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Using GIS to Identify High Value Areas in Large Coal Resources

by

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ABSTRACT: Identifying high value areas of unmined coal when large quantities of coal are available relative to annual markets is difficult because of the uncertainty of when the coal is to be mined. A GIS based methodology developed to value reserve coal in a producing coal region for the purpose of ad valorem taxation also identifies high value areas for mining investment. The methodology is unique in that it accounts for most mining, environmental, and market factors to determine when specific properties are to be mined. The methodology and database are useful for directing regional exploration and acquisition activities toward most favorable areas.

INTRODUCTION

The large resources of bituminous coal in West Virginia has been mined extensively since the late 1800's. In spite of the millions of tons of coal removed, many millions more remain in an area covering approximately 1000 square miles. Over 62 coal seams have had mining activity in an area that covers much of West Virginia (Figure 1). Presently, over 100 million tpy are mined from over 700 deep mines and an additional 60 million tpy are mined from 500 surface mines. At the present rate of mining, over 200 years of resources remain to be mined according to resource estimates made many years ago (C. W. Lotz Coal Map: Probable Original Mineable Extent of the Bituminous Coal Seam of West Virginia, West Virginia Geologic and Economic Survey, Map 19, 1970). Better estimates of the quantity of coal resources available are now being made by the West Virginia Geologic and Economic Survey (WVGES). However, even if the original estimates of the quantity of coal resources prove to have been too optimistic by a factor of two, there are still sufficient resources to support mining for the next 100 years.

Although mining has been conducted in the State for many years, large areas are still relatively unexplored. This is not surprising since exploration is costly and there is no economic incentive to prove reserves to be mined in years exceeding 30 or 40 years from now. Also, since there is no requirement in West Virginia to make public the results of coal exploration (as is required for oil exploration), exploration results over a significant portion of the State are not generally known by anyone other than the exploration coal company.

However, there is a need to identify those areas of the State that contain coal resources that are likely to be mined soonest, for these are the coal resources with the highest present value. A number of government agencies and types of investors are interested in identifying these areas. The West Virginia Department of Tax and Revenue wishes to appraise these properties for *ad valorem* tax purposes. Investors and coal producers are interested in property acquisitions. Governments and environmental groups and agencies wish to know, for a variety of purposes, where the next mining activity will take place and the extent of the mining.

The Department of Tax and Revenue embarked on a program to improve coal property appraisal in 1997. The goal of the program was to devise a better way to appraise each of the 180,000 coal properties in the State, to use public data wherever possible, and to construct a database and valuation model consistent with the perceived needs of the State governments, taxpayers, and the coal industry. Since obtaining geologic and economic data is an ongoing activity, the methodology would have to be able to automatically accept new data and self correct property value appraisals.

A methodology and database were developed that meet these criteria. The structure of this new appraisal methodology is presented in this paper.

FEE AND MASS APPRAISAL APPROACHES

Coal properties in West Virginia can be divided into two types; active and inactive. Active properties are those associated with active mining operations. The evaluation of coal properties associated with active mines can be accomplished by using an income approach to valuation (Eckert, 1990). In this method, future income is estimated for each of the active properties and discounted to the present to arrive at the present value of the property. Property taxes are then determined on the basis of this value. These properties are relatively few in number and information on production, tonnage, and prices are readily available, and production and price forecasts can be made over relative short periods of time (often five years or less). Therefore, it is possible to use a more detailed fee appraisal approach to value active coal reserves (Eckert, 1990).

However, active coal constitutes only a small number of the total 180,000 coal properties in the State. Most of the remaining properties are not associated with active mines and are classified as inactive reserves or resources. Because of the large area involved, the large tonnage of coal, and the large number of individual coal properties, it was clearly not possible to conduct detailed analysis on every coal property in the State. Even if such an evaluation plan were initiated and each property were thoroughly drilled and evaluated, it still would not be possible to determine the value of each of the 180,000 coal properties. This is because the value of a coal property is closely related to the time of mining and determining the value of each of the 180,000 coal properties would require identifying when each property would be mined from the present to 200 years into the future. This is an impossible task.

Therefore, a mass appraisal approach was taken to assess the value of inactive coal in West Virginia. A mass appraisal approach uses various property and regional indicators of value to determine the value of any given property. As a result, the appraised value for any single property may be greater than or less than the actual market value. However, on average, the range of deviation from market value for any property is acceptable.

An income approach was used in the mass appraisal of all coal properties (as opposed to a cost approach or a market approach). The income approach requires the identification of a fob coal price and a mineable coal quantity. Since almost all coal produced in West Virginia is sold for steam coal, usually to electric utilities, the value of the coal depends upon the cost to produce electric power at the electric generation station. Factors that affect the value of coal to the coal user include coal quality and mining and transportation costs. These factors, in turn, determine the fob mine prices and royalties for coal from any particular seam and in any particular location.

TIME OF MINING

Assuming that there are sufficient coal resources in West Virginia to support mining at current rates for 100 years or more, it will take at least 100 years to mine all coal properties. Those properties to be mined further in the future have lower present values than those to be mined sooner because of the effect of discounting. In fact, properties to be mined 30 or more years in the future have little present value. The value per ton of coal in the ground for coal to be mined at various time periods is shown in Figure 2. These values are based on a risk adjusted 12.5 per cent constant dollar discount rate.

As can be seen in Figure 2, coal to be mined within the first 5-year period can be classified as active reserves since mining is currently being conducted on these properties. These active reserves have an in ground value of around $1.00 per ton of recoverable and marketable coal.

Coal to be mined in the next 20-year period includes near term reserves that have an in ground value of around $.25 per ton. Coal to be mined 25 to 50 years from now has a value of only $.01 per ton and coal to be mined in years greater than 50 years from now has only negligible value.

While it might not be possible to determine exactly when any given coal property is to be mined in the future, it is possible, given sufficient information, to estimate in which of the four time periods shown in Figure 2 the coal is to be mined.

The remaining problems are now to obtain sufficient information to tell if coal is present and in what quantity and quality, to discover the regional fob mine prices, and to determine when the coal may be mined in the future based on mining and transporting costs, environmental constraints, and existence of mining infrastructure.

BUILDING THE DATABASE

The heart of any valuation methodology or model are the data required to both design and operate the model. It is as useless to design a model based on faulty data as it is to design a complex model that requires many variables for which no reliable values exist.

Data on coal transaction prices and quality as reported in the FERC Form 423 for each utility were obtained over the Internet. Estimates were made of coal transportation costs where necessary to obtain fob mine coal prices. Coal mining royalties on both producing and reserve coal were obtained through a search of coal transactions recorded at county courthouses. Over 80,000 records were collected and analyzed to create a base map of fob coal value by geographic area in West Virginia (Figure 3).

Coal seam quality and thickness were also obtained from various Federal and State sources and from the Internet. Over 60,000 data points with coal quality and thickness were collected from drill cores, seam channel samples, mine reports, and Geologic Survey samples in West Virginia and neighboring states (Figure 4).

It was not always clear if a given analyses was on a washed or unwashed basis or on an as received or dry basis. The moisture ash free (MAF) Btu values and whether the analyses were from strip or deep mined coal were used as indicators of the type of analysis reported. For consistency, all analysis were converted to a dry, marketable basis.

Similarly, some seam thickness measurements included coal only, some included total seam height with included seams. Some sources did not specify the basis of the measurements. All measurements except those that were clearly erroneous were used to create the seam thickness maps with the full knowledge that at any given point the seam thickness map may be inaccurate. Including all measurements to create generalized seam thickness maps is consistent with the mass appraisal approach to resource evaluation.

Considerable confusion exists in West Virginia about the names of coal seams because of correlation problems and the use of entrenched local coal seam names. A major task was to create a matrix of seam names by county so that a consistent scheme of coal seam names could be used in the appraisal. This correlation was accomplished with the help of the WVGES, which is now engaged in a coal mapping and evaluation program. The creation of the matrix was absolutely essential to the task of identifying and mapping coal seam extent and quality.

Other types of data collected included oil and gas well occurrences, coal transportation costs, environmental constraints, and historical regional coal transactions and mining activity. These types of data are used to help indicate the economic feasibility and time of mining. For example, if coal was never mined in a region, even during the coal boom years of 1977 to 1981, it is likely that it will not be mined anytime during the immediate future. Similarly, if a property is adjacent to an existing active mine and has coal of appropriate thickness and quality, it is likely that this coal will be mined in the near future, all else being equal.

Seam elevations were obtained from mine permit data. The seam elevations were combined with digitized topographic data for the State to form seam outcrop maps. As more seam elevation data becomes available and as the topographic data improves in the State, the seam outcrop maps will improve.

Identifying regional environmental constraints is a particularly important and difficult task. For example, it is currently difficult to obtain mining permits in West Virginia for certain seams that contain acidic overburden and contribute significantly to the State's acid mine drainage problem. This does not mean it is impossible to mine this coal, only more expensive. The locations of these seams were supplied by the West Virginia Department of Environmental Protection.

The large amount of data of various types was stored in a computerized geographical information system (GIS). The GIS database allows changes to be made as new data are obtained and provides the means to analyze the data and calculate coal values.

Certain other environmental constraints were more easily identified, especially with the aid of GIS. For example, the potential for subsidence damage in populated areas can be easily estimated.

An organized inventory of environmental constraints particular to certain seams in specific coal regions in the State has not been made. Such an inventory would be of help in determining coal values.

It is important to note that obtaining data is only one step in making a usable database. A second and important step is to inspect the data to make all entries consistent in nature and to eliminate inconsistent data. This "cleansing" of the data presented a large and tedious task with few short cuts.

BUILDING THE VALUATION MODEL

A statistical inspection of the "cleansed" data suggested how the valuation model was to be constructed. In other words, the data, not a preconceived notion, determined the design of the valuation model.

For example, there are scores of variables that determine the value of a coal property and when the property is to be mined. However, it is not possible to identify and quantify each of these variables for every coal property. Only those values that are observable and have recorded values can be used in a computerized valuation system. Therefore, a limited number of variables were identified and quantified for use in the valuation model.

Factors considered in the valuation process included:

- Coal existence
- Coal quality
- Coal thickness
- Identification of prime seam(s)
- Mining conditions
- Underground or surface
- Over and under mining
- Oil and gas well density
- Transportation costs
- Environmental conditions
- Coal prices and royalties

None of the above factors need explanation with the exception of the identification of prime seams. Many properties throughout the State have multiple seams, but only one seam on each property is commonly mined. Such a seam is termed a prime seam. If a property contains coal but does not contain a regional prime seam, then it is unlikely that this coal will be mined in the near future. The prime seam may also include multiple seams in areas that multiple seam open pit mining is feasible.

A number of other factors are also identified that act as proxies to mining cost. These include:

- The existence of nearby mining
- The regional mining history
- Regional transaction activity
- Adjacent ownership
- Environmental costs
- Use conflicts and costs

The existence of nearby mining is an indicator that neighboring properties are more likely to be mined sooner than later. Similarly, a history of mining activity in a region is viewed as being favorable to the mining of remaining properties sooner rather than later.

The presence of leasing or purchase activity also indicate that mining will take place sooner. The nature of the ownership of adjacent properties often indicate whether a property can be mined or not. The existence of environmental violations in mines in the region indicate an increased cost of mining. Similarly, the presence oil and gas wells may increase the cost of mining in proportion to the well density.

The idea is that not one single factor determines mining cost and when an inactive property will be mined. Rather, there is a combination of factors, as is shown by the GIS information layers in Figure 5. The evaluation model takes into account a weighted average of these factors by property to determine the time any particular property is to be mined.

The base value of the coal present depends upon the regional price and the quality of the coal. The time that this base price is discounted to the present value depends upon the property specific weighted average of the factors described above.

AGGREGATE VALUE

Initial output from the valuation model is a set of indices that represent the relative value of coal throughout the State. What is needed is a means to calibrate the determination of the indices so that the relative values will be in the correct proportions. This is accomplished by using the aggregate present value of all unmined coal as a calibration device. The aggregate value is simply the present value of an annuity that consists of the average per ton price of coal in the ground, the yearly production of coal in West Virginia, a risk adjusted constant dollar discount rate, and a time period. The average value per ton of coal in the ground and the yearly production are publicized numbers. A 12.5 per cent discount rate was used in this valuation and was supplied by the Department of Tax and Revenue. The number of years for the annuity equals the years of resource life at current mining rates, or some number over 100 years. The current aggregate value of all unmined coal in West Virginia is $2.1 billion.

The sum of the index values derived for all unmined coal properties in the State should approximate the aggregate value of $2.1 billion. If the sum of the index values is seriously over or under the aggregate value, then it is possible that an improper weighting of the factors has occurred within the coal valuation model.

The aggregate value also identifies that value that the sum of all appraised coal property values within the State must equal. If the total is known and if there is an index value for each property, then the index value can be used to allocate the aggregate value among all coal properties. This procedure provides both a check on the internal workings of the evaluation model and provides a means to insure the sum of the appraised values is not higher or lower than the guide provided by the aggregate value.

The aggregate value of all unmined coal is currently about $2.1 billion. The value of active reserve properties obtained through a fee appraisal process is about $1.0 billion. Therefore, by subtraction, the value of all inactive coal in the State is about $1.1 billion. It is the identification of the properties that make up the $1.1 billion that is of interest to coal developers and governments because these properties represent where coal will be mined in the future. The combined value the reserves and the active coal properties is shown in Figure 6.

OUTPUT

The great advantage of having the valuation model supported in a GIS format is that output from the valuation model can be in either tabular or graphic form. The graphic form provides a format for regional interpretation while the tabular data allows an inspection of the details on each property or region.

An example of the graphical representation of the characteristics of the Pittsburgh coal seam in West Virginia is shown in Figure 7. These views of the Pittsburgh seam show the regional patterns in coal thickness and sulfur, volatile matter, and Btu content. The data points used to construct these maps are also shown. As can be seen, data points outside the State boundaries are used to construct maps specific for West Virginia. The data point map also shows areas in which additional information is needed in the Pittsburgh seam. While the present maps may be criticized because of the lack of accurate data points and analyses in certain areas of the State, it is still better than any other publically available map series of the Pittsburgh seam. As additional information is gathered, the accuracy of the output maps automatically increases. Similar map series were made for the remaining 61 identified coal seams in the State.

The distribution of value of unmined coal is an item of great interest to various parties. The distribution of the value of all unmined coal is shown in Figure 8, which indicates the level of value that may be available for local property taxation. This value is also shown on a per acre basis in Figure 9. The distribution of unmined inactive coal is shown in Figure 10 which shows areas that may be considered exploration or acquisition targets for coal developers.

An item of current interest in West Virginia is the future effect mountain top mining methods will have on the State. To properly assess this effect it is necessary to know where future mountain top mining may take place in the future. However, sufficient publically available data were not available to determine the extent of this type of mining activity. Accurate seam outcrop maps were not available. Coal seam elevations for a limited area in West Virginia were obtained from mine permit data and were combined with digital elevation data for West Virginia to create more precise coal outcrop and overburden maps. These maps can now be used in conjunction with the evaluation process to identify the extent of future mountain top mining in the State using various cost and operating constraints.

An example of the outcrop mapping process is shown in Figures 11 through 13 (following page). Figure 11 shows the original mapped areal extent of the Coalburg seam in southern West Virginia. Figure 12 shows the improved outcrop map by combining seam elevations with the State topographic data. Figure13 shows the detail of the improved seam outcrop map and the resulting indication of amount of overburden for the Coalburg seam.

This mapping process is applied to all coal seams in West Virginia that are commonly mined by open pit multi-seam methods. The GIS modeling capabilities allow the identification of areas excluded to mountain top mining because of one or more criteria. For example, valley fill activities, which are necessary to for large mountain top mining operations, may be excluded in selected areas because of population density or other criteria.

VALIDATION

An important phase of constructing any mathematical model is the validation of the model results. Two questions concerning validation are "Does the model give the correct answers?" and "Does the model give correct answers over a wide range of input values?" Neither of these questions can be answered in a simple fashion.

One way to tell if the model gives correct answers is to compare the computed values with observed "real" values of individual coal properties reflected by property sales data. Actual "real" values that directly reflect the market value of coal properties are scarce because many property sales include other assets as well as coal. It is usually difficult to impute that portion of a property sale that is allocatable to coal alone. Also, the actual sales price of a coal property may be more indicative of the worth of a property to a single buyer or seller under special circumstances and may not be representative of the actual market value of the property.

Another comparison can be made between the computed value and actual lease transactions. Although lease transactions are more numerous than property sales, it is often still difficult to tell from the public record just how much was paid for coal.

However, general regional patterns of value can be obtained from historical sales and lease data. The regional patterns of coal value observed from actual transactions for all types of unmined coal compare favorable with the regional patterns obtained through the valuation model. From this validation perspective, the model gives correct answers.

Another dimension of the question "Does the model give the correct answers?" has to do with the acceptable level of variance between the model values of individual properties compared to the "real" value of the properties. Since the model uses a mass appraisal approach to determine value of coal properties, any single property could be over- or under-valued. To determine if the model gives correct answers in this case means it is first necessary to determine what level of variance is acceptable.

This raises two problems. The first is that it is sometimes difficult to pre-determine an acceptable level of variance. This is particularly true in the case of taxing authorities in which there exists no objective measure of acceptable variance. The second problem has to do with using public sales and lease data to determine value, as described in the preceding paragraphs.

The solution to these problems is to determine the value of individual properties based on as much detail as public information allows. While using this level of disaggregated data may or may not give a level of dispersion acceptable to all individuals, it is certainly better than any other alternative.

CONCLUSIONS

The value of unmined coal properties in West Virginia is of interest to coal developers, governments, and individual coal property owners. The determination of these values was made by using publically available data on coal occurrence, quality, and value as input to a GIS based coal property valuation model.

The model uses a weighted average mix of economic and physical indicators of value to identify the approximate time of mining for each of the 180,000 coal properties in the State. The base value of coal on each property is based on coal occurrence and coal quality. The discounted value of the base value determines the present value of the coal property.

The aggregate value of all unmined coal in the State is based on an assumed rate of mining, current coal prices and royalty rates, a period over which all coal is to be mined, and a risk adjusted constant dollar discount rate. The aggregate value of all unmined coal in West Virginia is currently $2.1 billion, of which actively mined coal is worth $1.0 billion and non-active reserve coal is worth $1.1 billion. The aggregate values are used to validate the model operations and to provide a value that the total appraised value of all individual coal properties in West must equal.

The valuation model gives graphical data for the examination of regional coal occurrence, quality, and values, and tabular data for the examination of individual properties within the State. The structure of the valuation model and database is constructed to accomplish the seamless addition of new and corrected data as such data become available.

The methodology is unique in that it accounts for most mining, environmental, and market factors to determine when specific properties are to be mined. The methodology and database are useful for directing regional exploration and acquisition activities toward most favorable areas.

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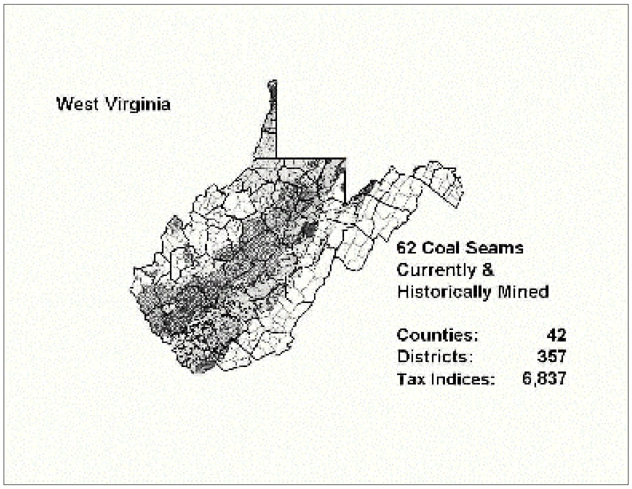

Figure 1:
Generalizd Map of Mineable
Coal Seams in West Virginia

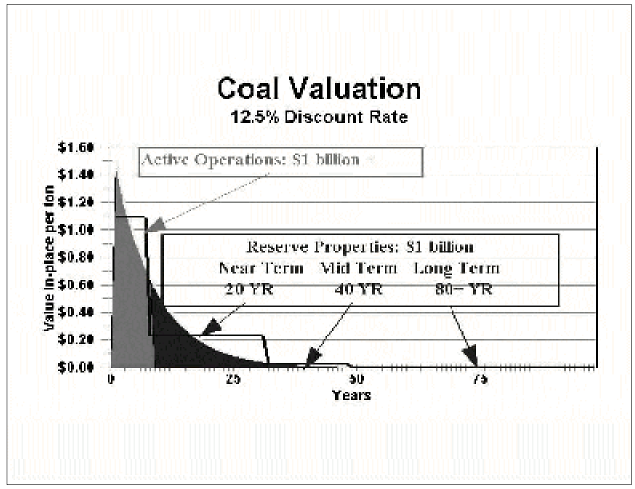

Figure 2:
Determination of the Time of Mining

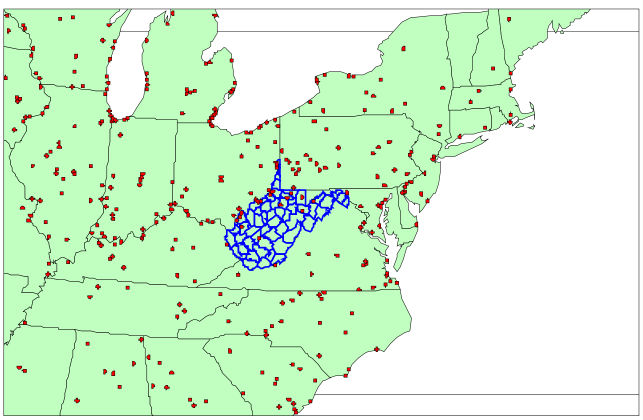

Figure 3:
Coal Sales to Regional Power Plants

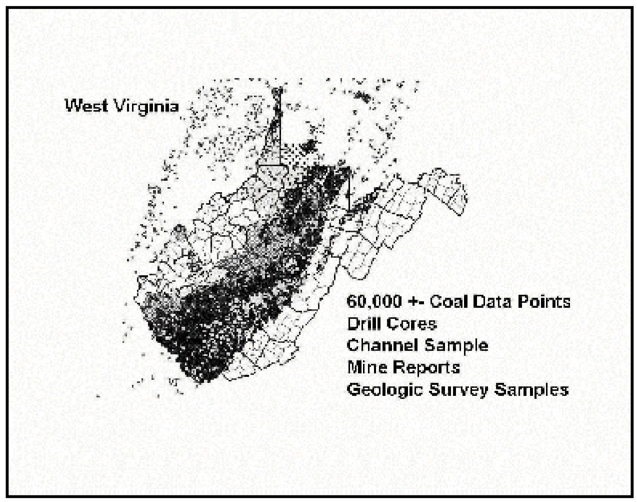

Figure 4:
Coal Characteristics - Data Points

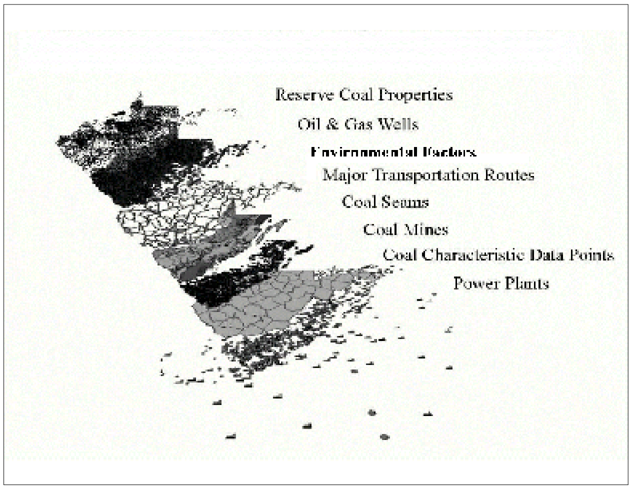

Figure 5:
GIS Layers

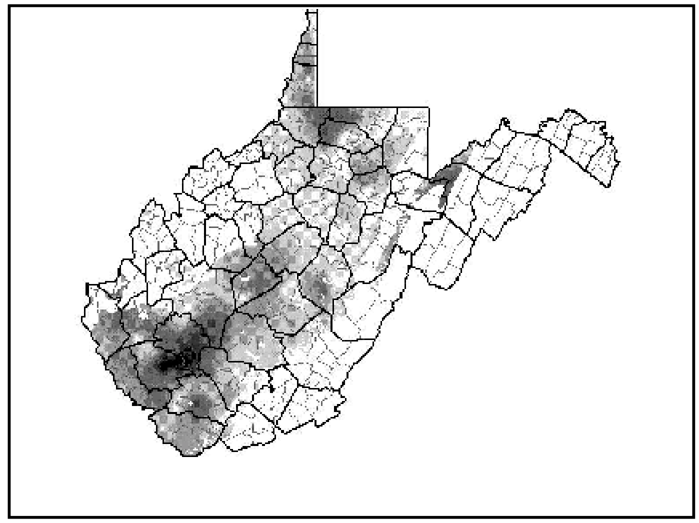

Figure 6:
Distribution of Active Mine Value

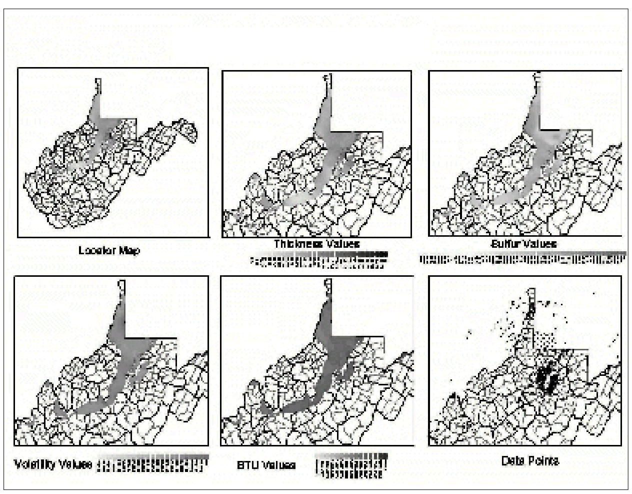

Figure 7:
Characteristics of the Pittsburgh Coal Seam

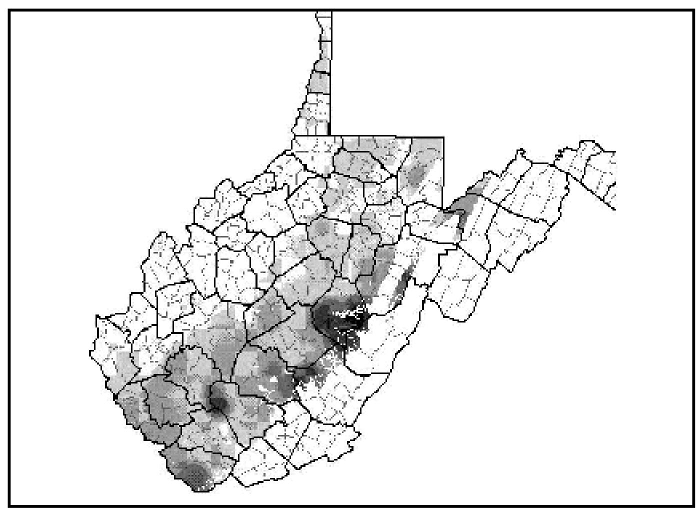

Figure 8:
Distribution of Reserve Coal Value

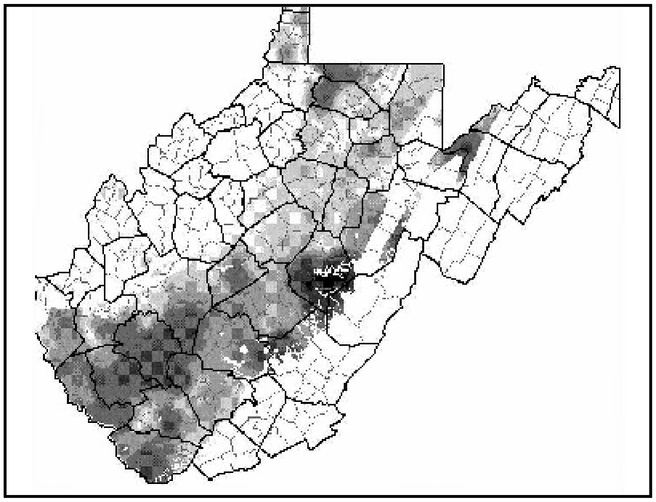

Figure 9:
Model Distribution of Total Value ($)
Active and Reserve Coal Properties

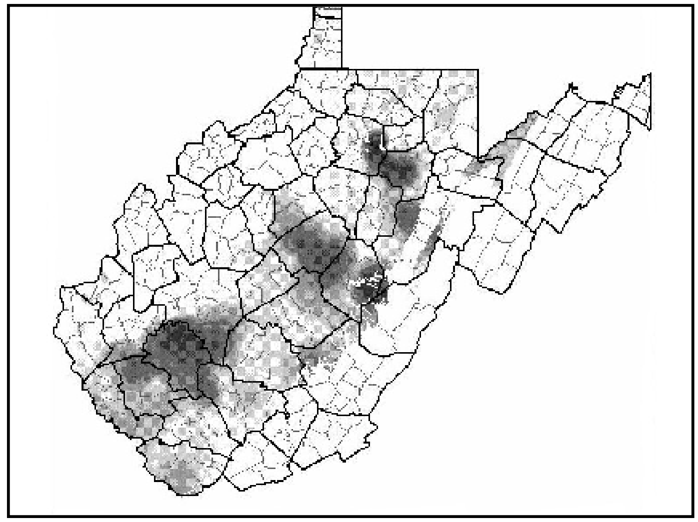

Figure 10:
Model Reserve Coal Value ($) per Acre

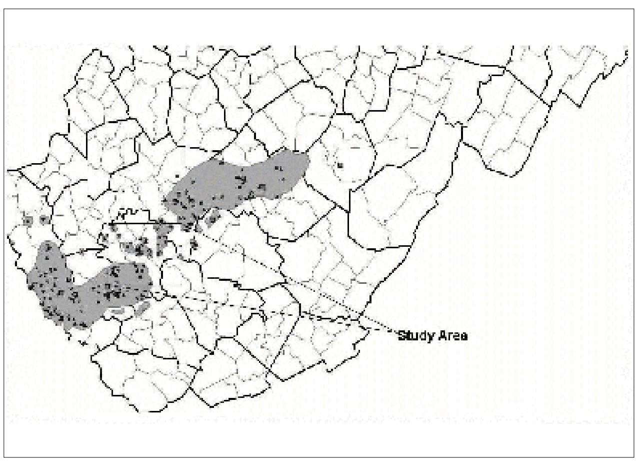

Figure 11:
Original Mapped Aerial Extent of the Coalburg Seam

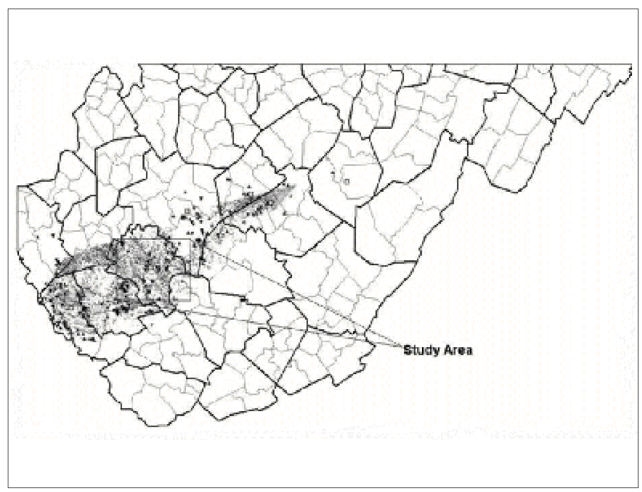

Figure 12:
Revised Extent of Coalburg
showing generalized overburden

Figure 13:
Enlarged Area of Resized Extent of Coalburg showing overburden