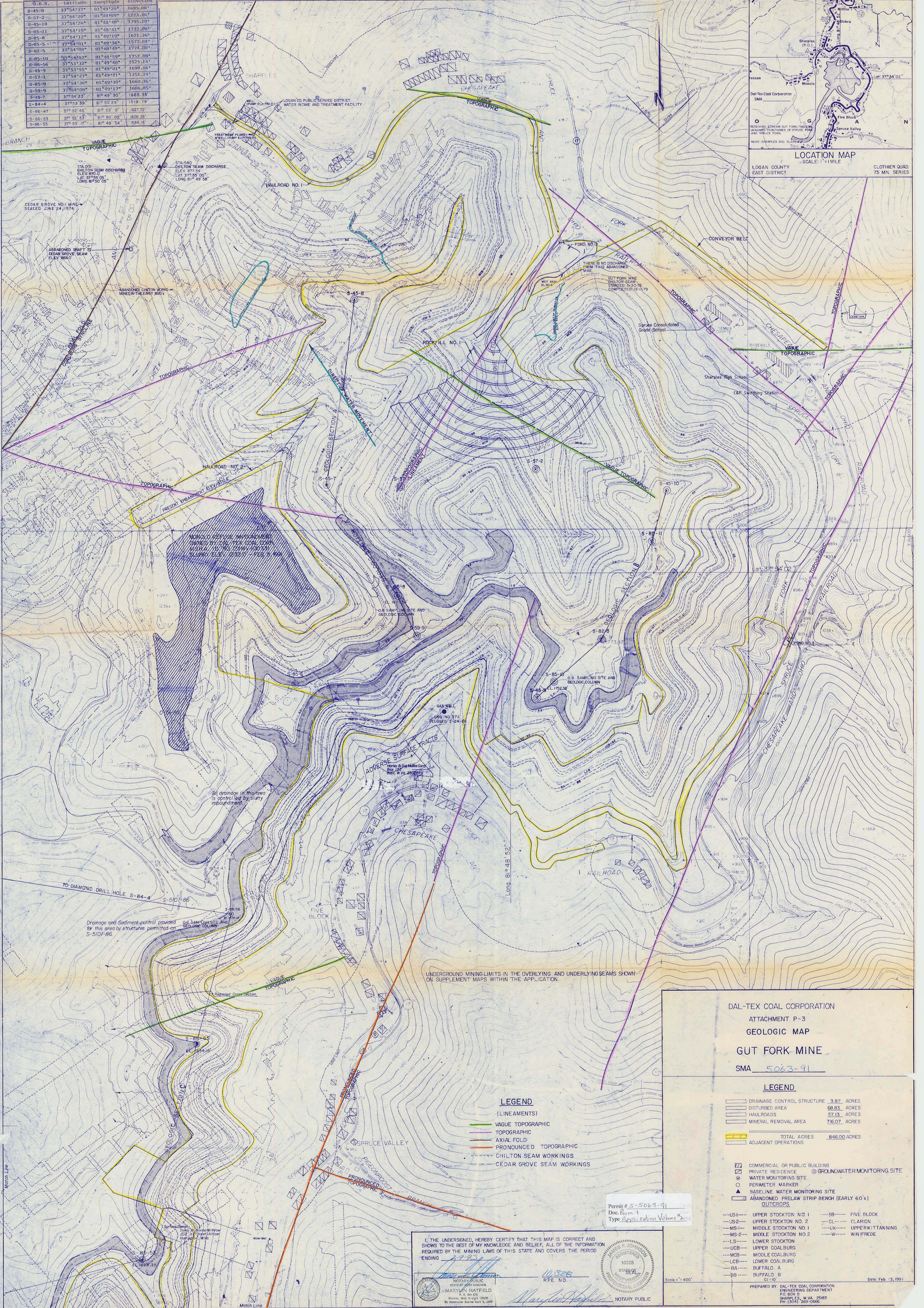
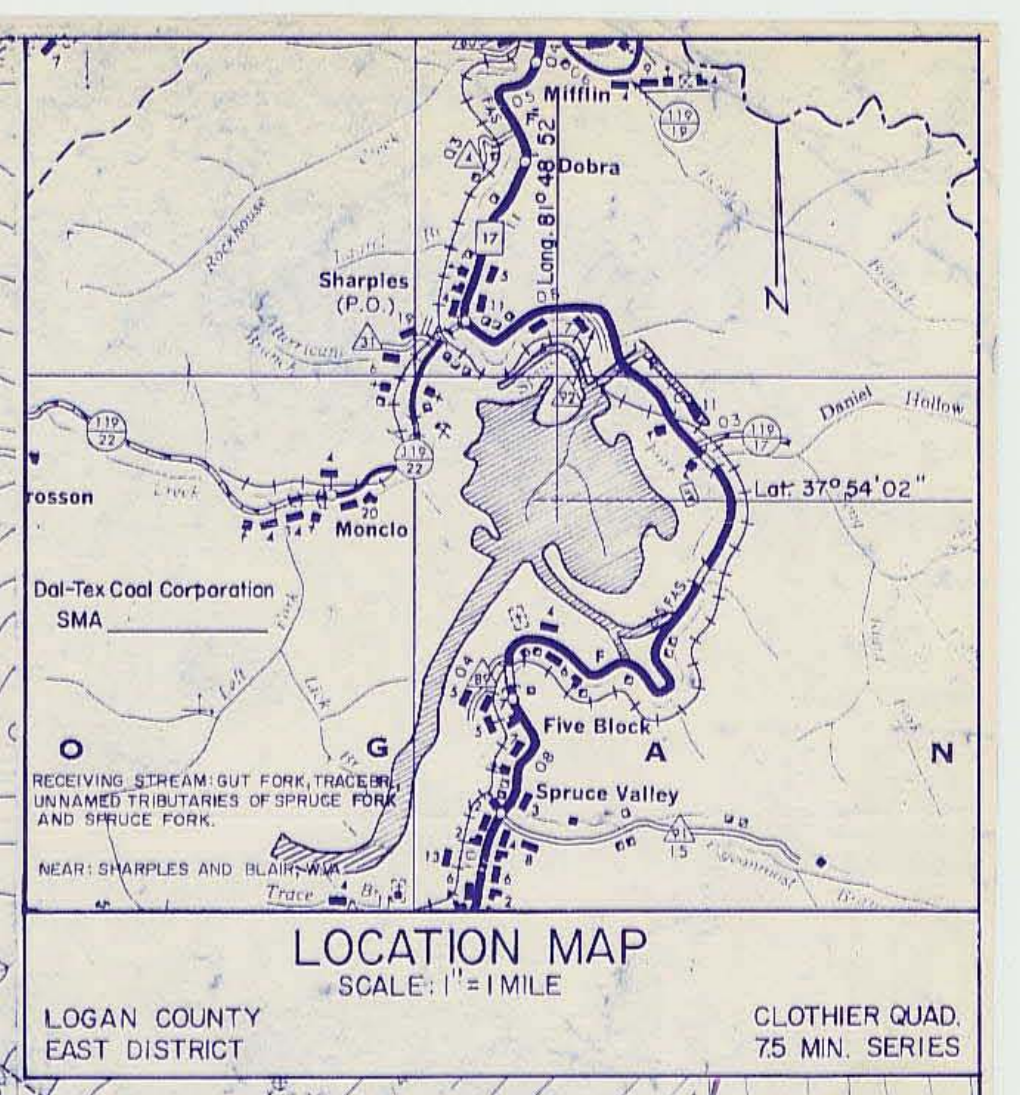


A summary review of rock cores and corresponding cross sections for the Del-Tex mines including the Gut Fork mine (Figures 4 and 5) compared to the proposed Spruce No 1 mine (Figure 6) is provided in Table 1. Figure 7 shows the geologic cross section locations across the Gut Fork mine (I & II) and Spruce No 1 mine (III & IV). Table 1 indicates that for the most part, the formations are repeated from the Del-Tex mine complex to the proposed Spruce No 1 mine location. Indeed as stated by the permittee, the same coal beds are proposed to be developed for the Spruce No 1 mine as for the Del-Tex mine. Also, these coal bed sequences are similar to those described in the literature for southern WV coal bed sequences (Figure 1) and the geologic column for the proposed Spruce No 1 mine (Figure 2). Essentially, all the formations in the Del-Tex complex that had in the past showed high Se levels and have led to environmental releases are present in the Spruce No 1 complex. According to the Se data in the rock core column, many of the rock formations above and below the coal beds also contained high levels of Se. For example, the shale rock above the Lower Stockton contains Se as high as 6.63 mg/kg. This rock layer may need to be removed to get to the Stockton and may contribute to Se releases.

A4.5 Differences in Mining Practices and Material Handling

Mingo Logan has maintained that mining within the Buffalo coal bed in the proposed Spruce No 1 mine will be limited to incidental contour mining and therefore will not result in the kind of environmental degradation that resulted from the Del-Tex mountain top mining (MTM) project which lies adjacent to the Spruce No. 1 mine. There will be less active operating areas and hence less incremental disturbance with the proposed Spruce No 1 mine. They also contend that enhanced erosion control, sedimentation control, and

D.D.N.	Lat. (N)	Long. (E)	Elevation (ft)
S-45-8	37°54'37"	81°49'29"	1695.00'
S-57-2	37°54'20"	81°49'59"	1223.46'
S-45-10	37°54'12"	81°48'48"	1745.10'
S-85-11	37°54'19"	81°48'41"	1732.09'
S-85-8	37°54'12"	81°49'19"	1621.36'
S-85-5	37°54'01"	81°49'36"	1572.84'
S-82-5	37°54'08"	81°48'49"	1774.09'
S-85-10	37°54'02"	81°48'59"	1752.08'
S-86-56	37°53'12"	81°49'48"	1525.14'
S-45-9	37°53'55"	81°49'01"	1699.06'
S-57-1	37°54'27"	81°49'21"	1251.24'
S-85-9	37°54'16"	81°49'30"	1660.36'
S-59-9	37°54'08"	81°49'17"	1686.83'
S-45-7	37°54'23"	81°49'30"	1665.35'
S-84-4	37°53'59"	81°50'28"	1519.79'
S-86-47	37°52'45"	81°53'2"	1627.70'
S-86-53	37°52'53"	81°50'02"	1628.21'
S-86-55	37°53'17"	81°49'54"	1534.18'



DAL-TEX COAL CORPORATION
 ATTACHMENT P-3
 GEOLOGIC MAP
 GUT FORK MINE
 SMA 5063-91

LEGEND

[Symbol]	DRAINAGE CONTROL STRUCTURE	3.87 ACRES
[Symbol]	DISTURBED AREA	68.83 ACRES
[Symbol]	HAULROADS	57.13 ACRES
[Symbol]	MINERAL REMOVAL AREA	716.07 ACRES
[Symbol]	TOTAL ACRES	846.00 ACRES
[Symbol]	ADJACENT OPERATIONS	

[Symbol]	COMMERCIAL OR PUBLIC BUILDING	[Symbol]	GROUNDWATER MONITORING SITE
[Symbol]	PRIVATE RESIDENCE	[Symbol]	CLARION
[Symbol]	WATER MONITORING SITE	[Symbol]	UPPER STOCKTON NO. 1
[Symbol]	PERIMETER MARKER	[Symbol]	MIDDLE STOCKTON NO. 1
[Symbol]	BASELINE WATER MONITORING SITE	[Symbol]	MIDDLE STOCKTON NO. 2
[Symbol]	ABANDONED PRELAW STRIP BENCH (EARLY 60's)	[Symbol]	UPPER KITTANNING
[Symbol]	OUTCROPS	[Symbol]	WINIFREDE

[Symbol]	US-1	UPPER STOCKTON NO. 1
[Symbol]	US-2	UPPER STOCKTON NO. 2
[Symbol]	MS-1	MIDDLE STOCKTON NO. 1
[Symbol]	MS-2	MIDDLE STOCKTON NO. 2
[Symbol]	LS	LOWER STOCKTON
[Symbol]	UCB	UPPER COALBURG
[Symbol]	MCB	MIDDLE COALBURG
[Symbol]	LCB	LOWER COALBURG
[Symbol]	BA	BUFFALO A
[Symbol]	BB	BUFFALO B
[Symbol]	CI	CLARION

LEGEND
 (LINEAMENTS)
 VAGUE TOPOGRAPHIC
 TOPOGRAPHIC
 AXIAL FOLD
 PRONOUNCED TOPOGRAPHIC
 CHILTON SEAM WORKINGS
 CEDAR GROVE SEAM WORKINGS

I, THE UNDERSIGNED, HEREBY CERTIFY THAT THIS MAP IS CORRECT AND SHOWS TO THE BEST OF MY KNOWLEDGE AND BELIEF, ALL OF THE INFORMATION REQUIRED BY THE MINING LAWS OF THIS STATE AND COVERS THE PERIOD ENDING 1/27/11

MARYLAIN HATFIELD
 NOTARY PUBLIC
 STATE OF VIRGINIA
 My Commission Expires April 3, 2019

10328 R.P.E. NO.
 MARYLAIN HATFIELD
 NOTARY PUBLIC

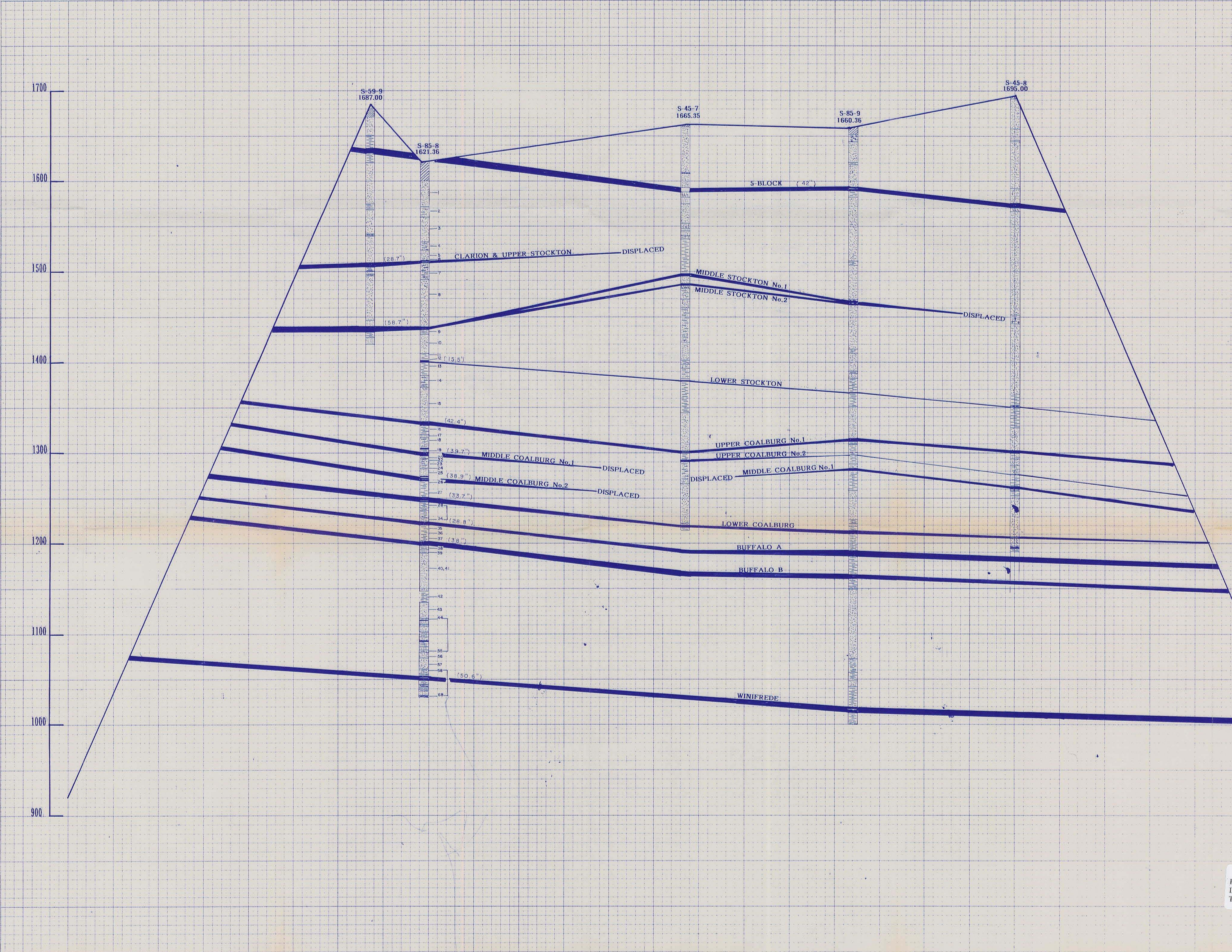
Permit # S-5063-91
 Doc. Perm. # 10328
 Type Application Volume 2

Scale 1" = 400'
 PREPARED BY: DAL-TEX COAL CORPORATION
 ENGINEERING DEPARTMENT
 P.O. BOX 3
 SHARPLES, W. VA. 25183
 PH: (304) 369-0666
 Date: Feb. 15, 1991

SCALE 3'-10" CROSS SECTION 100' HORIZ.
 HORIZONTAL DISTANCE
 HORIZONTAL DISTANCE

NO. 100
 TITLE SHEET
 SURVEY
 ORIGINAL

NO. 100
 TITLE SHEET
 SURVEY
 ORIGINAL



- NOTES: 1) The Major Underground Source In The Area Is The Abandoned Underground Works In The Chilton Seam At Elevations Of 900' - 1000'.
 2) Groundwater Uses In This Area Obtain Water From The Logan County Public Service District Or Private Wells, Both Of Which Derive Their Source Of Water From Alluvial Materials.
 3) For Further Information On Drill Hole S-85-8 Refer To Gut Fork Mine Geologic Column Map.
 4) No Strata Have Been Identified As Fractured Or Weathered.

I, the undersigned hereby certify that this map/drawing is correct and true to the best of my knowledge and belief, and that the information required by the mining laws of this state and covers the period...

James F. Johnson
 REGISTERED PROFESSIONAL ENGINEER
 STATE OF VIRGINIA
 No. 40328

APPROVED AND AUTHORIZED
 STATE OF VIRGINIA
 DEPARTMENT OF MINES
 on this 2 day of 10/25/92
 by Governor James S. Gilmore

- LEGEND
- COAL
 - SHALE
 - CASING
 - FIRECLAY
 - SILTSTONE
 - SANDSTONE
 - SANDY SHALE
 - SHALE WITH COAL STREAKS
 - SANDSTONE WITH COAL SPARS

DAL-TEX COAL CORPORATION
 Geologic Section A
 Proposed Gut Fork Mine
 SMA 5063-91

Scale: Hor. 1"=300' Date: 3-24-92
 Ver. 1"=50'

Permit # S-5063-91
 Doc. 18m.7
 Type Application Volume #

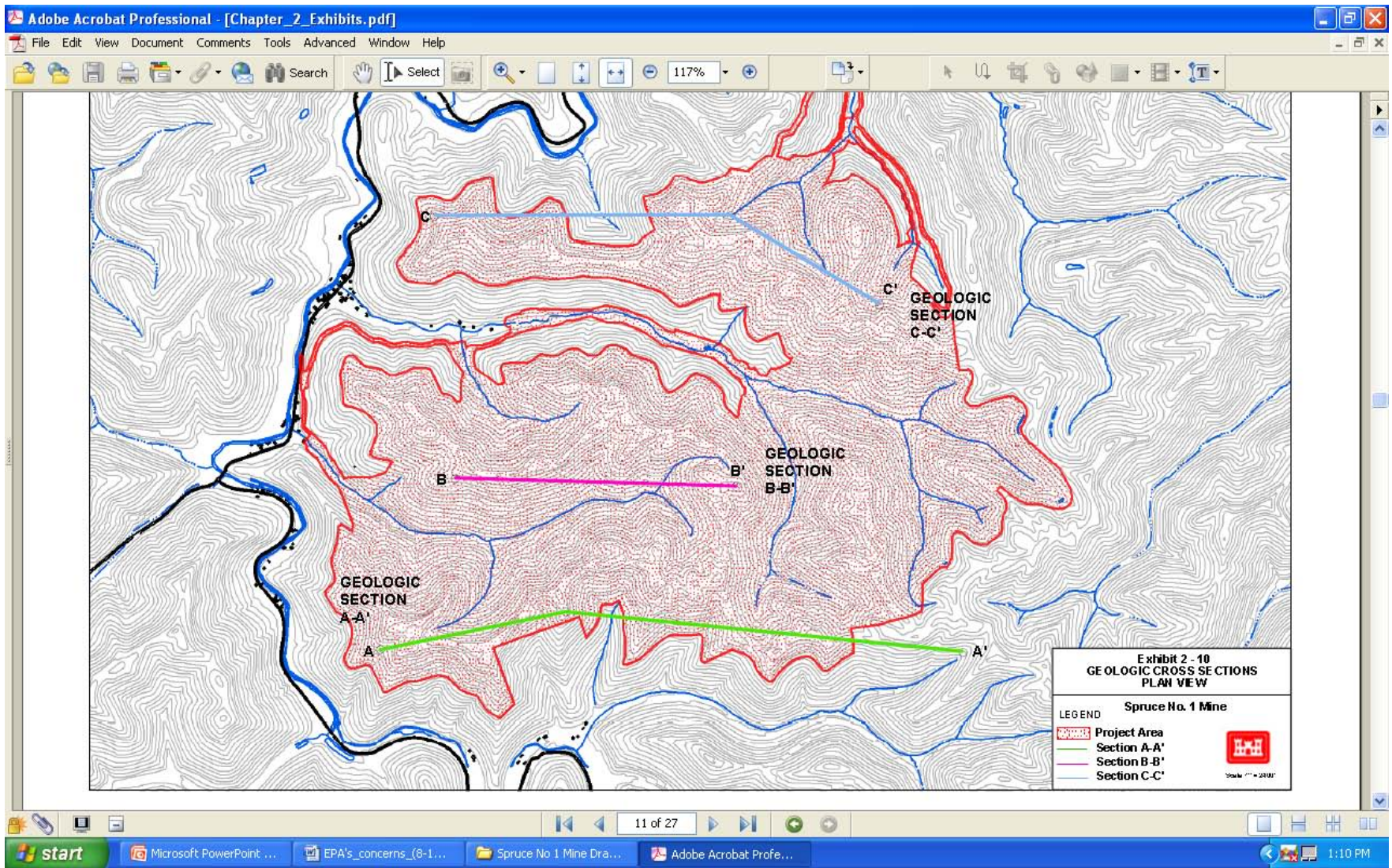


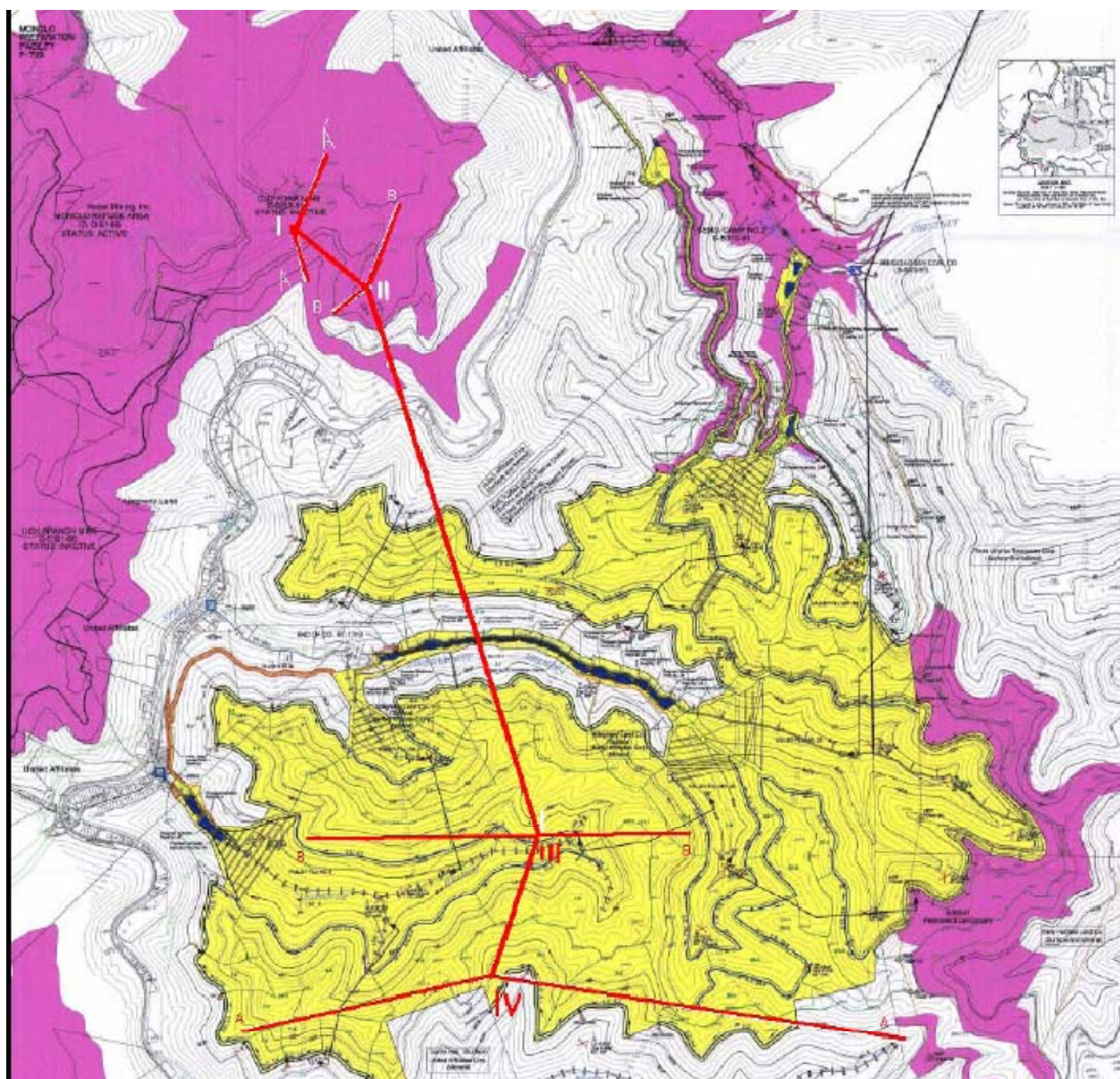
Figure 6: Spruce No 1 mine crosssection locations

Table 1: Sequences of rock cores and coal beds on a NW-SE crsoo section through the Del-Tex mines (Gut Fork Rockhouse mines) and proposed Spruce No 1 mine. (*Note: Coal beds are in black; Se data is for the Spruce No 1 mine*)

Rickhouse Mine	Gut Fork Mine	Spruce No 1	Se (mg/kg)
	Casing		
	Sandstone	Sandstone	0.02 – 0.20
	Shale	Shale	0.07 – 0.62
5-Block	5-Block	5-Block	1.84 – 9.8
	Shale	Shale	0.08
	Sandstone	Sandstone	0.03 – 0.46
Clarion	Clarion / Upper Stockton	Upper Stockton	0.85 – 1.98
		Clay (1')	0.85
	Shale	Shale	0.03 – 0.10
	Sandstone	Sandstone	0.03 – 0.36
	Middle Stockton No. 1	Middle Stockton (0.8')	1.49
		Clay (0.6')	0.5
		Shale (15')	0.22 – 0.64
	Middle Stockton No. 2	Middle Stockton (2.5')	1.44
		Shale	0.28
		Sandstone	0.13 – 0.16
		Shale	0.6 - 3.0
		Middle Stockton (2.6')	0.86 – 1.4
		Carbonates (0.6')	0.88
	Shale	Shale	0.22
	Sandstone	Sandstone	0.07
	Shale	Shale	0.9 – 6.63
Lower Stockton	Lower Stockton	Lower Stockton	1.3
		Clay	4.0
	Shale	Shale	0.16 – 2.4
		Clay	0.28
		Shale	0.04 – 0.16
		Carbonates	0.51
		Shale	0.10 – 0.86
	Sandstone		
	Upper Coalburg No. 1	Upper Coalburg	1.2
	Shale	Shale	0.3 – 1.23
	Upper Coalburg No. 2	Upper Coalburg	1.29
		Shale	0.42
		Upper Coalburg	3.44
	Shale	Shale	0.20 – 0.35
	Sandstone	Sandstone	0.08 – 0.27
Middle Coalburg	Middle Coalburg No. 1	Middle Coalburg	1.01
	Shale	Shale	0.18 – 0.22
	Sandstone	Sandstone	0.03 – 0.08
		Shale	0.16 – 0.72
	Middle Coalburg No. 2		
	Shale		
	Sandstone		
	Lower Coalburg	Lower Coalburg	4.14
	Shale	Shale	
	Sandstone	Sandstone	
	Buffalo A	Buffalo A	MISSING

	Shale	Shale	
		Clay	
		Shale	
Buffalo B	Buffalo B	Buffalo B	MISSING
	Shale	Shale	
	Sandstone	Sandstone	
	Shale	Shale	
	Sandstone	Sandstone	
	Winifrede	Winifrede	
		Sandstone	
		Chilton	

Figure 7: Geologic cross section locations across the Gut Fork mine (I), Rockhouse mine (II), and Spruce No 1 mine (III & IV)

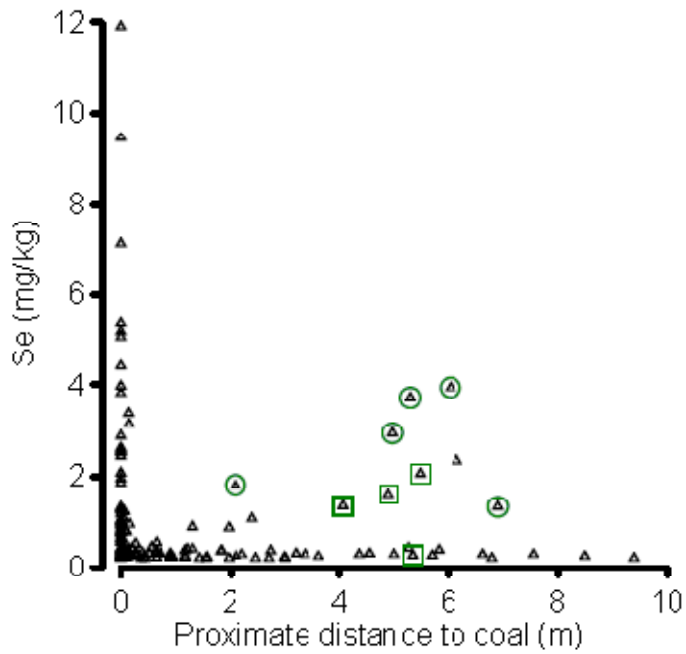


selective handling of acidic or Se-bearing overburden material makes USEPA's comparison of the Del-Tex mine and Spruce mine inappropriate. EPA does not find the permittee's evidence to be credible or convincing.

A4.5.1 Segregation of high Se materials

The permittee is proposing to selectively handle high Se bearing materials. A problem is distinguishing which layers to remove and handle separately and which ones to valley-fill. Adequately testing each layer in the field could be impossible. Just because a test at a location indicates that the rock materials above and/or below the coal bed could be valley-filled without any special handling does not mean rock materials 100' (or less) away can also be valley-filled without being tested. Microscale spatial differences in Se occurrence and concentrations make it difficult to predict a priori which drilled locations will have high Se concentrations above and below the coal beds. In addition, while Se is highest in coals and rocks that are adjacent to the coals, not all units close to the coal beds are high in Se and not all units away from the coal are low in Se (Figure 8). Even correlations with sulfur (S) and total organic carbon (TOC) are not always strong. Also, extraction data indicates that both organic and sulfide principal component analysis (PCA) show no single trend for Se (Vesper & Rhoads, 2008). Hence, these parameters are unreliable as indicators for Se occurrence. The practice of mountaintop coal mining disturbs large volumes of rock with huge quantities of overburden removed. Given the nature of Se distribution in these overburden materials, it is impossible to demonstrate how an effective on-site separation of high Se-bearing overburden materials will be performed without testing all materials within two to four feet above and below the coal beds.

Figure 8: Selenium distribution as a function of distance to the coal bed



- Proximate distance – shortest distance from bed to wall
- 0 distance = adjacent to coal
- Trends agree with Mullenex (2005) for a similar section in VW

Modified from Vesper, 2008

A4.5.2 Exposure of Selenium to Water Sources

The applicant contends that there are no significant seeps or springs that would indicate potentially significant discharge from any coal seam or rock stratum to be encountered.

This statement may be unfounded or even misleading given earlier statements about perched waters that could be aquifers that may be encountered and could produce significant discharges.

The permittee makes contradictory argument regarding drainage to aquifers, claiming that they aren't present but that those that are present won't be affected. For example, the permittee states that alluvial aquifers are typically below the valley floor and will be unaffected because all of the proposed mineral extraction will be conducted on coal beds that are above the valley floor. In cross-sections (Exhibits 2-11 to 2-13) provided by applicant, it is noted that there are several overlying perched aquifers which could recharge underlying formations including nearby alluvial aquifers during operations. The applicant repeatedly states that these perched aquifers "...would be considered insignificant" without providing any justification for the statement.

Further, the highly permeable backfill material is expected to decrease storm runoff and provide water to the alluvial aquifer. Given that this backfill material may leach constituents of concern, including selenium, salts, and metals, groundwater contamination is likely. In addition, depending on the extent of backfill material, there may be reversals of flow direction over time such that the alluvial aquifer recharges surface water instead of

the other way round and if the aquifer (or perched aquifer) is contaminated, it may end up contaminating surface water.

A4.5.3 Removal of Selenium When Coal Is Removed

The argument that the strata containing high levels of Se are the coal beds that will be removed is not strong. We know that elevated Se concentrations have been reported in Appalachian coals (Diehl, 2005; Vesper and others, 2008) and from streams that drain areas impacted by MTM in southern West Virginia (Bryant and others, 2002; Ferreri and others, 2004; Vesper and others, 2004; Vesper and other, 2008) and areas impacted by coal surface mining and reclamation in Ohio (Bonta and Dick, 2003). Given that in surface mining all of the coal is removed, the source of Se is more likely to be the associated strata disturbed by mining operations as well as the coal washing process and the resulting fines that may intermittently coating the streambed.

A4.6 Conclusions

The Agency is not convinced that the proposed changes in mining practices will not result in unacceptable concentrations of selenium in streams or potentially potable aquifers.

There is abundant selenium in the coal deposits. Conditions that make selenium bioavailable occur at mine sites in adjacent mines operated by the same company. The documentation does not demonstrate that the company can effectively distinguish material requiring isolation from water from those that have low selenium and might be used in valley fill. Furthermore, they do not provide convincing evidence that water will not interact with these exposed deposits or that the selenium will be removed when the coal is removed. Thus, EPA contends that there is a strong likelihood that toxic levels of selenium will be released if the Spruce 1 mine continues as planned.

References

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