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DOCUMENTATION OF THE
DEMONSTRATED RESERVE BASE
OF COAL IN THE UNITED STATES
(FINAL REPORT)

Volume One

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PREFACE

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The purpose of this report is to document the methodologies used to develop the 1979 Demonstrated Reserve Base (DRB) of coal. The audience for whom this report is intended consists of Energy Information Administration (EIA) personnel involved in the development and analysis of coal reserve/resource data. The audience may also include those government employees and private individuals who use directly the annual coal reserve data published by EIA.

All primary source documents used to prepare the 1979 DRB were reviewed. Using the methodologies and documentation found in the 1979 DRB published report¹ as a guide, each of the state-level published reserve estimates were re-derived. In those cases where the estimates could not be reproduced, EIA personnel from the Eastern and Western Energy Data Offices were consulted and the differences, for the most part, were resolved.

Throughout this report an attempt was made to describe the information flow that was an integral part of the DRB development. Particular attention and emphasis was given to those instances where deviations from standard, published EIA procedures were used to derive the DRB estimates.

The main body of this report summarizes the methodological procedures used to develop each state reserve estimate. The appendices to the report, found in Volume II, provide a detailed description of the entire DRB process.

¹Energy Information Administration, Demonstrated Reserve Base of Coal in the United States on January 1, 1979, U.S. Department of Energy, May 1981.

EJB

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EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

A. Study Overview

The preparation of the Demonstrated Reserve Base (DRB) of coal in the United States is a complex undertaking requiring review and analysis of numerous sources of information about in-place coal resources and coal production. This report documents the methodologies, assumptions, and procedures used to develop the 1979 DRB.

In general, the development of state-level coal reserve estimates for the 1979 DRB followed one of three basic approaches:

- simple depletion of either the 1971 or 1976 published DRB estimates using production statistics assembled by the Energy Information Administration (EIA) and/or the U.S. Bureau of Mines (BOM). Depletion of reported production was based on global coal recovery factors of 50 percent for underground mines and 80 percent for surface mines.
- the use of post-1976 information to adjust/revise previous state-level DRB estimates. These revisions were done for both entire states (e.g., Alabama) and portions of states (e.g., Virginia, Western Kentucky).
- a change in the methodological procedure used to adjust primary resource information to reflect changing technology and/or policy decisions (e.g., West Virginia).

The primary information used to assemble the individual reserve estimates represents a compilation of data from previous source documents under explicit criteria. Reserve estimates presented in the DRB are not the result of drill hole or other similar data measured directly by EIA.

The preparation of the 1979 DRB reflects a continuing effort on the part of EIA to develop and present meaningful statistics on mineable in-place coal on a national basis. This complex undertaking requires

the conscientious analysis of numerous and sometimes divergent data sources. It also requires that the analysts be knowledgeable in coal geology and basic mining engineering so when even the primary source documents must be adjusted or interpreted to meet global standards, any adjustments are made in a consistent and proper manner.

B. Description of the Data

Data used in the preparation of the DRB were obtained from coal resource evaluations for each coal-bearing state. These data were prepared by numerous agencies/individuals over a time-frame covering most of this century. The source documents used to prepare the DRB can be divided into two general types: 1) resource evaluations and reserve estimates or 2) production, depletion, and recovery sources. In many cases, both sources presented difficulties in developing an accurate, and more importantly, consistent coal reserve base.

Resource Evaluations and Reserve Estimates

The two leading agencies investigating resources and reserves in the United States are the U.S. Geological Survey (USGS) and the U.S. Bureau of Mines (BOM). For the 1979 DRB, these two agencies provided the most data to DRB development.

For the majority of USGS and BOM sources, the primary data were presented on either a bed/county or bed/township level. The data were generally categorized by standard reliability (measured, indicated and inferred), depth (0 to 1,000 feet), and thickness (14"-28", 28"-42", and greater than 42") ranges as defined in USGS Bulletin 1450-B. However, some variations did occur.

Other leading sources of reserve data occurred on the state level for entire states or specific regions within a state. These data also

followed the criteria of 1450-B but not as consistently as in USGS or BOM publications. The agencies responsible for these data included state geological surveys, private consultants and firms, universities, regional development commissions, and state Departments of Natural Resources.

A few additional sources were consulted, where necessary, for DRB development. These included the Keystone Coal Industry Manual, papers from various geology and mining conferences and symposiums, industry trade journals, and industry newsletters and book publications. These data may or may not have corresponded with the criteria set in Bulletin 1450-B.

Of the problems encountered with the various data sources, three types stand out. These are:

- Non-Standard Categories - Documents containing thickness, depth, or reliability categories which do not conform to standard 1450-B criteria. For example, estimating coal reserves by thickness categories of 14"-17", 17"-36", and greater than 36".
- Overlapping Reserve Estimates - Documents from different sources which either partially or fully overlap in geographic and reserve coverage. Problems arose when the criteria for evaluation between the documents could not be reconciled.
- Failure to Categorize Data - Sources which contained information on reserve quantities, but failed to give any thickness, depth, or reliability information.

These problems will be discussed in Section C of this summary.

Production, Depletion, and Recovery Sources

The second group of information sources is the depletion data sources used to update the estimates of original resources for every state to the year 1979. These sources included BOM Annual Yearbooks, state

mining reports, EIA production reports, state geological surveys, and private production reports. For the most part, these sources identified production on a statewide basis, usually by bed, by mine, and by county. Annual summaries presented data by county and state, while earlier summaries of production (late 19th century, early 20th century) presented data on a state-by-state basis by year.

C. General Methodologies and Comparisons With Previous DRB Estimates

The previous section indicates some of the difficulties encountered in employing the source documents. To summarize, these problems include:

- the use, in the source documents, of non-standard seam thickness, overburden depth, and reliability categories. (Example: the use, in the Texas source document, of an indicated reliability category that covers a portion of EIA's inferred category).
- overlapping of source documents
- failure to provide detailed categorization of reserve data.

These problems determined the methodological approaches employed in developing the DRB estimates for specific states. Although specific approaches vary from state to state, it is possible to provide general outlines of the approaches employed to handle each problem.

Two general approaches were employed to deal with the problem of non-standard categorization schemes. One approach was to modify the source data to fit the DRB criteria, while the objective of the other approach was to modify the DRB criteria to fit the format of the source data. A good example of the first general approach can be found in the Alaska methodology. Here, some coal resource information was presented in depth ranges of 0-2000' and 0-3000', as opposed to the 0-1000' range

needed by the DRB. To determine the quantity of coal falling in the 0-1000' depth range (i.e., the quantity meeting the criterion for inclusion in the DRB), it was assumed that Alaskan coal was distributed uniformly by depth. Having made this assumption, the quantity of 0-2000' coal falling in the 0-1000' depth category was determined by multiplying the amount of 0-2000' coal by 0.5. Likewise, the quantity of coal falling in the 0-3000' category was multiplied by 0.33 to determine the quantity falling within 1000' of the surface.

Illinois provides an example of the second general approach taken to deal with non-standard categorization schemes. The Illinois DRB estimates are based on source documents published by the Illinois State Geological Survey (ISGS). Due to the high degree of lateral continuity and consistency of thickness of Illinois coal beds, the ISGS employs a liberal reliability categorization scheme. As a result, the ISGS "proved" and "probable" reliability categories do not correspond with EIA's measured and indicated categories. But since the EIA agreed with the ISGS decision to extend the reliability radii around data points, because of the nature of Illinois seams, the ISGS reliability categories were accepted by EIA as the "correct" categories for Illinois, and all coal falling into the proved and probable reliability categories were included in the Illinois DRB estimates.

The desire to employ the most current data available created the problem of overlapping source documents. Often old reports covering the entire state were supplemented with newer reports covering only portions of the state. The general approach employed to combine the data contained in overlapping data sources involved two standard steps:

- identification of those reserves included in the old report and re-evaluated in the new report
- replacement of the old estimates with the new estimates.

Identification of the overlapping reserves was sometimes very easy and sometimes very difficult, generally depending on how well the data categories in the two given reports conformed. Wyoming coal resource data posed the most difficult identification problem; here it was necessary to employ a planimeter to identify and quantify the area of overlap.

Often, data simply were not categorized to the extent necessary to enable the application of each DRB criterion to the source data. The approaches employed to handle this problem were not as uniform as the approaches employed to handle the other problems discussed thus far. Wyoming provides examples of two approaches employed to handle this problem. In the first case, Wyoming production data were not available by rank, but were available by county. Thus, by assuming a rank for each county, estimates of production by rank could be obtained.

The second case involved tables of reserve data which, although identifying reserves as being strippable, did not provide information as to seam thickness, overburden depth, or reliability category. In this case EIA assumed that the data met the DRB criteria, and included them in the DRB.

The above discussion does not represent a comprehensive outline of all problems posed by the source data, or all approaches used to handle these problems. The problems encountered by EIA were many and varied, and often required original and unique responses. The development of DRB estimates for each state required subtle variations in general methodologies, because of the variety of problems encountered. This fact can be discerned by referring to the detailed state descriptions provided in the body of this report and in the appendixes.

In addition to the variety of approaches employed to handle the problems posed by the data sources, the variations in geological and

economic conditions found in different states sometimes required the adjustment of the standard DRB criteria. For example, the mining of some coal not meeting standard DRB criteria is currently taking place, and thus the criteria were adjusted to include this coal in the DRB. Examples of adjustments made to include coal currently being mined include:

- the acceptance of strippable bituminous coal less than 14" thick in Kansas, Missouri, and Oklahoma
- the inclusion of coal lying at depths of 1000'-2000' in Jefferson and Tuscaloosa Counties in Alabama, as well as the Pocahontas No. 3 seam in Virginia.

Other modifications of DRB criteria were made for reasons that are less clear. For example, in Wyoming strippable subbituminous reserves 2.5'-5' thick and 0'-10' thick were included in the DRB even though standard DRB criteria limits consideration of subbituminous coals to beds 5' thick or more. Modifications for unknown reasons, however, were the exception rather than the rule; most of the modifications were made to make the DRB criteria compatible with current mining practice or with the data categories found in the source documents.

In comparing the 1979 DRB estimates with previous (i.e., 1971 and 1976) estimates, very large differences (sometimes representing 100 percent of the earlier estimates) were often discovered. These differences usually reflect the use of updated source documents in the later DRB estimates and/or a re-evaluation of data contained in the original source documents. Often 10, 20, or more years have passed between the publication of documents presenting reserve estimates for a state (or portion of a state). The quantity of new reserves uncovered by new exploration programs in a 20-year period can be (and often is) enormous, especially in the west. Examples of the effect of new data sources on DRB estimates abound. In Texas, the 1971 DRB estimate was 3,272 million tons; in 1979 it was increased to 12,916.54 million tons. The 1971 surface lignite estimate for Montana was 7,131 million tons, versus

15,766.8 million tons in 1979. The Missouri 1976 surface estimate was 3,596 million tons, 1,002 million tons less than the 1979 estimate. And in both 1971 and 1976 no underground reserves were presented for Arizona, while in 1979 underground reserves were estimated at 101.56 million tons. The size of these discrepancies indicates a major, inherent problem with the DRB, and, in fact, with all coal resource publications -- the estimates represent the quantity of coal discovered and proved to some degree of reliability, and thus the estimates are subject to large fluctuations with the publication of new reports incorporating data obtained from recent exploration programs. This problem should always be kept in mind when working with DRB reserve estimates.

Some discrepancies between the 1979 DRB and previously published estimates were found that are not the result of the incorporation of new data. In some cases (such as Arizona), EIA was able to acquire "old", but previously confidential material for incorporation in the DRB. In other cases the discrepancies are apparently due to changes in methodology or the discovery of errors in previous estimates. For example, North Dakota surface lignite estimates published in 1976 were mistakenly depleted by underground production. This depletion was added back to derive the 1979 DRB.

The main body of this report provides detailed descriptions of the methodologies employed to develop the 1979 DRB estimates for each state. Additional examples of the general problems faced by EIA analysts in developing the 1979 DRB are presented in full. It is important to note that the reader will also find that, although similar problems were encountered in each state, subtle differences in the problems are the rule rather than the exception, and hence each state has required a separate, independent analysis.

1. INTRODUCTION

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Any report documenting the assumptions, procedures and methodologies used to develop the 1979 DRB must begin with a definition of demonstrated reserves. Demonstrated reserves, as defined by EIA, represent a quantity of coal of known reliability, falling within a set of economic criteria defined by ranges of seam thickness and overburden depth. Estimates presented in the 1979 DRB do not represent all coal resources thought to be in-place, nor do they represent resources that are recoverable through various mining methods/techniques. As it currently stands the DRB represents a conservative estimate of in-place coal of known reliability, but an over-estimation (by design) of the amount of coal that can be recovered using standard mining techniques.

The basic procedure used to develop coal reserve estimates for each of the coal-bearing states identified in the DRB is based on the use of published source documents prepared by various federal, state, and private agencies. In general, the methodological approach used to derive the DRB estimates consisted of identifying those resources meeting a pre-defined set of criteria for reliability, seam thickness and overburden depth and then depleting those estimates based on production records obtained from various sources.

Due to the magnitude of this effort several variations from "standard procedure" were required. These variations resulted from:

- information in source documents that did not conform to established criteria
- the use of several, often overlapping, source documents to prepare a single state estimate
- the need to incorporate local anomalies to provide a better picture of state reserves and mining practices

- a lack of specific information on reliability, seam thickness and/or seam depth.

Irrespective of these variations the key ingredients to preparing the 1979 DRB were conservatism and consistency. The DRB is prepared on a national level. For it to be useful it must be consistent in content. Although it is often tempting to include rough reserve estimates for a particular state, because "...we know there is more coal than is currently estimated," EIA must be consistent in its approach if the information provided is to be useful to a wide spectrum of users.

This last point requires additional clarification. Most resource analysts agree that there are significant deposits of lignite in Louisiana. These, however, do not appear in the 1979 DRB. The reason they do not appear is that there are no currently available published documents which provide resource estimates by reliability, seam thickness or depth categories. Therefore, any published estimate would run contrary to EIA standards, without back-up data to justify the procedural variance. The argument could be made that, "...if you know some coal exists, why not publish an estimate and update it as more information becomes available?" That argument is invalid because, in this example, Louisiana is not an isolated case. If variations from standard procedure are made for one state or coal deposit, without proper back-up documentation, then they must be made for all other similar cases. This would result in a DRB that could not be defined with respect to the quality and consistency of the reserve estimates.

Chapters II and III of this report summarizes the methodological approaches used to develop the 1979 DRB. Deviations from standard criteria are discussed including the logic behind each adjustment. This report also includes two Appendixes (Volume II) which provide a step-by-step description of all procedures, assumptions and methodologies used to develop the 1979 DRB reserve estimates.

2. THE EASTERN STATES

2. THE EASTERN STATES

A. Introduction

This chapter reviews the methodologies, assumptions and procedures used to prepare the 1979 reserve estimates for those coal-bearing states lying in the eastern half of the United States. The reason for presenting this discussion in two parts is based primarily on the way in which the 1979 DRB was prepared. That is, state reserve estimates were prepared by EIA Regional Offices based on geographic location. While uniform national standards are applied in estimating coal resources, some regional variations to established criteria must be considered. These variations can be better discussed and understood within the context of a relatively small geographic unit such as a state or region, as opposed to the nation as a whole.

For the most part, DRB classification criteria are based on coal characteristics such as rank, thickness and depth, as well as economic factors that influence mining feasibility. According to the global criteria put forth by EIA, coal reserves included in the DRB must be at least 28 inches thick (60 inches if the coal rank is subbituminous or lignite) and lie at depths no greater than 1,000 feet. Surface mineable reserves include those coal deposits found within 200 feet of the surface.

Some of the important deviations from global criteria prevalent in the eastern portion of the U.S. fall into two basic categories: (1) inclusion of coal seams lying at depths greater than 1,000 feet, and (2) the inclusion of some coal in the 14" to 28" thickness category. Deep coal (coal found at a depth greater than 1,000 feet) is included in the DRB estimates for Alabama and Virginia. In-place quantities of thinner seams of bituminous coal are included in the DRB estimates for seven of the 13 eastern coal-bearing states.

The following sections of this chapter describe the procedures used to develop the 1979 DRB estimates for each of the eastern states.

B. Alabama Methodology Summary

The estimated 1979 DRB for bituminous coal and lignite in Alabama is 6.7-million-tons. This is an increase of about 3.6-million-tons over the 1976 published estimate. The reason for this increase can be traced to a recent statewide resource evaluation conducted by the Geological Survey of Alabama (GSA) under a U.S. Department of Energy grant.¹ The product of this study consisted of 9 tables which presented original resources, remaining resources (as of January 1978), and 1978 DRB estimates for the Warrior, Plateau and Cahaba fields. The data in these tables were presented by county, bed, reliability category (measured and indicated), bed thickness category (14"-28", 28"-42" and greater than 42"), and potential mining method (strip, covering those reserves under less than 120' of overburden, and underground, covering reserves in the 120'-1,000' and 1,000'-2,000' depth range).

To calculate a January 1978 DRB using EIA's standards, state total DRB estimates for surface and underground mining, excluding the 14"-28" underground reserves, were calculated. The estimates included strippable coal (0-120' overburden depth) greater than 14" thick in the measured and indicated reliability categories, and underground coal (120'-1,000' deep) greater than or equal to 28" thick in the same reliability categories. Also, measured and indicated reserves of the Mary Lee bed in Jefferson and Tuscaloosa Counties, and the Pratt bed in Tuscaloosa County, greater than 42" thick at depths of 1,000'-2,000' (and 2,000'-3,000' for the Mary Lee bed in Tuscaloosa County) were included in the

¹Geological Survey of Alabama, Preliminary - Reserve Base of Bituminous Coal and Lignite in Alabama, U.S. Bureau of Mines, Grant Agreement G177080, later administered by U.S. Department of Energy, 1980.

calculated DRB estimates because these seams are currently being mined. Finally, 5.23-million-tons of underground reserves and 3.20-million-tons of surface reserves in the Coosa coal field (which was not included in the GSA study) were included in the DRB estimate.

The Coosa field estimates were based on W. C. Culbertson's Geology of the Coal-Bearing Rocks of Alabama,² with additional information from H. E. Rothrock's Geology and Coal Resources of the Northeastern Part of the Coosa Coal Field, St. Clair County Alabama.³

The Culbertson report presented resource estimates according to standard DRB criteria. The resource data in Rothrock, however, were given in thickness categories of 14"-20" and greater than 20". The exact methodology used to adjust the Rothrock data is unclear. Also, neither report gave strippable reserves. EIA developed an estimate of the strippable portion based on core log data in Rothrock. However, the methodology employed for assigning the resources to thickness, reliability and mining method could not be determined.

Using the GSA, Culbertson and Rothrock data, a remaining bituminous coal reserve estimate as of January 1978 was computed. EIA and Alabama coal production records were then used to determine the amount of coal mined in 1978 by mining method. Depletion factors of 2.00 and 1.25 for underground and surface production respectively were employed. This resulted in a total 1978 depletion of 16.22-million-tons for surface mining and 11.30-million-tons for underground. Applying the 1978 depletion estimates to the 1978 remaining reserve estimates resulted in the following:

²Culbertson, W. C., Geology of the Coal-Bearing Rocks of Alabama, U.S. Geological Survey Bulletin 1182-B, 1964.

³Rothrock, H. E., Geology and Coal Resources of the Northeast Part of the Coosa Coal Field, St. Clair County, Alabama, Geological Survey of Alabama Bulletin 61, 1949.

Surface:

1993.28 million tons 1978 DRB
- 16.22 depletion
1977.06 million tons calculated 1979 DRB, as compared with
1977.10 published 1979 DRB

Underground:

3711.26 million tons 1978 DRB
- 11.30 depletion
3699.96 million tons calculated 1979 DRB, as compared with
3699.74 published 1979 DRB

The 1979 lignite reserve estimates were based solely on the work of Shotts.⁴ This work provided remaining strippable resources by county, reliability category (measured, indicated, and inferred) and bed thickness category (2.5'-5', 5'-10', greater than 10'). The published 1979 DRB estimate of 1,083-million-tons represents the sum of all remaining reserves in the measured and indicated reliability categories and all seam thickness categories. This deviates somewhat from standard DRB criteria in that lignite reserves less than 60" thick were included in the DRB.

The Shotts resource estimates were not depleted since there was no lignite production between 1971 and 1979.

⁴Shotts, R. Q., Unpublished calculations on lignite resources in Alabama, Department of Mining Engineering, University of Alabama, Tuscaloosa; File data of the U.S. Bureau of Mines, Pittsburgh, PA, 1973.

C. Georgia Methodology Summary

The 1979 DRB for Georgia was developed directly from Johnson (1946)⁵ for Walker and Dade counties, and from the Department of Natural Resources (DNR) for Chattooga County.⁶

Walker and Dade Counties, covered by Johnson, were originally estimated to contain 3.3 million tons of surface and underground mineable coal that met DRB criteria. The reserve figures presented in Johnson did not conform to standard DRB seam thickness criteria. Therefore, it was necessary to estimate the amount of reserves falling within DRB criteria using linear interpolation and extrapolation of Johnson's reserve figures. These reserves were depleted to January, 1979 by using production data from BOM Yearbooks and EIA annual production reports. The total depleted from these two counties to January 1979 was 0.58 million tons.

Chattooga County, estimated by the Georgia DNR, contained 1.8 million tons of strippable coal averaging 14 inches in thickness. This was split in half as an estimate of the reserves over 14 inches thick. Therefore, the Chattooga County reserves of January, 1979 were identified as 0.90 million tons.

The 1979 DRB for Georgia, therefore, can be expressed as follows:

3.33	million tons (Original Walker and Dade County estimates)
-0.58	Depletion of Walker and Dade County reserves to January, 1979
+0.90	million tons (Chattooga County reserves)
3.65	million tons 1979 DRB

⁵Johnson, V.H., Coal Deposits on Land and Lookout Mountains, Dade and Walker Counties, Georgia, Preliminary Coal Inventory Map published by the U.S. Geological Survey, 1946. Reprinted 1959.

⁶Georgia Department of Natural Resources, Surface Mined Land Reclamation Program Report, 1978.

D. Illinois Methodology Summary

The 1979 DRB is based primarily on bed/county level data obtained from Cady's Mineable Coal Resources of Illinois⁷ report. Additional data from Illinois State Geological Survey (ISGS) Circulars⁸ were employed

⁷Cady, G. E., Mineable Coal Resources of Illinois: Illinois State Geological Survey Bulletin 78, 1952.

⁸Clegg, K. E., Surface Geology and Coal Resources of the Pennsylvanian System, Sangamon, Macon, Menard and parts of Christian and Logan Counties, Illinois State Geological Survey Circular 312, 1961.

Clegg, K. E., Surface Geology and Coal Resources of the Pennsylvanian System in Clark and Edgar Counties, Illinois, , Illinois State Geological Survey Circular 380, 1965.

Hopkins, M. E., Harrisburg (Number 5) Coal Reserves of Southeastern Illinois, Illinois State Geological Survey Circular 431, 1968.

Reinersten, D. L., Strippable Coal Reserves of Illinois, Part 4, Adams, Brown, Calhoun, Hancock, McDonough, Pike, Schuyler and the southern parts of Henderson and Warren Counties, Illinois State Geological Survey Circular 374, 1964.

Searight, T. K., and Smith, W. H., Strippable Coal Reserves of Illinois, Part 5B, Mercer, Rock Island, Warren and parts of Henderson and Henry Counties, Illinois State Geological Survey Circular 439, 1969.

Smith, W. H., Strippable Coal Reserves of Illinois, Part 1, Gallatin, Hardin, Johnson, Pipe, Saline and Williamson Counties, Illinois State Geological Survey Circular 22, 1957.

_____, Strippable Coal Reserves of Illinois, Part 2, Jackson, Monroe, Perry, Randolph and St. Clair Counties, Illinois State Geological Survey Circular 260, 1958.

_____, Strippable Coal Reserves of Illinois, Part 3, Madison, Macoupin, Jersey, Greene, Scott, Morgan and Cass Counties, Illinois State Geological Survey Circular 311, 1961.

_____, Strippable Coal Reserves of Illinois, Part 6, LaSalle, Marshall Counties, Illinois State Geological Survey Circular 419, 1968.

Smith, W. H., and Berggren, D. J., Strippable Coal Reserves of Illinois, Part 5A, Fulton, Henry, Knox, Peoria, Stark, Tazewell and parts of Bureau, Marshall, Mercer and Warren Counties, Illinois State Geological Survey Circular 348, 1963.

in the development of the estimates for some of the counties. Finally, a set of calculation sheets developed by the ISGS and containing revisions to the Cady report estimates were employed to update the Cady estimates. An example of the use of these source documents to determine the 1971 No. 6 seam/Bureau County surface and underground estimates is provided by the following paragraph.

First, the No. 6 seam/Bureau County surface estimate was developed on the basis of data contained in Table 7 of Circular 348. Exhibit 1 summarizes the data obtained from Table 7. By summing the Exhibit 1 data across the relevant thickness/reliability categories the January 1971 reserve estimate was obtained. The No. 6 seam/Bureau County total reserve estimate was obtained from the Cady addendum. Since this addendum presents only a single total for each bed/county combination, it was necessary to employ the original Cady report to distribute the total to thickness and reliability categories. The percentages of the total No. 6 seam/Bureau County reserves falling in each thickness/reliability category, calculated from the Cady report, were applied to the total reserve estimate from the Cady addendum; Exhibit 2 presents the results. The 1971 underground reserve estimate was then determined by subtracting the Exhibit 1 data from the Exhibit 2 data, and summing across the relevant thickness/reliability categories. Depletion to 1979 was based on BOM/EIA production data, to which depletion factors of 2 for underground mining and 1.25 for surface mining were employed.

It should be noted that the DRB for Illinois includes all coal resources from the ISGS reliability categories I-A and I-B. While not matching exactly EIA's "measured" and "indicated" categories, they have been equivocated to EIA standards due to the high level of consistency of Illinois coalbeds.

A flowchart of the Illinois DRB methodology, which includes the logic for both the 1971 and 1979 DRBs, is provided by Figure 1.

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		Depth Range 0 to 1,200 Feet; Strip 0 to Feet														
Coal Bed Name	Code Number	Measured			Indicated			Inferred			Measured and Indicated			Total		
		14"-28"	28"-42"	> 42"	14"-28"	28"-42"	> 42"	14"-28"	28"-42"	> 42"	14"-28"	28"-42"	> 42"	14"-28"	28"-42"	> 42"
No. 7 348 (59)	480	0	27.72	15.29	0	100.87	42.42	105.72	61.15	0.00	10.38	60.56	0.00	116.10	250.30	57.71
No. 6 348 (59)	484	0	7.57	91.28	0	15.86	135.47	0.00	132.45	103.46	0.00	0.00	161.10	0.00	155.80	491.31
No. 2 78 (50)	496	0	266.55	161.16	0	135.00	30.25	0.00	628.83	0.00	0.00	0.00	0.00	0.00	1,030.30	191.41

Figure 1. Illinois DRB Methodology
(Some exceptions exist for selected counties)

E. Indiana Methodology Summary

The development of the 1979 DRB for Indiana consisted of a three step process using data developed by both the Indiana Geological Survey (IGS)^{9,10} and the U.S. Geological Survey (USGS).¹¹ Total resources were developed by IGS (as of January 1965) for each Indiana bed/county combination and formed the basis for the 1979 DRB. In general, the January 1965 bed/county surface and total resources were depleted to 1971 based on mine-level production records obtained from IGS. Once this was completed, the total strippable resources were subdivided by reliability (measured, indicated and inferred) and thickness (14"-28", 28"-42" and greater than 42") category using the Preliminary Coal Maps developed by IGS and the USGS report. This procedure yielded the bed/county total and surface resources on which the 1979 DRB was based.

Strippable reserves¹² in the 14"-28", 28"-42", and greater than 42" thickness categories, and measured and indicated reliability categories, were summed across all bed/county combinations to yield a total state reserve estimate as of January 1971, which was depleted to derive the 1979 DRB. Total reserves in the 28"-42" and greater than 42" thickness categories, and measured and indicated reliability categories, were also summed across all county/bed combinations. From the result, the total state strippable reserves in the 28"-42" and greater than 42" measured and indicated categories were subtracted to yield the total

⁹Weir, C.E., Coal Resources of Indiana, Indiana Geological Survey, Bulletin 42-1, 1973.

¹⁰Preliminary Coal Maps, Indiana Geological Survey, PCM 1 through PCM 15.

¹¹Spencer, F.D., Coal Resources of Indiana, U.S. Geological Survey, Circular 226, 1953.

¹²Strippable coal consists of coal less than 60 feet deep for some seam/county combinations, and less than 90 feet deep for others.

January 1971 underground reserves. This total was depleted to yield the 1979 DRB. Depletion was accomplished by accumulating production for the years 1971-1978 using EIA production records and applying standard depletion factors of 2.00 and 1.25 for underground and surface mined coal respectively.

In summary, the IGS report provided total resources by bed and county. Total resources were then divided by reliability category and an estimate of strippable resources was obtained using IGS Preliminary Coal maps. Lastly, the resource base was further divided into seam thickness categories using distribution percentages calculated from the USGS report. By summing across all DRB reliability and seam thickness categories a remaining reserve base (as of January 1971) was derived, which was then depleted to 1979.

F. Eastern Kentucky Methodology Summary

The 1979 published demonstrated reserve base for Eastern Kentucky was derived simply by depleting the 1971 DRB using state level coal production data maintained by EIA. The major development of Eastern Kentucky reserve estimates was performed as part of the 1971 DRB effort.

The 1971 DRB for the Eastern Kentucky coal region was derived from the original resource estimates of Huddle¹³ for all but five counties. These other five counties were covered by "Dowd Reports,"¹⁴ and were incorporated into the anticipated Huddle work. For these five counties

¹³Huddle, J. W., Lyons, E. L., Smith, H. L., and Fenn, J. C., Coal Reserves of Eastern Kentucky, U.S. Geological Survey Bulletin 1120, 1963.

¹⁴The term "Dowd Reports" refers to a series of BOM reports prepared by J.J. Dowd and others on coking coals throughout Appalachia.

the remaining reserves were calculated as of the year identified, (i.e., Floyd: January, 1949; Harlan: January 1952; Knott: January, 1950; Letcher: January, 1952; and Pike: January, 1948.

Depletion of the original resource to the January, 1971 resource base was achieved by using various production sources. Pre-1955 production was obtained from the Kentucky Department of Mines and Minerals Annual Reports on a bed and county basis. Production from January 1955 to January 1971 came from BOM microfilm files and BOM Minerals Yearbook figures.

In terms of estimating the proportion of reserves available for surface mining, neither the Huddle or Dowd reports provided significant information on depth of cover. It appears that the strippable resource estimates for the January, 1971 resource base were simply a straight percentage of the total resource by bed. It is unclear, however, how the percentages were derived.

All in all, the methodology used to prepare the 1979 DRB for eastern Kentucky was straightforward, consisting of a review of the 1971 DRB procedure and depletion based on state-level production records for the years 1971 through 1978. There are questions, however, as to the bed/county accuracy of the 1971 DRB numbers and the estimation of strippable reserves.

G. Western Kentucky Methodology Summary

The methodology used to derive the Demonstrated Reserve Base of Coal in western Kentucky is based simply on the depletion of resource estimates provided by Smith and Brant.¹⁵ The report prepared by Smith

¹⁵Smith, G. E., and Brant, R. A., Western Kentucky Coal Resources, Kentucky Geological Survey, University of Kentucky, 1980.

and Brant provided original resource information by bed, county, thickness category, reliability (Class I, Class II, Class III), and overburden thickness (0 to 150 feet and greater than 150 feet). Exhibit 3 provides an example of the county summary information given in the report.

In developing the baseline DRB reserve estimates, two steps were taken-- the reliability classification of Smith and Brant was compared against, and taken as the equivalent of, the DRB categories (Class I equals measured, Class II equals indicated, and Class III equals inferred), and all coal under less than 150 feet of cover was placed in the strip-pable category.

Depletion of western Kentucky resources was conducted in two stages: the first covering the period 1790 through 1975 using information provided by the Kentucky Geological Survey; the second covering the period 1976 through 1979 using EIA production statistics.

The Smith and Brant report contained a table (Exhibit 4) listing total depletion ("Mined and Lost") by county through 1975. Subsequent to this report Brant and Hester¹⁶ published a production summary for the western Kentucky coal field covering the same time period (Exhibit 5). It appears that the Brant and Hester data were used for depletion purposes.

As shown by Exhibit 5, the Brant and Hester handout summarized production in three basic categories: undifferentiated, surface, and underground. To establish depletion EIA field office personnel assumed that the undifferentiated production was split 60 percent underground,

¹⁶Brant, R. A., and Hester, N. C., Coal Resources of Kentucky, Kentucky Geological Survey, 1980 Handout.

Exhibit 3. Western Kentucky Coal Resources

County Summaries

(Coal Resources in Thousands of Tons)

TOTALS					0-150' OVERBURDEN CATEGORY				150' + OVERBURDEN CATEGORY			
TOTALS					TOTALS				TOTALS			
14-28" 28-42" 42"+					14-28" 28-42" 42"+				14-28" 28-42" 42"+			
BRECKINRIDGE COUNTY												
R. CLASS I	10	10			10	10						
II	0	0			0	0						
III	258	258			258	258						
TOTAL	268	268			268	268						
BUTLER COUNTY												
R. CLASS I	73,870	25,145	33,857	14,868	69,312	24,653	30,284	14,375	4,558	492	3,573	493
II	112,221	30,820	57,374	24,027	100,115	29,106	50,013	20,998	12,106	1,714	7,361	3,031
III	227,601	55,746	79,685	92,170	152,579	46,409	61,124	45,046	75,022	9,337	18,561	47,124
TOTAL	413,692	111,711	170,916	131,065	322,006	100,168	141,421	80,417	91,686	11,543	29,495	50,648
CALDWELL COUNTY												
R. CLASS I	7,229	0	2,169	5,060	7,229	0	2,169	5,060	0	0	0	0
II	23,182	1,618	6,386	15,278	22,459	1,446	6,386	14,627	723	72	0	651
III	36,965	361	21,688	14,916	32,941	289	21,086	11,566	4,024	72	602	3,350
TOTAL	67,376	1,879	30,243	35,254	62,629	1,735	29,641	31,253	4,747	144	602	4,001
CHRISTIAN COUNTY												
R. CLASS I	63,151	2,421	29,615	31,115	63,151	2,421	29,615	31,115	0	0		
II	2,521	1,523	998	0	2,476	1,478	998	0	45	45		
III	5,048	3,120	1,928	0	4,991	3,063	1,928	0	57	57		
TOTAL	70,720	7,064	32,541	31,115	70,618	6,962	32,541	31,115	102	102		
CRITTENDEN COUNTY												
R. CLASS I	8,291	867	6,988	436	8,291	867	6,988	436	0		0	
II	12,728	1,541	8,265	2,922	12,295	1,541	7,832	2,922	433		433	
III	20,615	506	14,880	5,229	20,615	506	14,880	5,229	0		0	
TOTAL	41,634	2,914	30,133	8,587	41,201	2,914	29,700	8,587	433		433	

Exhibit 4. Western Kentucky Coal Field Data by County
(Thousands of Short Tons)

	TOTALS	MINED & LOST	REMAINING
BRECKINRIDGE COUNTY	268	0	268
BUTLER COUNTY	413.692	9.058	404.634
CALDWELL COUNTY	67.376	236	67.140
CHRISTIAN COUNTY	70.720	7.375	63.345
CRITTENDEN COUNTY	41.634	0	41.634
DAVISS COUNTY	1,330.323	22.500	1,307.823
EDMONSON COUNTY	159.607	1.214	158.393
GRAYSON COUNTY	105.038	181	104.857
HANCOCK COUNTY	170.276	2.702	167.574
HENDERSON COUNTY	6,852.765	32.114	6,820.651
HOPKINS COUNTY	8,814.801	879.702	7,935.099
MCLEAN COUNTY	3,576.413	22.876	3,553.537
MUHLENBERG COUNTY	4,723.837	981.488	3,742.349
OHIO COUNTY	1,824.572	220.545	1,604.027
UNION COUNTY	6,506.974	124.460	6,382.514
WARREN COUNTY	8.148	96	8.052
WEBSTER COUNTY	6,322.849	58.184	6,264.665
WESTERN KENTUCKY COAL FIELD TOTAL	40,989.293	2,362.731	38,626.562

Exhibit 5. Production Summary for the Western Kentucky Coal Field,

1970-1975

(in Short Tons)

County	Undifferentiated		Surface 1890-1975	Underground 1890-1975	Total Production 1790-1975
	1790-1889*	1890-1975			
Breckinridge	75,000				75,000
Butler	226,524	345,899	3,384,489	3,373,648	7,330,560
Caldwell			117,903		117,903
Christian	210,172	2,310,477	1,411,254	2,511,725	6,443,628
Crittenden	301,418	10,613	63,935	141,768	517,734
Daviess	920,500	1,279,733	22,805,847	6,744,839	31,750,919
Edmonson	178		705,822	165,364	871,364
Grayson	892		634,573	5,000	640,465
Hancock	783,970	426,674	1,427,360	661,156	3,299,160
Henderson	928,817	6,182,446		15,016,521	22,127,784
Hopkins	4,853,557	60,554,978	165,677,798	283,352,889	514,439,222
McLean	840,179	2,589,623	5,047,186	1,913,414	10,390,402
Muhlenberg	2,397,465	51,764,430	300,987,395	184,648,222	539,797,512
Ohio	1,792,048	19,196,891	100,139,178	38,028,718	159,156,835
Todd	530				530
Union	1,900,567	14,817,040	1,936,580	109,131,887	127,786,074
Warren	24,155		2,000		26,155
Webster	184,051	22,172,608	15,320,760	53,040,757	90,718,176
TOTAL	15,440,023	181,651,412	619,662,080	698,735,908	1,515,489,423

* Separated from later undifferentiated production figures because of numerous estimates.

40 percent surface. A second assumption was then made, that all underground production would be depleted based on a recovery factor of 55 percent.

Depletion for the years 1976 through 1978 was computed using EIA annual production records for western Kentucky as a whole. Unlike depletion through 1975, underground depletion for these three years was based on a recovery factor of 50 percent. Surface depletion for all years was based on 80 percent recovery.

The final derivation of the published DRB was simply the sum of all Class I and II resources greater than 28 inches as presented by Smith and Brant minus the calculated depletion for the period 1790 through 1978.

H. Maryland Methodology Summary

The 1979 DRB is based on data contained in Wallace, et. al., (1953)¹⁷ along with information from Averitt (1975).¹⁸ Wallace presented his estimates by basin (coalfield) while Averitt summarized the same reserves by basin and by county, (either Allegheny or Garrett counties).

Also from the Averitt report, a percentage breakdown of the coal falling in each of the five Maryland coal basins was obtained. The breakdown is as follows:

¹⁷Wallace, J. J., Dowd, J. J., Williams, L., Abernethy, R. F., and Reynolds, D. A., Estimate of Known Recoverable Reserves of Coking Coal in Allegheny County, Maryland, U.S. Bureau of Mines Report of Investigations 4970, 1953.

¹⁸Averitt, Paul, Coal Resources of the United States, January 1, 1974, U.S. Geological Survey Bulletin 1412, 1975.

Georges Creek Basin	50%
Upper Potomic Basin	20%
Castliman Basin	15%
Upper Youghiogheny Basin	5%
Lower Youghiogheny Basin	10%

Averitt suggested that 75 percent of the coal contained in the Georges Creek Basin occurs in Allegheny County, while the remainder occurs in Garrett County (the only other coal-bearing county in Maryland). The other four basins, according to Averitt, fall entirely within Garrett County. To determine the total resources in the Georges Creek Basin (in both Allegheny and Garrett counties), the Allegheny County total resource estimate of 730.1 million tons was divided by 0.75, yielding 973.47 million tons. To obtain the total resources for the state, the 973.47-million-ton figure was divided by 0.5, since Averitt has estimated that 50 percent of the resources in the state occur in the Georges Creek Basin. The total state resource estimate of 1,946.94 million tons was then re-distributed to the five Maryland coal basins according to Averitt's percentage breakdown given above. This resulted in a resource base as of January 1951.

To subdivide the basin resource estimates by mining method, 10 percent of each basin estimate was assumed to be amenable to surface mining, while 90 percent was left for underground mining. The 10/90 split was based upon professional judgment, and was developed by considering the structure, shape and relief of the coal basins, and by observing that all identified resource coal beds crop out.

To arrive at the reserve estimates from which depletion was taken, the coal reserves falling within DRB criteria were totaled based on the same proportions found in the Wallace report. Depletion of the January 1951 reserve estimates was based on production data obtained from the annual reports of the Maryland Bureau of Mines (for the period 1951-1955), BOM annual reports (for the period 1955-1970), and the DOE computer tapes (for the period 1971-1978). The cumulative underground depletion

was obtained by multiplying the 1951-1978 underground production by 2.00, while the cumulative surface depletion was determined using a depletion factor of 1.25. The results were 36.26 million tons of surface depletion, and 16.34 million tons of underground depletion.

Figure 2 illustrates the general flow of work for the Maryland DRB.

I. Michigan Methodology Summary

The 1979 DRB was developed from data in a U.S. Geological Survey coal resource estimate of 1950 by Cohee and others.¹⁹ These data were modified for subsequent coal production and information on additional measured resources in the Kalliokoski study (1976).²⁰ For the DRB it was judged reasonable to assign the thickness categories for the indicated and inferred resources in the same proportion as in the measured resource. The 50-to-100 feet overburden depth was considered to be the surface mineable demonstrated reserve base.

Production and depletion of Michigan coal reserves were also taken from Cohee, et. al. (1950). Table 6, page 56 of Cohee supplied the production from 1860 to 1949 on a state level. Depletion was assumed at 40 percent production based on the Cohee (1950) study. There has been no appreciable production since 1950 in Michigan.

¹⁹Cohee, G. V., Burns, R. N., Brown, A., Bront, R. A., and Wright, D., Coal Resources of Michigan, U.S. Geological Survey Circular 77, 1950.

²⁰Kalliokoski, J., Magnitude and Quality of Michigan's Coal Reserves, U.S. Bureau of Mines Open File Report 102-76, 1976.

Figure 2. Flowchart of Maryland DRB

The 1979 DRB can be derived by applying the following methodology:

8.33 (million tons of Saginaw Co. reserves; Kalliokoski, 1976)
-0.02 million tons (1950-52 production not previously depleted;
Kalliokoski, 1976)
8.31 million tons
119.39 million tons (Cohee et. al., 1950 Tables 4, 5 & 6)
122.70 published 1979 DRB

J. North Carolina Methodology Summary

The derivation of the 1979 DRB in North Carolina is based entirely on the work of Reinemund.²¹ The majority of information used to derive the 1979 DRB came from two tables prepared by Reinemund, shown here as Exhibits 6 and 7. To use the information presented in these tables two basic problems had to be overcome:

- A methodology had to be derived to convert the Reinemund seam thickness categories and average thicknesses to standard DRB criteria (14" to 28", 28" to 42", and greater than 42").
- A methodology had to be derived to split the Reinemund resources figures reported at depths from 0 to 2,000 feet to the DRB criterion of 0 to 1,000 feet.

In terms of the seam thickness categories the following approach was followed:

- All coal shown in Exhibit 7 as having an average thickness of 15, 18, 20, and 21 inches was placed in the 14 to 28 inch category along with 50 percent of the coal listed as having an average height of 28 inches.

²¹Reinemund, J.A., Geology of the Deep River Coal Field of North Carolina, USGS Professional Paper 246, 1955.

Exhibit 6. Reserves of Coal in the Deep River Coal Field,
Chatham, Lee, and Moore Counties, North Carolina
(in Thousands of Short Tons)

Bed, reserve class, and overburden	Range in thickness (inches)	Area (acres)	Estimated original reserves	Mined and lost in mining, Jan. 1, 1950	Remaining reserves, Jan. 1, 1950	Recoverable reserves, Jan. 1, 1950 (assuming 50 percent recovery)
Cummock:						
Measured:						
0-2,000.....	> 36	1,494	20,934	1,574	19,360	9,680
	28-36	2,483	9,037	13	9,022	4,511
	14-28	770	2,399	31	2,368	1,184
2,000-3,000.....	> 36	199	1,183	0	1,183	592
	28-36	149	805	0	805	402
Indicated:						
0-2,000.....	> 36	1,136	6,787	0	6,786	3,393
	28-36	813	1,463	0	1,463	732
	14-28	6,921	20,724	0	20,724	10,362
2,000-3,000.....	> 36	1,285	7,302	0	7,302	3,651
	28-36	1,090	4,923	0	4,923	2,462
	14-28	494	2,055	0	2,055	1,027
Inferred: 0-2,000.....	14-28	8,195	22,373	0	22,373	11,187
Total			101,969	1,620	100,348	50,185
Gulf:						
Measured: 0-2,000.....	14-28	1,767	5,306	1	5,305	2,653
Indicated: 0-2,000.....	14-28	2,065	4,664	0	4,664	2,332
Total			9,970	1	9,969	4,985
Grand total			111,939	1,621	110,317	55,170
Total in beds:						
36 inches or more.....			36,204	1,574	34,631	17,316
28-36 inches.....			18,628	13	18,613	9,307
14-28 inches.....			57,125	32	57,093	28,547

¹ Includes 8,469 thousand tons averaging 42 inches in thickness.

Exhibit 7. Thickness and Original Reserves of Coal by Areas

Beds	Area No.	Thickness (inches)	Estimated original reserves (thousands of short tons)		
			Bituminous	Anthracite and coke	Total
Cummoek	1.....	30	5,366		5,366
	2.....	42	5,796	64	5,860
	3.....	28	3,881	228	4,109
	4.....	32	3,215	396	3,611
	5.....	36	805		805
	6.....	40	5,121	58	5,179
	7.....	32	2,809		2,809
	8.....	42	1,573	210	1,783
	9.....	40	1,183		1,183
	10.....	38	2,255	278	2,533
	11.....	40	6,412	374	6,786
	12.....	38	7,142	160	7,302
	13.....	30	839	2,796	3,637
	14.....	20	247	808	1,051
	15a.....	30	1,829	2,034	3,863
	15b.....	21	2,841	4,268	8,107
	16.....	21	236	280	496
	17.....	15	117	130	247
	18.....	18	202	224	426
	19.....	18	7,620	940	8,560
	20.....	18	19,915	2,458	22,373
	21.....	18	2,855	560	3,415
	22.....	18	202	224	426
Total Cummoek bed.....			85,519	16,470	101,989
Gulf	1 (part).....	18	1,343		1,343
	1 (part).....	15	1,118		1,118
	2.....	15	2,066	24	2,090
	4 (part).....	24	1,202	148	1,350
	4 (part).....	15	782	22	844
	6 (part).....	24	1,552	16	1,568
	6 (part).....	15	972	10	982
	8 (part).....	15	637	38	675
Total Gulf bed.....			9,642	328	9,970
Grand total.....			95,161	16,798	111,959

- All 30- 32- 36- and 40-inch coal was placed in the 28" to 42" category, plus 50 percent of the 28-inch coal and 60 percent of the 42-inch coal.
- The remaining 40 percent of the 42-inch coal was considered as having a seam height greater than 42 inches.

To further divide the resource base defined by Reinemund into depth-of-cover categories of 0 to 1,000 feet and greater than 1,000 feet, the coalfield maps presented in the Reinemund report were completely reviewed. Based on this review an estimate of the percent of the total resource lying within 1,000 feet of the surface was made for each coal bed area. This breaks down from as little as 3.5 percent of the identified resource (area 11, Exhibit 7) to as much as 100 percent for areas 14, 16, 17, 18, and 22.

Once the Reinemund estimates were adjusted to reflect standard DRB classifications, the resource estimates were depleted using production data through 1952, the last year of reported production.

Production records from 1852 through 1949 were taken directly from Reinemund. Depletion for this period was computed using a factor of approximately 1.52, based on Reinemund's estimates of recovery. Production for 1949 through 1952 came from BOM production reports. For the years 1950 and 1951 it was necessary to adjust the BOM estimates because for these two years the Bureau reported a combined production for both North Carolina and Georgia. During these years combined production was reported as 41.9 and 26.6 thousand tons. The North Carolina production was estimated as 21.9 thousand tons in 1950 and 1.6 thousand tons in 1951. Since all reported production in North Carolina came from underground mines during this period depletion was calculated based on a 50 percent recovery factor.

Lastly, it should be noted that the North Carolina resource base as reported by Reinemund includes both anthracite coal and coke. This

resource is small and configured in a manner that makes it uneconomical to mine. However, because of the total configurations of the Deep River Coalfield, about 17 percent of the anthracite resource was included in the DRB (this coal was classified as bituminous).

K. Ohio Methodology Summary

Simply stated, the 1979 DRB for Ohio was derived by depleting original bed/county resource estimates developed by Brant and Delong²² from 1800 through 1978. However, as part of this overall process several adjustments had to be made to the Brant and Delong data in order to adjust the resource estimates to meet standard DRB reliability and seam thickness criteria, and to estimate strippable reserves.

Brant and Delong provided original resource estimates, by county and bed, for proven, probable and inferred reliability categories, and for 14"-28", 28"-54" and greater than 54" thickness categories. Reserves unclassified as to reliability and thickness are also presented. For the derivation of the 1979 DRB the proven reliability category was taken as being equivalent to EIA's measured category, and the probable category was deemed equivalent to the EIA indicated category. The resources presented as "unclassified" in the Brant and Delong report were not distributed to other reliability or thickness categories. Those resources for which a reliability category was known were reassigned to the standard DRB thickness categories of 14"-28", 28"-42" and greater than 42". This reassignment was accomplished by reviewing the numerous sources used to prepare the original Brant and Delong report to identify detailed bed/county seam thickness estimates.

²²Brant, R. A., and Delong, R. M., Coal Resources of Ohio, Ohio Division of Geological Survey Bulletin 58, 1960.

Since the Brant and Delong report estimated original resources, some method of depleting the estimates to January 1979 was required. This was accomplished in three steps. First, using unpublished bed/county BOM reserve records,²³ the Brant and Delong resource estimates were depleted to January 1969 (the BOM estimates were subtracted from the Brant and Delong estimates to determine depletion). These "new" estimates were updated to January 1971 using production data from the BOM and the Ohio Division of Mines. Then, to distribute the depletion to the measured and indicated reliability categories and the thickness categories of 14"-28", 28"-42" and greater than 42", the total bed/county depletion was assigned to the standard DRB reliability/thickness categories in proportion to the Brant and Delong resources in each category. Two exceptions to this general proportioning scheme were:

- If evidence indicated that a coalbed had never been surface-mined, no depletion was assigned to the 14"-28" thickness category.
- If depletion in a category equaled the original resource of that category (signifying exhaustion of that category), yet evidence indicated mining currently occurring in that category, then a portion of the depletion (equivalent to annual production x depletion factor x expected years of life remaining in mine in question) was moved from that category to the inferred categories. (Apparently, this was done to "make room" for future depletion of the measured or indicated category in question.)

The final depletion (1971 through 1978) was accomplished using production data from BOM Minerals Yearbooks (1971-1976) and EIA Energy Data Reports (1977 and 1978).

²³These reserve estimates were developed by DeCarlo of BOM.

To split the Brant and Delong estimates into strippable and underground resources a report by Reed²⁴ (updated by Hinkle) was used. However the surface DRB estimate is problematic in that, while it is known that the strippable resource estimates are based on Hinkle's revision to the Reed report, it is not clear how Hinkle made these revisions. Another problem may lie in the methodology used to distribute surface resources to thickness and reliability categories.

In general, this procedure involved distributing the surface resource estimates to reliability and thickness categories based on the proportion of the total resources in each category calculated from the Brant and Delong report.²⁵ If the surface estimate exceeded the total resource estimate in any category, the former figure was reduced to the latter. To obtain the strip resources in the 14"-28", measured and indicated reliability categories, it was assumed that the 14"-28" resources equaled the surface resources divided by the total resources, in each reliability category, multiplied by the total 14"-28" resources in the reliability category.

The Ohio methodology discussed above is presented in graphic form in Figure 3.

L. Pennsylvania Methodology Summary

The 1979 DRB for Pennsylvania is divided into the anthracite reserves of eastern Pennsylvania, and the bituminous reserves of western Pennsylvania. Although the methodologies are similar, different sources and factors provide sufficient contrast to warrant individual treatment.

²⁴Reed, Avery H., The Strippable Coal Reserves of Ohio (January 1, 1968), U.S. Bureau of Mines, Unpublished Report.

²⁵This step was followed using remaining resources as of January 1971.

Figure 3. Ohio Methodology

Pennsylvania Anthracite

The primary source for the 1979 DRB for anthracite was Edmunds (1972),²⁶ who estimated original anthracite resources by county for all coal greater than 14 inches thick.

The basic methodology for obtaining the 1979 DRB hinges on the procedure used to derive the January 1971 DRB. The Edmunds estimate was for a total original resource, and the first step was to deplete the resource figures to January 1971. The 1971 DRB was then all those identified resources which met DRB criteria. The 1979 DRB was the result of depleting the 1971 DRB to January, 1979.

The BOM procedure for obtaining the 1971 resource base rests on the production records contained in the annual state reports of the Pennsylvania Anthracite Division. The production, both strip and underground, was totaled from 1870 to 1971. Depletion was obtained by using the factors of 2.0 for underground, and 1.11 for surface reserves. The 1.11 reflects historical surface depletion factors for anthracite contained in BOM files.

Once the January 1971 resource base by county was obtained, the total county resource base for the anthracite was split. This was done based on the following assumptions made by BOM:

²⁶Edmunds, W. E., Coal Reserves of Pennsylvania -- Total Recoverable and Strippable (January 1, 1970), Pennsylvania Bureau of Topographic and Geological Survey Information Circular 72, 1972.

Depth

- 50% of the county resource -- lies 0-1000'
- 35% of the county resource -- lies 1000'-2000'
- 15% of the county resource -- lies 2000'-3000'

Thickness

- 10% of the reserve (0-1000') is 14"-28"
- 41% of the reserve (0-1000') is 28"-42"
- 49% of the reserve (0-1000') is greater than 42"

Given these assumptions, the new total county resource base for January 1971 was as follows:

County	Original Resource Base ^a	Depletion		January 1971 Resource Base	Revised Resource Base
		Underground	Strip		
Carbon	630.00	390.28	17.38	222.34	111.17
Columbia	615.00	195.14	12.63	407.23	203.62
Dauphin	870.00	63.53	0.35	806.12	403.06
Lackawanna ^b	2,030.00	1,461.26	24.52	544.22	408.17
Lebanon	1,000.00	--	0.21	999.79	499.90
Luzerne ^b	4,525.00	3,521.55	83.28	920.17	690.15
Northumberland	2,600.00	951.18	39.74	1,609.08	804.54
Schuylkill	12,130.00	2,457.83	150.60	9,521.57	4,760.76
Sullivan ^c	35.00	13.61	0.34	21.05	21.05
Susquehanna	15.00	14.52	0.53	0.00	0.00
Wayne ^c	10.00	7.26	0.02	2.72	2.72
				15,054.29	7,905.12

^aAll resource figures are in millions of tons.

^bThese counties were split 75/25, instead of 50/50.

^cThese counties retained all their resource tonnage.

Strippable resources for anthracite were developed on a county basis by BOM engineers. These reserve amounts and proportions could not be derived/verified from the source documents by SRC.

Because the strippable reserve was underivable, the reserve estimates of 161.17 million tons could not be documented.

The underground reserve estimate of January 1971 was derived by following BOM thickness criteria of 90 percent (41 percent = 28-42", 49 percent = greater than 42") falling within DRB criteria limits. By subtracting 161 million (strippable reserves) from 7,905 and then multiplying by 0.90, the underground reserve of about 6,975-million-tons can be derived. The reason for assuming that 90 percent of underground resources are greater than 28 inches thick is unclear.

Depletion from January 1971 to January 1979 was relatively straightforward. Depletion was based on the factors of 2.00 and 1.11. The source for the production from 1971 through 1976 was the BOM Minerals Yearbooks, and for years 1977 and 1978, EIA production reports.

Figure 4 shows the general methodology for developing the 1979 anthracite DRB.

Pennsylvania Bituminous

Numerous sources were used to derive the original reserve base of Pennsylvania bituminous coal. They are too numerous to list, (see Volume II) but can be grouped under three major headings, namely:

- The "Dowd" reports, covering Allegheny, Armstrong, Cambria, Clarion, Clearfield, Fayette, Greene, Indiana, Jefferson, Somerset, Washington and Westmoreland counties. The remaining reserves were reported as of the respective publication year.
- USGS Bulletins, used as the primary source in Beaver, Butler and Lawrence Counties. Original reserves were identified.
- Reese and Sisler (1978), used as the primary source in Bedford, Blair, Bradford, Cameron, Centre, Clinton, Elk, Fulton, Huntingdon, Lycoming, McKean, Mercer and Tioga counties. In addition, this report supplemented the Dowd work on selected seams and in estimating the inferred reserves. Resources as of January 1927 were estimated in this report.

Figure 4. Flowchart of Pennsylvania Anthracite

Figure 5 illustrates these sources on a bed and county basis. Strippable reserves were obtained from the 1968 unpublished Avery Reed report, entitled The Strippable Coal Reserves of Pennsylvania.

The "Dowd" reports covered 12 counties and all major seams (i.e., coking coal) within these counties. They estimated coal reserves in standard thickness (14"-28", 28"-42", greater than 42") and measured and indicated categories only. No inferred resources were estimated and not all seams were covered in the Dowd counties. The reserves were estimated as of January of the year indicated in the report.

The USGS Bulletins were used for three counties. Again, reserves were estimated by standard thickness (14"-28", 28"-42", greater than 42") and reliability (measured, indicated, and inferred) categories. However, these bulletins estimated only original resources. Strippable resources were estimated to a depth of 60 feet.

The Reese and Sisler report estimated resources on a bed/county level throughout the state. Unfortunately, the report was based on 1,692 tons/acre-foot, provided estimated resources greater than 18", and gave no reliability categories.

Finally, the Reed report estimated strippable reserves greater than 28 inches. No reliability or thickness categories were given.

To use Reese and Sisler, several manipulations of the data were necessary. First, the resources by bed were multiplied by 1.066 to place the estimates on a standard material density of 1,800 tons per acre-foot. Secondly, the thickness categories of 14"-28", 28"-42", and greater than 42" were graphically derived from source descriptions of each seam. From these manipulations, an original bed resource by thickness was obtained.

Figure 5. Sources for Pennsylvania Estimates

<u>County</u>	<u>Seam</u>	<u>Source</u>	
ALLEGHENY -	REDSTONE PITTSBURGH U. FREEPORT M. KITTANNING L. KITTANNING L. FREEPORT - R&S	} DOWD R&S	DOWD = Dowd Reports R&S = Reese and Sisler USGS = USGS Bulletins
ARMSTRONG -	PITTSBURGH U. FREEPORT L. FREEPORT U. KITTANNING M. KITTANNING L. KITTANNING CLARION MAHONING - UNKNOWN BROOKVILLE - R&S	} DOWD R&S	
BEAVER -	ALL FROM USGS		
BUTLER -	ALL FROM USGS		
CAMBRIA -	ALL FROM DOWD		
CLARION -	U. FREEPORT L. FREEPORT M. KITTANNING L. KITTANNING U. CLARION L. CLARION BROOKVILLE U. KITTANNING - R&S ALTON (MERCER) - R&S	} DOWD R&S	

Figure 5. (Continued)

CLEARFIELD - U. FREEPORT
L. FREEPORT
U. KITTANNING
M. KITTANNING
L. KITANNING
BROOKVILLE

} DOWD

CLARION - UNKNOWN

FAYETTE - WAYNESBURG
SEWICKLEY
PITTSBURGH
U. FREEPORT
REDSTONE
L. KITTANNING
BROOKVILLE

} DOWD

BAKERSTOWN - UNKNOWN

L. FREEPORT - R&S

U. KITANNING - R&S

GREENE - WAYNESBURG
SEWICKLEY
PITTSBURGH

} DOWD

U. FREEPORT - R&S

INDIANA - PITTSBURGH
U. FREEPORT
L. FREEPORT
U. KITTANNING
M. KITTANNING
L. KITTANNING
BROOKVILLE

} DOWD

JEFFERSON - MAHONING
U. FREEPORT
L. FREEPORT
U. KITTANNING
M. KITTANNING
L. KITTANNING
CLARION
BROOKVILLE

} DOWD

Figure 5. (Continued)

LAWRENCE - USGS

SOMERSET - REDSTONE
PITTSBURGH
U. FREEPORT
L. FREEPORT
U. KITTANNING
M. KITTANNING
L. KITTANNING
CLARION
SEWICKLEY - R&S
LITTLE PITTSBURGH - R&S
BAKERSTOWN - UNKNOWN
BROOKVILLE - R&S

WASHINGTON - WASHINGTON
WAYNESBURG
REDSTONE
PITTSBURGH
U. FREEPORT

WESTMORELAND - WAYNESBURG
REDSTONE
PITTSBURGH
U. FREEPORT
L. FREEPORT
L. KITTANNING
SEWICKLEY - UNKNOWN
M. KITTANNING - R&S

The original resource base for each Dowd county was then depleted to January 1971. A standard depletion factor of 2.00 was used. However, production for the period between the Dowd reports (early 1950s) to January 1971 required several stages.

The first stage was to deplete the resources of January 1927, of Reese and Sisler seams, to the same year as the remaining reserves given in the Dowd report. This was done using the Pennsylvania Department of Labor production statistics and a standard depletion factor of 2.00 for underground mining.

Each county was then depleted to January 1971 from production reports prepared by BOM. This depletion was not a strict yearly depletion of coal reserves, but included several shortcuts because of time constraints encountered by BOM staff.

The first shortcut was an "averaging" of 10-year production between the years 1956 to 1965. This was done by adding the 1956 and 1965 production together, dividing by 2 and multiplying by 10. The second shortcut was the "substituting" of production data for 1970 with 1969 production. The reason for this substitution was that the actual production for 1970 was not published. This production was then depleted by using a factor of 2.00 for underground production.

To derive a percentage between "measured", "indicated", and "inferred" from the January 1971 resource total for the Reese and Sisler seams in Dowd counties, a proportion, derived from a Dowd seam split between measured and indicated within the county, was used. This proportion varied from county to county.

The USGS counties estimated original reserves for underground Pennsylvania bituminous. To update these counties to January 1971, it was necessary to deplete the underground reserves by yearly production and the standard depletion factor of 2.00. Sources for this production

included BOM production reports and Pennsylvania Labor Department reports. Again, the production between 1956 and 1965 was averaged, and the 1970 production estimated.

The Reese and Sisler counties were handled somewhat similar to the USGS counties. The resources of January 1927 were depleted to January 1971 by using the production averaging methods between 1956 and 1965, estimating the 1970 production, and using a depletion factor of 2.0. The remaining resources were split, 40/60 (40 percent - measured & indicated, 60 percent - inferred) to derive the reserves as of January 1971.

The strippable reserve estimates for January 1971 were developed by a completely different methodology based on the Reed report (1968), and Edmunds (1972).

The original strippable reserves for Pennsylvania bituminous were identified in Table 4 of Edmunds as 2,272.5 million tons. From this total, the strip coal production to January, 1968 from Reed (Table 1, page 12) of 586.630-million-tons was subtracted to yield a January 1968 figure of 1,685.87-million-tons. (This production figure was not changed to a depleted figure before being used.) From the January 1968 figure, the depleted strip and auger production from 1968 to January 1971 of 90.024 million tons (from U.S. Minerals Yearbooks) was subtracted to yield the January 1971 reserve base of 1,575.85 million tons.

The January 1979 reserve base is a straight depletion of the January 1971 totals. Underground depletion used 2.00 as the depletion factor, while surface depletion used 1.25. Figure 6 illustrates the general methodology for the 1979 DRB.

Figure 6. Flowchart of Pennsylvania Bituminous

M. Tennessee Methodology Summary

The 1979 DRB for Tennessee was derived by depleting the 1971 DRB and revising some county-level reserve estimates based on recently acquired data.

The 1971 demonstrated reserve base for Tennessee is based upon the work of Luther (1959),²⁷ Luther and Johnson (1972),²⁸ and various BOM Reports of Investigations (i.e., "Dowd" reports). This work was modified for the 1979 DRB by a more recent study by Wilson (1979)²⁹ on the Richland and Sewanee seams in 11 Tennessee counties. Figure 7 shows the general progression of the reserve base methodology to 1979.

Resources for six Tennessee counties was estimated by Luther, as of January 1959. The recoverable resource for each seam by county was estimated by Luther by standard reliability (i.e., measured, indicated, and inferred) and thickness categories greater than 28" (28"-42", and greater than 42"), with given recovery factors for each seam. To get the resource as of January 1959, the recoverable tonnage was divided by the corresponding recovery factor for each seam. The five Tennessee counties exempt from this procedure were Anderson, Campbell, Claiborne, Morgan, and Scott. These counties were estimated from the Luther and Johnson report as of January 1968.

²⁷Luther, E. T., The Coal Reserves of Tennessee, Tennessee Department of Conservation and Commerce, Division of Geology, Bulletin 63, 1959.

²⁸Johnson, R. C., and Luther, E. T., Strippable Coal in the Northern Cumberland Plateau Area of Tennessee, Tennessee Department of Conservation, Division of Geology, Report of Investigations 34, 1972.

²⁹Wilson, R. L., Evaluation of the Coal Reserves in the Whitwell Shale in the Southern Cumberland Plateau in Tennessee, Geosciences Department, University of Tennessee at Chattanooga, under U.S. Department of Energy Grant Number DOE-ET-77-G-01-9009, 1979.

Figure 7. General Tennessee Methodology

Luther and Johnson was also used to derive the strippable reserve estimate for Tennessee. The reserves falling within DRB criteria were identified and broken into bed and county categories.

All county reserve estimates were then depleted to January 1971. Underground estimates were depleted from January 1959 or January 1968 to January 1971.

Updating the 1971 DRB to the 1979 DRB was a two-step process, designated as either a "Wilson" or non-Wilson county update.

Deriving the 1979 DRB from the 1971 DRB for the so-called "Wilson" counties required using data from Wilson (1979). The counties under scrutiny by Wilson were:

Bledsoe
Cumberland
Grundy
Hamilton
Marion
Morgan

Rhea
Roane
Sequatchie
Van Buren
White

The object of the Wilson report was to estimate the reserves of two major seams, the Sewanee and Richland.

The basic procedure for the Wilson counties was to take the previous 1971 figures, subtract the identified January 1971 remaining reserves of Sewanee and Richland coals, then add in the new estimates based on Wilson's work to derive a new 1971 reserve base. These counties were then depleted to January 1979.

Non-Wilson counties were directly depleted from January 1971 to January 1979 using BOM and EIA reports.

N. Virginia Methodology Summary

The 1979 DRB is derived from two primary sources, which are Coal Resources of Virginia by Brown, Barryhill, Taylor, and Trumball, USGS Circular 171, 1952, and "The Strippable Coal Reserves of Virginia", by Hinkle, (unpublished) BOM Information Circular. Figure 8 illustrates the procedure used to arrive at the 1979 DRB for Virginia.

The USGS Circular 171 gives total resources as of January 1951. This report lists resources by county and coalbed, by thickness (14 to 28 inches, 28 to 42 inches, and over 42 inches), and by reliability category (measured, indicated, and inferred). Circular 171 does not differentiate between strippable and underground resources. To determine the strippable resource, the BOM Information Circular by Hinkle was used.

Both the bituminous and anthracite DRB figures for 1979 were re-developed from the 1971 DRB and the original source documents. The first step in this process was to re-estimate the Brown figures for identified coal resources as of January 1951. This was done to account for new information (Hinkle and Island Creek Coal Company reserve data) on both strip and deep resources. A three step process was used that can be summarized in the following manner:

- The bed/county strippable reserve estimates of January 1968 from Hinkle were depleted to January 1971 by BOM annual reports.
- The strippable reserves were proportioned into thickness ranges and reliability categories based on information in Hinkle.
- The strippable reserves were then depleted back to January 1951, where adjustments to the Brown and others data took place.

This basic procedure was followed for all counties and seams. In some cases the Hinkle numbers were used as a direct replacement for the

Figure 8. Virginia DRB Methodology

Brown estimates. This was done for those seams reporting no underground production between 1951 and 1971 and where the Hinkle resource estimates were greater than those reported by Brown. Also, for the Pocahontas #3 seam, 600 million tons of inferred coal was added to the DRB. The majority of the Pocahontas #3 seam in Buchanan County, Virginia lies at depths between 1,000 and 2,000 feet. Although this resource lies outside standard DRB criteria in both reliability and depth classifications the decision was made to include this coal in the DRB based on reserve estimates found in Island Creek Coal Company's Annual Report.

From this re-estimated reserve base of 1951, depletion to 1979 was accomplished by using BOM Minerals Yearbooks and EIA production reports.

Virginia anthracite estimates for the January 1979 DRB were also based entirely on Brown and others (1952). The resource estimates found in Brown are original resources and therefore had to be fully depleted to January 1979.

An assumption was made for Virginia anthracite figures that centered around the apportioning of historical production from the anthracite fields. The historical production was split as 80 percent from Montgomery County and 20 percent from Pulaski County. Historical production records from Brown and others suggest the dominance of production from Montgomery County and the figures were adjusted to reflect this situation.

O. West Virginia Methodology Summary

The 1979 DRB for West Virginia was derived using two basic methodologies; one for those counties covered by reserve reports prepared by Dowd and others, and another for the rest of the state. The basic

source documents used are the Dowd et. al. reports (1952-1956), Headlee and Nolting (1940), the West Virginia Geological Survey (WVGS) county reports (1909-1930), and Reed (1968) (see Exhibit 8). The "Dowd" counties used Dowd et. al. (1952-1956), Headlee and Nolting (1940), and Reed (1968) as the source documents. The non-Dowd counties used the WVGS county reports (1909-1939), Headlee and Nolting (1940), and Reed (1968) to arrive at their estimates.

The principal difference between the reserve estimations for the Dowd and non-Dowd counties lies in the estimation of measured and indicated reserves. Prior to the preparation of the 1979 DRB, coal underlying the 33 non-Dowd counties was assumed to be 40 percent measured and indicated and 60 percent inferred because the source documents used to prepare the reserve estimates did not split resources by standard thickness or reliability category.

The reserves in the non-Dowd counties for the 1979 DRB were calculated as follows: (1) a description of each coalbed including total in-situ tonnage and average thickness was determined for each district from the West Virginia Geological Survey (WVGS) county reports. Because the tonnage reported in the county reports was given as 1,742 ton/acre-foot, the tonnages were converted to 1,800 ton/acre-foot using a factor of 1.033, and (2) a plot of thickness versus cumulative percent of total tonnage was used to determine the tons of coal in the less than 14", 14"-28", 28"-42" and greater than 42" thickness categories. An estimate of the percent combined "measured and indicated", and percent "inferred" was made from descriptions of the mining, exploration and drilling in the county. These percentages were used to further subdivide the tonnage in each thickness category into combined "measured and indicated" and "inferred" tonnages. Each coalbed was tabulated to arrive at a county total.

The Dowd counties relied on the Dowd reports for a major portion of the reserve estimates. These reports identified remaining coal reserves

Exhibit 8. West Virginia Source Documents

1. Dowd Reports - BOM Report of Investigations 4893, 5160, 5171, 5207, 5267, 5259, 5233, 4924, 4066, 5068, and 5077.
2. Reed, A., Strippable Coal Reserves of West Virginia, Unpublished U.S. Bureau of Mines Report, 1968.
3. West Virginia Geological Survey County Reports.
4. Eavenson, H., The First Century and a Quarter of American Coal Industry, Privately printed, Koppers Bldg. Pittsburgh, Pa., 1942, Waverly Press Inc., Baltimore, Md.

by thickness (14"-28", 28"-42", and greater than 42") and in "measured" or "indicated" reliability categories. These reports, like the WVGS reports and Headlee and Nolting studies, do not differentiate between underground and strippable reserves.

Strip resources by bed and county were obtained from the "Strippable Coal Reserves of West Virginia", by Avery Reed (unpublished BOM report). Reed calculated an original strip resource for coal greater than 28 inches. An original strip DRB was calculated by multiplying the strip resource by the ratio of the total coalbed DRB to the total coalbed resource. The estimate was then depleted to January 1968; however the derivation of the DRB was based on the original resource estimate.

Production figures by county were obtained for the years 1800-1885 from the First Century and a Quarter of American Coal Industry, by Howard Eavenson. Production for the years 1886-1930 came from U.S. Geological Survey Mineral Reports. Production for the years 1931-1970 (except 1954 and 1961) came from the BOM Annual Reports. Production for 1954 and 1961 came from West Virginia Department of Mines Annual Reports. Production for 1971-1978 came from EIA production printouts. The total underground production was depleted using a factor of 2.0. Strip and auger production was summed and depleted using a factor of 1.25. The sum of the depleted totals was subtracted from the county resource and reserve. Depleted surface production was subtracted from the original strip resource and reserve. Figures 9 and 10 illustrate the general methodology followed to arrive at the 1979 DRB.

Figure 9. West Virginia Non-Dowd County Methodology

Figure 10. West Virginia Dowd County Methodology

3. THE WESTERN STATES

3. THE WESTERN STATES

A. Introduction

This chapter provides a discussion of the basic procedures used to develop 1979 coal reserve estimates for those coal-bearing states lying in the western half of the United States. For the purposes of this discussion western states are defined as those states lying west of the Mississippi River. In terms of coal resources, these states can best be described by the dramatic contrasts that exist among the various coal deposits. In states like Wyoming and Montana coal seams often reach thicknesses of 100 feet or more, while in Missouri, Oklahoma and Kansas the 1979 DRB includes coal seams less than 14 inches thick. These contrasts, along with various other mining variables have (when adequate documentation is available) entered into the final derivation of DRB estimates.

B. Alaska Methodology Summary

The original resources of Alaska coal, on which the 1979 DRB is based, were derived from a report by Barnes.³⁰ The Barnes report presents original bituminous resource data by measured, indicated and inferred reliability categories, by coal field and district, by bed thickness (14"-28", 28"-42", greater than 42"), and by overburden thickness (0-1000', 1000'-2000', 2000'-3000', and, when a finer breakdown cannot be made, 0-2000' and 0-3000'--these categories are mutually exclusive). The same information for subbituminous and lignite coal combined (although the thickness categories are different: 2½-5', 5'-10', and

³⁰Barnes, F. F., Coal Resources of Alaska, U.S. Geological Survey Bulletin 1242-B, 1967.

greater than 10') is also provided in this report. Using the information contained in Barnes, an original bituminous reserve figure of 710.05 million tons was derived, and an original combined subbituminous and lignite reserve figure of 5587.13 million tons was obtained. The original bituminous reserves of 710.05 million tons of coal consists of all coal in the measured and indicated resources categories, greater than 28" thick, and under less than 1000 feet of cover. The subbituminous and lignite reserves of 5587.13 million tons consists of all coal greater than 5 feet thick in the same reliability and overburden depth categories. The only adjustments made to the resource estimates to arrive at the 710.05-and 5587.13-million-ton figures were to multiply all coal in the 0-2000' overburden depth category by 0.5 (on the assumption that half of this coal falls into the 0-1000' category), and to multiply all coal in the 0-3000' category by 0.33 (to obtain the coal in the 0-1000' category).

To break the bituminous reserve estimate down into strippable reserves and underground reserves, EIA assigned 12 percent of the 710.05-million-ton original reserve estimate to the surface category, and the remainder to the underground category (i.e., 85.21 million tons surface, and 624.84 million tons underground). The 12 percent estimate was based on the methodology employed by the BOM.³¹ BOM assumed a maximum strippable overburden thickness of 120 feet; thus 12 percent of the coal determined to lie within 1000 feet of the surface was considered strippable.

The 5587.13 million tons of subbituminous and lignite original reserves was subdivided into 116.7 million tons of lignite and 5470.43 million tons of subbituminous. The breakdown by rank was obtained from Warfield of the BOM.

³¹U.S. Bureau of Mines, Strippable Reserves of Bituminous Coal and Lignite in the United States, U.S. Bureau of Mines Information Circular 8531, 1971.

As with bituminous coal, 12 percent of the original subbituminous reserves of 5470.43 million tons was assumed to be strippable (i.e., 656.45 million tons strippable, and 4813.98 million tons underground). Likewise, 12 percent of the 116.7 million tons of lignite reserves was assigned to the strippable category (14.00 million tons), and the remainder was dropped from the DRB (since lignite is assumed to be uneconomical to mine by underground methods).

Production for the years 1880-1975 was derived from a table entitled "Alaska Coal Production," obtained from the Alaskan office of the BOM. This table presents the cumulative production for the years 1880-1940, and then the annual production for the years 1941-1976, by mining method and by coal field. To obtain the desired production by rank, a rank was assigned to each field in the table. Production for the years 1976-1978 (which was taken as being subbituminous) was obtained from the EIA annual reports. The published DRB was derived by multiplying the strip production by 1.25 and the underground production by 2.00 and subtracting from the total reserve estimates by rank.

C. Arizona Methodology Summary

The original underground reserves,³² upon which the 1979 Arizona DRB is based, were derived solely from a reserve report written by Robinson and Robinson, Inc., for Peabody Coal Company.³³ This report

³²All of the underground (and all of the surface) Arizona reserves consist of bituminous coal.

³³Robinson and Robinson, Inc., Report of Reserves and Quality of Coal in the Black Mesa Coal Field, Navajo County, Arizona, in Lands Leased by Peabody Coal Company on the Reservation of the Navajo Indians and the Joint Reservation of Navajo and Hopi Indians, to be used at the Navajo Power Plant, for the Navajo-Four Corners Power Plant Steering Committee and Fuel and Water Supply Task Force, May 1969, 1969.

presented original reserve data for Peabody's Black Mesa coal dedicated to the Navajo Power Plant. The reserve data are broken down by seam and "area" (the different "areas" are outlined on maps included in the report). The reserves in each area and seam are broken down by average coal thickness, and both the individual seam thicknesses and the reserves are reduced by one foot of top coal. Only coal 7-15 feet in thickness, and 130' to 270' deep was included in the underground reserves.

The only adjustment made by EIA to the Robinson and Robinson reserve data was to increase the reserves by the amount reduced by leaving out the one foot of top coal. The additional reserves were added to the reserves shown for each area/seam/thickness category, and then the total across all area/seam/thickness categories was calculated. The result was 101.56 million tons. This figure represents the remaining reserves as of the date of the report (1969). The BOM Minerals Yearbooks and EIA production reports indicated that there was no underground production from 1969 to 1979. Thus, depletion was taken as zero and the 101.56 million ton figure was published as the Arizona DRB.

The original surface reserves were obtained from the 1979 Keystone Coal Industry Manual.³⁴ In the section entitled "Arizona," on page 454 of the Manual, the following statement is made:

"The only measured reserves are of strippable coal proved up by Peabody Coal Company - 387 million tons within 130 feet of the surface".

³⁴1979 Keystone Coal Industry Manual, "Arizona", New York, New York: McGraw-Hill, Inc., 1980.

The 387 million tons mentioned in this statement was taken as the original reserve base on which the 1979 DRB was based. The Robinson and Robinson report was used to calculate the reserves by coal bed and seam thickness category (4'-5', 5'-10', 10'-15', 15'-20') for that portion of the 387 million-ton total that is dedicated to the Navajo Plant.³⁵

Surface production was obtained from the BOM Minerals Yearbooks for the years 1970-1975, and from the EIA annual reports for 1976-1978 (prior to 1970 there was no surface production). A total cumulative surface production, as of January 1, 1979, of 51.45 million tons was obtained. This total production was multiplied by 1.25 to obtain 64.31 million tons of depletion. Thus:

387.00 million tons original reserves
<u>-64.31 depletion</u>
322.69 million tons calculated 1979 DRB

The published 1979 surface DRB was 322.69 million tons, which matches our calculated DRB precisely.

³⁵The portion dedicated to the Navajo Plant was calculated by EIA to be equal to 354.485 million tons. An error was made, however, in calculating this value. For area J-24, Brown seam, the tons per acre, rather than the tons, were erroneously used in the calculation. This resulted in an increase in the 5'-10' reserve estimates from 812 thousand tons to 9.856 million tons, and an increase in the 10'-15' thick reserves from 4.588 million tons to 40.48 million tons. These errors, it should be remembered, did not affect the published state total DRB (based on the 387 million ton original reserve estimate from the Keystone). The error affected only the reserve estimate for the 5'-10' and 10'-15' Brown Seam coal.

D. Arkansas Methodology Summary

The 1979 DRB for Arkansas comes primarily from a USGS publication by Haley (1960).³⁶ Anthracite and bituminous coal reserve estimates are given on a bed/county level as of January 1960. Reliability categories for anthracite and bituminous are the standard measured, indicated and inferred categories. Depth categories from Haley include divisions of 0-60', 60'-500', 500'-1000', 1000'-2000', and 2000'-3000'. Surface mineable coal for anthracite and bituminous was taken from the 0-60 foot depth.

Surface mineable lignite is taken from Woodward and Gilbreath, (1976).³⁷ The report provided lignite estimates based on drill hole data. All resource estimates were assumed to be within the measured reliability category. Only average seam thickness was reported by Woodward and Gilbreath. Seam depths were not identified since the authors assumed it was strippable based on prior experience and professional judgment.

The original reserve base derived from these reports for use in the 1979 DRB can be summarized as follows:

	(In Million Tons)		
	<u>Underground</u>	<u>Surface</u>	<u>Total</u>
Anthracite	88.60	7.80	96.40
Bituminous	365.15	122.70	429.60
Lignite	-	25.65	25.65
	<u>453.75</u>	<u>156.15</u>	<u>551.65</u>

³⁶Haley, B. R., Coal Resources of Arkansas, U.S.G.S. Bulletin 1072-P, 1960.

³⁷Woodward, M. B., and Gilbreath, L., Arkansas Lignite Characteristics, U.S. BOM Grant Number G0254007, Arkansas Geological Commission, 1976.

To arrive at these figures, several assumptions for the coals were made:

- Strippable anthracite (7.80 million tons) is the total of all measured and indicated anthracite coal greater than 28" in the 0-60 foot depth range.
- The underground anthracite reserve (88.60 million tons) is the sum of all measured and indicated anthracite coal between 60 and 1000 feet deep and greater than 28".
- Strippable bituminous coal (122.70 million tons) is the sum of all measured and indicated bituminous coal greater than 14" thick and less than 60 feet deep.
- Underground bituminous coal (365.15 million tons) is the sum of the measured and indicated bituminous coal greater than 28" lying between 60 and 1000 feet in depth.
- The lignite estimate (25.65 million tons) is the sum of all measured coal reported by Woodward and Galbreath when thickness is greater than 5 feet.

The production and subsequent depletion of Arkansas coal reserves was obtained from the Arkansas Geological Commission (AGC) for years 1840 through 1975.

Arkansas production for 1976 through 1978 was obtained from information contained on Form EIA-7 reports. Depletion was derived by using the standard depletion factors of 2.00 for underground and 1.25 for surface mining. The total production and depletion can be summarized as:

<u>1840-1979</u>	<u>Underground</u>	<u>Surface</u>	<u>Total</u>
Production	90.62	14.184	104.80
Depletion	181.24	17.730	198.97

By subtracting all Arkansas depletion from the bituminous coal rank, the 1979 DRB published figures can be derived. The general methodology can be seen in the flowchart of Figure 11.

Figure 11. Arkansas DRB Methodology

E. Colorado Methodology Summary

The Colorado DRB was derived by depleting a 1971 resource base developed through the review and analysis of 16 different information sources. The principal source of coal resource data was Landis and

Cone, Coal Resources of Colorado Tabulated by Bed. This report provided detailed information by township and coal bed. This work covered all of Colorado except for the Trinidad coal field in Huerfano and Las Animas Counties, and those resources in the San Juan River and Raton Mesa regions. To complete the estimation of the original resources, USGS bulletins and investigation maps of the coal-bearing regions were obtained. The Landis and Cone numbers for each township were entered onto the maps. The supplemental information was then used to fill in any data gaps. Exhibit 9 at the end of this discussion summarizes all the references used for the 1979 DRB.

This basic procedure was followed for many of Colorado's coal bearing areas. Landis and Cone was used as the principal data source and, where necessary, additional information was gathered and added to the Landis estimates.

Once the total resource base was established, which was mostly on a township basis, BOM Information Circular 8531 was used to split the identified resource and reserve base into strip and underground categories. Information Circular 8531 provided strippable resource/reserve data by county and by seam. To match the various data sets, some adjustments had to be made to the township-level resource estimates. While most townships lie within a single county, some cross county lines. In these cases, the fraction of in-place coal lying in each county had to be estimated. These estimates were based on detailed reviews of USGS Coal Investigation Maps and in some cases engineering judgment. Once the resource/reserve base was adjusted to reflect county totals it was split between underground and surface mineable coal based on Information Circular 8531.

In addition to using numerous data sources to establish the resource/reserve base, it was also necessary to rely on many sources to classify the coal according to rank. Landis and Cone provided good information

Exhibit 9. Colorado References

1. Landis, E.R., and Cone, G.C., Coal Resources of Colorado Tabulated by Bed, U.S. Geological Survey Open File Report, 1971.
2. Harbour, R.L., and Dixon, G.H., Coal Resources of Trinidad-Acuilar Area, Las Animas and Huerfano Counties, Colorado, U.S. Geological Survey Bulletin 1072-G, 1959.
3. Johnson, R.B., Geology and Coal Resources of the Walsenburg Area, Huerfano County, Colorado, U.S. Geological Survey Bulletin 1042-0, 1958.
4. _____, Coal Resources of the Trinidad Coal Field in Huerfano and Las Animas Counties, Colorado, U.S. Geological Survey Bulletin 1112-E, 1961.
5. Johnson, R.B., and Stevens, J.G., Coal Resources of the LaVeta Area, Huerfano County, Colorado, U.S. Geological Survey Coal Investigation Map C 20, 1954.
6. Wood, G.H. Jr., Johnson, R.B., and Dixon, G.H., Geology and Coal Resources of the Gulnare, Cuchara Pass, and Stonewall Area, Huerfano and Las Animas Counties, Colorado, U.S. Geological Survey Coal Investigation Map C 26, 1956.
7. _____, Geology and Coal Resources of the Starkville-Weston Area, Las Animas County, Colorado, U.S. Geological Survey Bulletin 1051, 1957.
8. Wood, G.H. Jr., Johnson, R.B., Eargle, D.H., Duffner, R.T., and Major, H., Geology and Coal Resources of the Stonewall-Tercio Area, Las Animas County, Colorado, U.S. Geological Survey Coal Investigation Map C 4, 1951.
9. Barnes, H., Geology of the Ignacio Area, Ignacio and Pagosa Springs Quadrangles, LaPlata and Archuleta Counties, Colorado, U.S. Geological Survey Oil and Gas Investigation Map OM 138, 1953.
10. Barnes, H., Baltz, E.H., and Hayes, P.T., Geology and Fuel Resources of the Red Mesa Area, LaPlata and Montezuma Counties, Colorado, U.S. Geological Survey Oil and Gas Investigation Map OM 149, 1954.
11. Landis, E.R., Coal Resources of Colorado, U.S. Geological Survey Bulletin 1072-C, 1959.
12. Zapp, A.D., Geology and Coal Resources of the Durango Area, LaPlata and Montezuma Counties, Colorado, U.S. Geological Survey Oil and Gas Investigation (Prelim.) MAP 109, 1949.

Exhibit 9. (Continued)

13. Shomaker, J.W., Beaumont, E.C., and Kottlowski, F.E., Strippable Low-Sulfur Coal Resources of the San Juan Basin in New Mexico and Colorado, New Mexico Bureau of Mines and Mineral Resources Memoir 25, 1971.
14. Rich, C.H., Jr., and Speltz, C.N., Lignite and High-Alumina Clay in the Denver Basin, Colorado, U.S. Bureau of Mines Unpublished Report, 1976.
15. U.S. Bureau of Mines, Strippable Reserves of Bituminous Coal and Lignite in the United States. U.S. Bureau of Mines Information Circular 8531, 1971.
16. Jones, D.C., and Murray, D.K., Coal Mines of Colorado, Statistical Data, Colorado Geological Survey Information Series 2, 1976.

on coal rank, but, as discussed above, they did not cover all coal-bearing areas. The supplemental sources used to identify additional coal resources did not, however, give a breakdown of deposits by rank. To divide fully the resource base, engineering judgment coupled with historical production and coal quality information had to be used to estimate coal rank in those areas not covered by Landis and Cone.

Lastly, the lignite resources of the Denver Basin were only partially estimated by Landis and Cone in their identification of Colorado coal deposits. Estimates of the lignite resources and subsequent demonstrated reserve base were taken directly from worksheets used to prepare an unpublished BOM report by Charles Rich and others, Lignite and High Aluminum Clay in the Denver Basin Coal region, Colorado. Since no Colorado lignite production has occurred since the date of the resource estimate no depletion was necessary.

Depletion of the bituminous and subbituminous resource/reserve base for Colorado followed standard DRB practice (50 percent average recovery for underground production, 80 percent recovery for surface). Production statistics through 1974 came from the Colorado Geological Survey and BOM Mineral Yearbooks. EIA production reports were used for 1975 through 1978.

F. Idaho Methodology Summary

The demonstrated reserve base for Idaho is based solely on the work of Kiilsgaard, in a pamphlet called The Geology and Coal of the Horseshoe Creek District, Teton County, Idaho, #92, published in 1951.

Basically, the document stands alone. The original reserves are estimated to be 4.62 million short tons. All the coal falls in the indicated category. Depth categories are split between 0, 600, and 1,200 feet. Kiilsgaard presented his data as the original resource.

Coal production for Idaho has not been recorded officially since 1951. However, pre-1951 records show 100,000 tons being produced. Kiilsgaard indicates the Brown Bear and Progressive underground mines were the chief producers of Idaho coal. No surface production was reported and therefore total depletion was calculated using the standard 50 percent recovery factor. This yielded the 1979 DRB of 4.42 million tons.

G. Iowa Methodology Summary

The Iowa DRB relied on two sources, Landis (1965)³⁸ and Garvin and Van Eck (1975, 1976)³⁹ for providing resource estimates of Iowa coals. The underground reserves are based on the report by Landis, while the BOM studies by Garvin and Van Eck supplied strippable figures.

The original reserve base for Iowa, as calculated from the Landis report, contained total reserves. It was not until the Garvin and Van Eck reports that strippable coal was properly broken out of the Iowa DRB. Landis reported a total of about 3,500-million-tons of measured and indicated coal over 14" in Iowa. A total of 2,882-million-tons was identified as the original reserve base.

Production and depletion for Iowa was obtained from the Iowa Division of Mines and Minerals for 1840 through 1969. Production from January 1970 through 1978 was taken from Minerals Yearbooks and DOE/EIA reports.

³⁸Landis, E. R., Coal Resources of Iowa, Iowa Geological Society Technical Paper 4, 1965.

³⁹Garvin, Paul L., and Orville J. Van Eck, Strippable Coal Reserve study in selected Iowa Counties, Bureau of Mines Grant Numbers G0254008 and G0264013, Iowa Geological Survey, Iowa City, Iowa, 1975 and 1976.

The summary of this production and associated depletion, as shown on file notes, is as follows:

Surface production 1840-1975	28.93 million tons
Underground production 1840-1975	<u>328.64</u> million tons
Total production 1840-1975	357.57 million tons
Surface depletion at 80% recovery	36.16 million tons
Underground depletion at 50% recovery	<u>657.28</u> million tons
Total depletion 1840-1975	693.44 million tons
Depletion from 1/1/76 to 1/1/79	<u>2.48</u> million tons
Total depletion through 1/1/79	695.92 million tons

Unfortunately, when one subtracts total depletion from the original Landis reserve estimate of 2,882.7 million tons a remaining DRB (as of January, 1979) of 2,186.8 million tons is derived--12 million tons less than the published figure. The explanation lies in the use of the computer programs generating the reserve numbers. It appears that when the Garvin and Vank Eck data were incorporated with the Landis data, several seams contained more stippable reserves than Landis reported as a total reserve. Consequently, the underground portion of the Landis reserve was subtracted out of the total and the strippable figure put in, and the total difference amounts to 12 million tons.

H. Kansas Methodology Summary

The methodology used to derive the 1979 DRB estimated for Kansas consisted simply of depleting the strippable bituminous resource estimates prepared by Brady and others ⁴⁰ using EIA production data.

⁴⁰Brady, L. L., Adams, D.B., and Livingston, N.D., An Evaluation of the Strippable Coal Reserves in Kansas, Geological Survey Mineral Resources Series 5, 1976.

The Brady report provided resource information by county and seam, and included coalbeds with a minimum mining height of 12 inches to reflect current mining practices. These data represented remaining resources as of January 1976. Therefore depletion was necessary only for the years 1976 through 1978.

I. Missouri Methodology Summary

The 1979 Missouri DRB is based on depletion of resource estimates found in two reports written by Robertson in 1976⁴¹ and Robertson and Smith in 1980.⁴² The 1976 report provides total remaining resource estimates⁴³ for the entire state by thickness, reliability categories and mining method. The 1980 report presents measured and indicated resources by the same thickness categories employed in the 1976 report, by bed and county, by overburden thickness categories (0'-60', 60'-90', 90'-120', 120'-150', greater than 150'), and by measured and indicated reliability categories. However, unlike the 1976 report, this report did not cover the entire state.

The 1976 remaining surface reserves, on which the 1979 DRB is based, were derived by taking the state's total measured and indicated strip-pable resources (that portion of the coal under 150 feet or less of

⁴¹Robertson, C.E., A Detailed Evaluation of Missouri Coal Reserves, Missouri Department of Natural Resources, U.S. Bureau of Mines Grant No. G0254029, 1976 (unpublished).

⁴²Robertson, C.E. and Smith, D.C., Evaluation of the Mineable Coal Reserves of the Northern Bevier, Mendota, and Novinger Coal Fields in North-Central Missouri, Missouri Department of Natural Resources Open File Report 79-2-ER, 1980.

⁴³As of July 31, 1976.

cover), 8 inches or more in thickness, from the 1976 report, and adding the 8 inches measured and indicated resources under less than 150 feet of cover from the 1980 report. It is important to note that EIA did not replace the 1976 resource data with the data presented in the 1980 report; rather the 1980 resources for Northern Bevier, Mendota, and Novinger coal fields were added to the 1976 resources for the entire state. Since the resource estimates presented in the 1980 report represent remaining resources as of November 30, 1977, while the estimates presented in the 1976 report represent remaining resources as of July 31, 1976, the depletion between July 31, 1976 and November 30, 1977 was added back into the resource estimate,⁴⁴ so that the sum of the resources from the 1980 report and the 1976 report represent the remaining resources as of July 31, 1976.

The 1976 remaining underground reserve base estimate was derived solely from the 1976 report. It was calculated by subtracting the total measured and indicated strippable resources (less than 150 feet) falling into the 28"-42" and greater than 42" thickness categories (obtained from Table 5 of the report) from the total measured and indicated resources greater than 28" under 1000 feet or less of cover (from Table 4 of the 1976 report). The result was the remaining measured and indicated reserves, as of July 31, 1976, falling in the 150'-1000' overburden thickness category, and the greater than 28" coal thickness category.

These remaining reserves were then depleted, using data obtained from EIA annual production reports and applying standard depletion factors.

⁴⁴This depletion was derived by multiplying total production during this period (from the EIA annual reports) by 1.25.

J. Montana Methodology Summary

The methodology used to develop the 1979 Montana DRB consists of three parts: (1) the estimation of original surface reserves, (2) the estimation of original underground reserves, and (3) depletion.

The original surface (both subbituminous and lignite) reserve estimate on which the 1979 DRB is based was derived from information contained in a handout prepared for the 1977 Rocky Mountain Coal Symposium,⁴⁵ along with information included in a report by Matson and Blumer.⁴⁶

The symposium handout provided lump sum resource estimates for each coal bed/coal field combination in Montana. In addition to coal-bed/coalfield resource data, the Matson and Blumer report also divided the resources into reliability and seam thickness categories. This report, however, only covered a portion of the state. Using the Matson and Blumer report, resources in the inferred reliability category were subtracted from the overlapping coalbed resource data contained in the symposium handout.

After subtraction of the inferred reserves, the next step was to break the lump-sum reserve estimates presented in the handout into subbituminous and lignite reserves. The breakdown by rank was accomplished with the aid of the map of Montana's coal fields included in the handout. This map indicated the position of each of the coal fields included in the table in the handout. In addition, the map was divided into two

⁴⁵ _____, Strippable Subbituminous and Lignite Coal Fields, Montana, Handout at 1977 Rocky Mountain Coal Symposium, Golden, Colorado, May 9 and 10, 1977.

⁴⁶Matson, R. E., and Blumer, J.W., Quality and Reserves of Strippable Coal in Southern Montana, Montana Bureau of Mines and Geology Bulletin 91, 1973.

sections by a north-south line; to the east of this line (according to the notation on the map) lie the lignite fields, and to the west lie the subbituminous fields. Thus, the map was used to identify which fields are lignite and which are subbituminous. The Pumpkin Creek coal field (which contains the Sawyer bed) straddles the cutoff line; 45 percent of the 2426.5-million-tons in this field was assigned to the lignite reserves, and the remainder was assigned to the subbituminous fields. All other fields were assigned either to lignite or subbituminous according to their position with respect to the cutoff line, with one exception--the Sand Creek field (containing the Knoblock bed) is shown on the map as lying in the lignite area, but this field was assigned to the subbituminous category. After the assignments to rank were completed, the coal field/coal bed estimates were summed across the state to yield original surface lignite and subbituminous reserves.

Figure 12 illustrates the procedure discussed above.

Montana's original underground reserves, on which the 1979 DRB is based, were derived from a report by Combo, Brown, Pulver, and Taylor ⁴⁷ (which covers the entire state), along with the following reports (which cover portions of the state):

Prichard, George E., and Landis, Edwin R., Coal Resources and Cenozoic Geology of the Girard Coal Field, Richland County, Montana, U.S. Geological Survey Bulletin 1310, 1975.

Baker, A.A., The Northward Extension of the Sheridan Coal Field, Big Horn and Rosebud Counties, Montana, U.S. Geological Survey Bulletin 806-B, 1929.

Bass, N.W., The Ashland Coal Field, Rosebud, Powder River and Custer Counties, Montana, U.S. Geological Survey Bulletin 831-B, 1932.

⁴⁷Combo, J. X., Brown, D. M., Pulver, H. F., and Taylor, D. A., Coal Reserves of Montana, U.S. Geological Survey Circular 53, 1949.

Figure 12. Original Surface Reserves Methodology

Bryson, R.P., and Bass, N. W., Geology of Moorehead Coal Field, Powder River, Big Horn, and Rosebud Counties, Montana, U.S. Geological Survey Bulletin 1338, 1973.

Dobbin, C.E., The Forsyth Coal Field, Rosebud, Treasure and Big Horn Counties, Montana, U.S. Geological Survey Bulletin 812-A, 1929.

Pierce, W.G., The Rosebud Coal Field, Rosebud and Custer Counties, Montana, U.S. Geological Survey Bulletin 847-B, 1936.

Roberts, A. E., Geology and Coal Resources of the Livingston Coal Field, Gallatin and Park Counties, Montana, U.S. Geological Survey Professional Paper 526-A, 1966.

Rogers, G.S., and Lee, W., Geology of Tullick Creek Coal Field, Rosebud and Big Horn Counties, Montana, U.S. Geological Survey Bulletin 749, 1923.

Warren, W. C., Reconnaissance Geology of the Birney-Broadus Coal Field, Rosebud and Powder River Counties, Montana, U.S. Geological Survey Bulletin 1072-J, 1959.

The calculated county totals from the above reports were compared with the totals presented in the Combo, Brown, Pulver, and Taylor report. In several cases these totals did not match. For the purposes of the DRB the larger estimate was always used.

Once county total resource estimates were derived, the Combo, Brown, Pulver, and Taylor report was used to distribute the resource information by seam thickness and reliability category. Those resources unclassified as to thickness or reliability by Combo were assigned to the measured and indicated reliability category, and the 5'-10' or greater than 10' thickness categories. Resource estimates meeting DRB criteria were then summed to provide an original underground reserve base for Montana.

The above discussion represents a simplified description of the methodology used to derive the Montana underground reserve estimate. A more detailed discussion is presented in Appendix B of this report. An illustration of the basic methodology is provide by Figure 13.

Figure 13. Methodology for the Development of
Underground Reserve Estimates

The underground and surface reserve estimates developed using the methodologies discussed above represent original reserves. To derive the 1979 DRB, these estimates had to be depleted for production from about 1880 through 1978. The information sources used to develop Montana production estimates by mining method and coal rank included:

- 1880-1949 - Combo, Brown, Pulver, and Taylor
- 1905 - Montana Coal and Lignite Deposits
- 1923-1945, 1948-1971 - reports of the State Board of Equalization
- 1946-1947 - Combo, Brown, Pulver and Taylor
- 1950-1978 - BOM Minerals Yearbooks
- 1976-1977 - EIA Energy Data Reports.

These data sources provided production statistics in many varying formats. It was necessary, therefore, to make several adjustments, including adjustments based on engineering judgment, to arrive at reasonable production estimates for each coal rank and for both strip and underground mining methods. Once this was accomplished the production data were multiplied by standard DRB depletion factors and the totals subtracted from the appropriate reserve estimate to arrive at the published DRB figure. The entire depletion process is illustrated in Figure 14.

Like the derivation of the underground reserve estimate, the calculation of production and associated depletion estimates was a complex undertaking. A more detailed discussion of the entire process is provided in Appendix B.

Figure 14. Montana Depletion

K. New Mexico Methodology Summary

Two sources were used for the New Mexico DRB, namely Read and others, (1950)⁴⁸, who estimated total resources, and Shomaker and others, (1971)⁴⁹, who covered strippable reserves.

Read summed the anthracite, bituminous and subbituminous resources by coalfield and county. Reliability categories included measured, indicated and inferred divisions with thickness splits of (anthracite/bituminous) greater than 14", and subbituminous coal greater than 30 inches. Therefore, a percentage determination was required for the 1979 DRB to place the correct reserves into the proper thickness (greater than 28", greater than 5') classifications. No strippable reserves were identified by Read. Of the 61,754.6 million tons identified by Read, 2,418.3-million-tons was taken as underground reserves falling within DRB criteria. Because the data disaggregation is on a coalfield level, some manipulation of the data from Read was necessary to derive the coal data on a bed/county level.

⁴⁸Read, C. B., Duffner, T. T., Wood, G. H., and Zapp, A. D., Coal Resources of New Mexico, U.S.G.S. Circular 89, 1950.

⁴⁹Shomaker, J. W., Beaumont, E. C., and Kottlowski, F. E., compilers and editors, Strippable Low-Sulfur Coal Resources of the San Juan Basin in New Mexico and Colorado, New Mexico Institute of Mining and Technology, Bureau of Mines and Mineral Resources Memoir 25, 1971.

The original resource, from Read, can be summarized as follows:

<u>County</u>	<u>Original Resource (In Million Short Tons)</u>
Bernalillo	2.60
Catron	267.40
Colfax	4,709.00
Lincoln	1,416.60
McKinley	13,194.70
Otero	227.40
Rio Arriba	3,047.60
Sandoval	4,962.80
San Juan	32,500.50
Santa Fe	47.50
Socorro	148.60
Valencia	1,224.20
	<hr/>
	61,748.90

The reserve estimates were derived from Read by following the standard DRB criteria for subbituminous (greater than 5' thickness), bituminous (greater than 28") and anthracite (greater than 28" thickness). It was necessary to sum the reserves from tables 6 through 13 in the Read report which identified thicknesses and reliability according to DRB criteria. The text discussion of the coalfields were used to supplement the tables.

The strippable resource for New Mexico was obtained from Shomaker and others published in 1971. This source identified strippable resources in "measured and indicated" and "inferred" categories up to 250 feet in depth. Shomaker divided his estimates into township and range resources for each coalfield. Each township, range and coalfield was identified on a county basis by EIA personnel to correspond with the resource estimates of Read and the DRB criteria.

In deriving the 1979 DRB numbers, two key assumptions were made. First, between the 1976 DRB and 1979 DRB numbers, a decision was made to split

the underground and surface coal production by coal rank. It was assumed that all underground mining was of bituminous coal and all surface mining was subbituminous. Secondly, production from 1882 to 1948 reported in Read was assumed to be all underground mining.

Production and depletion data was obtained from several sources. Production through 1947 came from Read. Production from 1948 to 1979 was obtained from BOM and EIA annual production reports. Depletion factors of 2.00 and 1.25 for underground and surface mining losses respectively were used. The depletion of New Mexico coal reserves can be summarized by the following table.

Depletion
(In Million Short Tons)

<u>Rank</u>	<u>1881-1971</u>	<u>1971-1979</u>	<u>Total</u>
Anthracite	-	-	-
Bituminous	260.35	12.28	272.63
Subbituminous	37.97	88.72	126.69

This leads to the next table which outlines the reserve estimates for the 1979 DRB for New Mexico.

<u>Rank</u>	<u>Original Reserve</u>	<u>Depletion to January 1979</u>	<u>1979 DRB</u>
Anthracite	2.30	-	2.30
Bituminous	2,115.20	272.63	1,842.57
Subbituminous	2,823.30	126.69	2,696.61
	<u>4,940.80</u>	<u>399.32</u>	<u>4,541.48</u>

L. North Dakota Methodology Summary

The published 1979 DRB for North Dakota is 9971.22 million tons; all of this coal is lignite amenable to surface mining. The original resource on which this is based was derived by adjusting county-level resource data obtained from R.A. Brant's Lignite Resources of North Dakota.⁵⁰ Two adjustments were made to the estimates presented in the Brant report: first, each county resource estimate was multiplied first by 0.7 (Brant estimated that 70 percent of the North Dakota reserves lie within 500 feet of the surface); second, the results were multiplied by 0.4 (to estimate the amount of reserves lying within 200 feet of the surface--(i.e., the strippable reserves). The results were summed across all counties by seam thickness and overburden category to obtain the original reserves. A typed version of the calculation sheet used to develop this estimate is presented in Exhibit 10; the data presented in the first four columns of this sheet were taken directly from the Brant report.

Depletion was calculated on the basis of state-level production data contained in the Brant report for the years 1884-1950. Brant obtained the production data from State mine inspectors. Their records indicate that in 1927 40 percent of the State's production was by surface mining and that by 1950 the figure had risen to 86 percent.⁵¹ Thus, EIA interpolated the pre-1950 production split to be 65 percent underground mining and 35 percent surface mining. Recovery factors (which were based on information contained in Brant and staff professional judgment) of 70 percent for surface mining and 40 percent for underground mining were used to determine the pre-1950 depletion.

⁵⁰Brant, R.A., Lignite Resources of North Dakota, U.S. Geological Survey Circular 226, 1953.

⁵¹Prior to 1927 production was predominantly by underground mining but a breakdown for this period is lacking.

Exhibit 10. Calculation of Strippable Coal in North Dakota

County	<u>Measured^a</u>		<u>Indicated^a</u>		Reserve Base	0-500' (70%)	0-200' (40%)
	5-10'	10'	5-10'	10'			
Adams	28.56	38.20	115.64	83.13	265.53	185.87	74.35
Billings	251.54	213.45	1,066.26	1,344.40	2,835.65	1,984.96	793.98
Bowman	52.94	166.39	472.52	444.30	1,136.45	795.31	318.12
Burke	148.78	11.05	329.70	80.56	539.09	371.06	148.43
Burleigh	5.66	36.20	89.86	76.07	207.79	145.45	50.18
Divide	63.41	53.85	374.48	300.08	791.82	554.27	221.71
Dunn	303.78	194.93	1,574.52	918.96	2,992.19	2,094.53	837.81
Golden Valley	205.77	27.62	979.46	76.73	1,289.58	902.71	361.08
Grant	180.45	21.50	457.43	10.59	669.97	468.98	187.59
Hettinger	47.56	49.02	508.56	241.74	847.28	593.10	237.24
McHenry	3.91	9.93	21.44	4.24	39.52	27.66	11.07
McKenzie	761.04	25.56	2,116.00	308.71	3,211.31	2,247.92	899.17
McLean	305.87	31.75	1,206.48	379.21	1,923.31	1,346.32	538.53
Mercer	425.94	649.61	2,056.17	1,621.89	4,753.61	3,327.53	1,331.01
Morton	338.64	41.82	1,301.75	286.21	1,968.42	1,377.89	551.16
Mountrail	67.97	79.52	368.05	233.57	749.11	524.38	209.75
Oliver	206.25	52.21	1,257.16	407.32	1,922.94	1,346.06	538.42
Renville	5.29	18.57	35.01	-	58.87	41.21	16.48
Sheridan	-	-	-	-	-	-	-
Slope	169.68	356.08	1,827.30	2,600.45	4,993.51	3,495.46	1,398.18
Stark	150.94	136.44	836.39	1,092.72	2,216.49	1,551.54	620.62
Ward	37.43	145.55	381.36	340.93	905.27	633.69	253.48
Williams	241.91	63.87	1,251.64	556.42	2,143.84	1,500.69	600.29
State Total	3,963.72	2,463.12	18,627.18	11,398.23	35,452.25	25,516.58	10,246.64

^aData from USGS Circular 226 - Table 1.

Depletion for the years 1951-1978 was based on production data obtained from production records of the BOM (through 1975) and EIA annual reports (1976-1978). Underground production was insignificant during this period, and a recovery factor of 80 percent was employed to determine the surface depletion. The total depletion from surface mining for the period 1884-1978 was then determined, and the original reserve figure was reduced by this amount to obtain the 1979 DRB.

M. Oklahoma Methodology Summary

The Oklahoma 1979 DRB is based on S. A. Friedman's Investigation of the Coal Reserves in the Ozarks Section of Oklahoma and Their Potential Uses,⁵² which provides information on remaining resources as of January 1974. The 1979 DRB was calculated by depleting those resources meeting DRB criteria to 1979.

Due to the nature of Oklahoma coal deposits and current mining activities in the state, some exceptions to standard DRB reserve criteria were made. Specifically, the 1974 remaining strippable reserves included all coal falling in the measured and indicated reserve categories with a thickness equal to, or greater than, 12" (and for some counties coal in the 10"-12" thickness range was included in the DRB). The overburden limit for strippable coal in Oklahoma was set at 100 feet.

Underground reserves included all coal in the 101'-1000' depth categories, with a thickness greater than 28", and identified as being in either the measured or indicated reliability categories.

⁵²Friedman, S. A., Investigation of the Coal Reserves in the Ozarks Section of Oklahoma and Their Potential Uses, Final Report to the Ozarks Regional Commission, July 10, 1974, Fourth Printing, 1977.

The 1974 remaining reserves calculated from Friedman were depleted on the basis of production data obtained from the BOM Minerals Yearbooks (for the years 1974 and 1975), and the EIA annual production reports (for the years 1976-78).

N. Oregon Methodology Summary

The 1979 Oregon DRB is based on data presented in D. C. Duncan's Geology and Coal Deposits in Part of the Coos Bay Coal Field, Oregon,⁵³ and Ralph S. Mason's and M. I. Erwin's Coal Resources of Oregon.⁵⁴ The underground reserve estimate was based solely on Table 2 in the Mason and Erwin Report. This report provides remaining (as of July 1945) reserve data on 17 coal-bearing areas of Oregon. The underground DRB estimate, however, is based on reserve totals for only 3 of the 17 areas. It appears that several reserve areas were eliminated because of overburden depth categorization (0-1500'), as well as average coal thickness (5').

Surface reserves were estimated based on information contained in both the Mason and Duncan reports. Reserves of Reserve Area 1 (from Table 2 of the Mason and Erwin report) with an overburden depth of 0-200' and a coal thickness range of 3.6' to 5.2' were included in the surface DRB estimate. None of the coal in the other 16 reserve areas was added to the Area 1 coal. The Duncan report provided data on strippable reserves in the Englewood and Riverton area of the Coos Bay Field. These reserves were added to the tonnage estimates provided by the Mason and Erwin report.

⁵³Duncan, D. C., Geology and Coal Deposits in part of the Coos Bay Coal Field, Oregon, U.S. Geological Survey Bulletin 982-B, 1953.

⁵⁴Mason, Ralph S., and Erwin, M. I., Coal Resources of Oregon, U.S. Geological Survey Circular 362, 1955.

Reserve estimates were depleted using production data obtained from the BOM Western Field Operation Center. These data covered production from 1945 to 1975. EIA annual reports indicate that there was no production from 1976 through 1978.

O. South Dakota Methodology Summary

The South Dakota 1979 DRB estimate, for all counties other than Harding County, is based on Paul Averitt's revision of D. M. Brown's Lignite Resources of South Dakota⁵⁵ and information from the South Dakota Geological Survey. These data were summarized in the Northern Great Plains Resources Program's Mineral Resources Work Group Report.⁵⁶ For Harding County the DRB is based on the back-up data used to prepare J. A. Redden's Lignite Reserves, Harding County, South Dakota,⁵⁷ published in 1978. The back-up data present reserve estimates by section. Due to errors made when totaling the section estimates, the Harding County estimate presented in the Redden report does not equal the total of the section estimates.

The Northern Great Plains Resources Program's (NGPRP) report provides a DRB lignite reserve estimate for South Dakota of 428-million-tons (the published 1971 DRB estimate). Using Redden's updated Harding

⁵⁵Brown, D. M., Lignite Resources of South Dakota, U.S. Geological Survey Circular 159, 1957.

⁵⁶Northern Great Plains Resources Program, Mineral Resources Work Group Report, 1974.

⁵⁷Redden, J. A., Lignite Reserves, Harding County, South Dakota, U.S. Bureau of Mines Grant Number G0 264015, 1978; later administered under U.S. Department of Energy Contract Number ET-76-G-01-90779.

County reserve figures, the NGPRP estimate was reduced by 60-million-tons. This figure was further reduced by 1.9 million tons to reflect depletion from the 19th century.

P. Texas Methodology Summary

The 1979 Texas DRB was developed from resource data presented in Lignite Resources in Texas.⁵⁸ These estimates are divided into measured, indicated and inferred reliability categories, but EIA judged that the measured category includes coal in both the measured and indicated categories (as defined by EIA), and the indicated category includes coal in both EIA's indicated and inferred categories. Thus, EIA decided to include only measured resources from the report. This report presents resource estimates of lignite under 200 feet or less of cover, 3 feet or more thick, by geologic groups and formations, and by region. The total measured strippable lignite resources presented in the report equals 12,916 million tons.

To arrive at the 1979 published DRB, the above resource estimate was depleted using production data obtained from the Texas Bureau of Economic Geology⁵⁹ (TBEG), BOM Minerals Yearbooks and EIA annual production reports. The TBEG data were for production prior to 1974. For the pre-1950 period, EIA assumed a recovery factor of 50 percent (during this period most Texas production came from shallow underground mines). Between 1950 and 1974, a 75 percent recovery factor

⁵⁸Kaiser, W. R., Ayrs, W. B., Jr., and La Brie, L. W., Lignite Resources in Texas, Bureau of Economic Geology Report of Investigations 104, 1980.

⁵⁹Kaiser, W.R., Texas Lignite: Near-Surface and Deep-Basin Resources, Texas Bureau of Economic Geology Report of Investigations 79, 1974.

was assumed. Depletion for the years 1975 through 1978 was calculated using the standard surface recovery factor of 80 percent.

Q. Utah Methodology Summary

The 1979 DRB for Utah is taken directly from the Monograph Series, Numbers 1, 2 and 3, published in 1972 by Doelling and Graham.⁶⁰ These reports estimated Class I, Class II and Class III coal resources up to 3000' in depth.

The procedure used for establishing the original Utah reserve base centered on interpreting the geologic maps and accompanying discussion of each coalfield quadrangle contained in the monographs. Quadrangle estimates were then apportioned among the member counties making up the quadrangle.

The difficulty in obtaining reserves meeting DRB criteria lies in the flexible nature of the Monograph Series. The resources are based on class estimates of reliability, which correspond, but do not match exactly, to the following DRB criteria:

- Class I - measured
- Class II - indicated
- Class III - inferred
- Class IV - (potential) no DRB criteria.

⁶⁰Doelling, H. H., Central Utah Coal Fields, Utah Geological and Mineralogical Survey Monograph Series 3, 1972.

Doelling, H.H., and Graham, R. L., Southwestern Utah Coal Fields, Utah Geological and Mineralogical Survey Monograph Series 1, 1972.

_____, Eastern and Northern Utah Coal Fields, Utah Geological and Mineralogical Survey Monograph Series 2, 1972.

Also, Doelling estimated resources for all coal seams with a 4-foot mineable limit. According to Doelling, "In most cases, the reserves under 4 feet have been eliminated as well as coal at a depth greater than 3,000 feet."

Because of the Doelling treatment with the 48" cutoff of mineable coal, it became necessary to derive the coal reserves from the detailed quadrangle discussions, which included production reports, mining descriptions and detailed seam descriptions of all coal horizons in the quadrangle. These descriptions identified reserves lying within 1,000 feet at a specified average thickness. Interpretation of the discussions on the coal seams, in many cases, was the only reference point available to build the reserve base. Strippable coal was identified where mentioned; however, these strippable estimates were given as tons recoverable. It was necessary to identify recoverable percentage factors for that seam and calculate back to the in-place tonnage. The total original underground and surface reserves matching DRB criteria were the sum of the quadrangle estimates for all three monographs. These reserves can be summarized as follows:

(In Million Tons)		
<u>Rank</u>	<u>Underground Original</u>	<u>Surface Original</u>
Bituminous	6,720.56	267.89
Subbituminous	1.10	-

Production and subsequent depletion of the original Utah reserves were based on quadrangle discussions (1870 to 1970) in Doelling, BOM Production Reports and Yearbooks (1971-1975), and EIA Annual Reports (1976, 1977, 1978). A major split in depletion factors occurred between depletion from the period 1870-1976, and 1976-1979.

Production and depletion from the original reserves to January 1976 is assumed to have been done on a coalfield basis with information from Doelling and BOM production data. Each coalfield was depleted using actual depletion factors derived from local production. Underground production and depletion for each coalfield to January 1976 can be summarized by the following table:

<u>Coal Field</u>	<u>Production (Millions)</u>	<u>Depletion (Millions)</u>	<u>Coal Field Depletion Factor</u>
Alton	0.0475	0.19	4.00
Kaiparowits	0.0430	0.14	3.25
Kolob	0.6080	1.45	2.38
Vernal	0.2710	0.46	1.70
Henry Mountains	0.0080	0.02	2.50
Ligo	2.6570	6.63	2.50
Coalville	4.0000	8.00	2.00
Salina Canyon	0.4300	1.05	2.44
Sterling	0.0600	0.00	0.00
Wales	0.1750	0.00	0.00
Wasatch Plateau	116.1710	74.55	0.64
Book Cliffs	225.5797	337.49	1.50
Emery	<u>2.6764</u>	<u>6.69</u>	<u>2.50</u>
	352.7271	436.67	1.24

After 1976, depletion was accomplished by using a straight depletion factor of 2.00. Surface production and subsequent depletion for Utah were considered small and generally localized by Doelling; therefore, no depletion of the surface reserves was necessary. An illustration of the basic methodology is provided by Figure 15.

Figure 15. Utah DRB Methodology

R. Washington Methodology Summary

The 1979 DRB for Washington is based on Beikman and others (1961).⁶¹ Beikman estimated the reserves as of January 1960, so depletion from 1960 was necessary.

Beikman gave the coal reserve estimates by bed and township within given counties. This source also derived the resources for measured, indicated and inferred reliability categories for 0-100', 100'-200' and 200'-300' depths. Thickness categories included 14"-28", 28"-42" and greater than 42" for bituminous reserves, and 2.5-5.0', 5.0'-10.0', and greater than 10 feet for subbituminous and lignite reserves.

The total underground reserves for bituminous, subbituminous and lignite coals in Washington are the sum of the remaining reserves for every coal field in Washington, given the criteria of being in:

- a measured and indicated reliability category greater than 28" for bituminous (5' - subbituminous) lying between 0-1000 feet deep.

Two studies added more reserves to the Washington reserve base after the Beikman reserve estimate. Moen (1969)⁶² and Vonheeder (1977)⁶³ both estimated more underground reserves for a remote township of Whatcom County. Moen estimated an additional 9.03 million tons and Vonheeder

⁶¹Beikman, H. M., Gomer, H. D., and Dana, T. A. M., Coal Reserves of Washington, Washington Division of Mines and Geology Bulletin 47, 1961.

⁶²Moen, W. S., Mines and Mineral Deposits of Whatcom County, Washington, Washington Division of Mines and Geology Bulletin 57, 1969.

⁶³Vonheeder, E. R., Coal Exploration on State-Administered Lands in Whatcom and Skagit Counties During 1976, Washington Geologic Newsletter, Volume 5, No. 1, 1977.

added 2.16 million tons for a combined total of 11.19 million tons, which was added to the underground bituminous reserve estimates.

Washington strippable reserves were derived from BOM Information Circular 8531 (1971) entitled Strippable Reserves of Bituminous and Lignite Coal in the United States, and Beikman.

Production and subsequent depletion to 1979 was done in two stages, 1960 to 1976, and 1976 to 1979. In both periods the standard depletion factors of 1.25 and 2.00 were used.

Production from 1960 to 1976 was obtained from a letter by the Western Field Office of BOM in Spokane, Washington, for years 1960 through 1974, and from EIA data for years 1975 and 1976. Depleting from 1976 to 1979 resulted in an addition error which understated the production for that period by more than 13 million tons. This error was transferred into the 1979 reserve base estimate by the following explanation:

- The production between 1976 and 1979 amounted to 13.874 million short tons. However, when this amount was added to the previous production (i.e., from 1960-1975), it was taken as 13.874 thousand tons. Hence, the indication of no depletion between the 1976 and 1979 published figures.

The true total production for Washington through 1978 is as follows:

	(In Million Tons)		
	<u>Underground</u>	<u>Surface</u>	<u>Total</u>
Bituminous	1.204	0.071	1.275
Subbituminous	-	28.652	<u>28.652</u>
			29.927

This resulted in a depletion of 38.312 million tons, instead of the 20.99 million tons used to deplete the January 1960 reserve base to January 1979. An illustration of the basic methodology is provided by Figure 16.

S. Wyoming Methodology Summary

Development of the Wyoming DRB estimates was very complicated, due to the desire to incorporate recent data sources covering only portions of the state. The discussion of the Wyoming DRB methodology can be broken into 3 main areas: development of the original bituminous estimates, development of the original subbituminous estimates, and development of the depletion estimates.

The primary source of the bituminous estimates was Tables 4 and 5 in USGS Circular 81.⁶⁴ This report presents measured and indicated bituminous reserve estimates by township, overburden thickness category (0'-1,000', 1,000'-2,000', 2,000'-3,000'), and coal thickness category. All bituminous reserves meeting the DRB criteria were obtained from this report and summed across townships.

The bituminous reserve estimates obtained from the Circular 81 report required revision, because the Wyoming Geological Survey^{65,66,67} had

⁶⁴Berryhill, H. L., Jr., Brown, D. M., Brown, A. and Taylor, D. A., Coal Resources of Wyoming, U.S. Geological Survey Circular 81, 1950.

⁶⁵Glass, G. B., The Geological Survey of Wyoming, Private Communication, February 20, 1981 (telephone).

⁶⁶Glass, G. B., The Geological Survey of Wyoming, Private Communication, February 18, 1981 (letter).

⁶⁷Glass, G. B., and Roberts, J. T., Coals and Coal-Bearing Rocks of the Hanna Coal Field, Wyoming, The Geological Survey of Wyoming Report of Investigations Number 22, 1980.

Figure 16. Washington DRB Methodology Flow Chart

indicated that bituminous reserves of the Hanna Coal Field had been classified in the Circulars as subbituminous. To determine the quantity of bituminous coal in the Hanna Field, the Glass and Roberts report previously footnoted was employed in conjunction with another Glass and Roberts report entitled Remaining Strippable Coal Resources and Strippable Reserve Base of the Hanna Coal Field in Southcentral Wyoming.⁶⁸ Glass and Roberts' Report of Investigations Number 22 indicated that all coal in the Hanna Field is bituminous in rank except for coal in the Ferris Formation (occurring in the Seminoe Mining District), which is subbituminous in rank. A stratigraphic section in Report of Investigations Number 22 enabled an identification of beds falling in the Ferris Formation. Then, by referring to Report of Investigations Number 17, which presents estimates of original Hanna Field reserves under less than 200' of cover by mining district, coal bed, township, and measured, indicated, and inferred reliability categories, the quantity of coal contained in the Ferris Formation was derived. This quantity was then subtracted from the total Hanna Field reserve estimate (obtained from Report of Investigations Number 22⁶⁹), to yield the Hanna Field bituminous reserve estimate. In both Reports, all coal in the Hanna Field was identified as occurring under less than 200' of cover, so the Hanna Field bituminous estimate was classified as strippable.

⁶⁸Glass, G. B., and Roberts, J. T., Remaining Strippable Coal Resources and Strippable Reserve Base of the Hanna Coal Field in South Central Wyoming, Geological Survey of Wyoming Report of Investigations Number 17, 1979.

⁶⁹This report provides remaining (as of 1978) strippable reserve estimates for the Hanna Field by mining district, measured, indicated and inferred reliability categories, and overburden thickness categories (0'-100', 100'-200', and 0'-200'). Also, average coal thickness categories are given for each mining district; the lowest figure given is 5.9' for the Corral Creek District.

An additional 110 million tons of strippable bituminous coal from the Northern Little Snake River and Salt Wells deposits were added to the Hanna Field estimate to yield the total original strippable bituminous reserve estimate. The Northern Little Snake River and Salt Wells coal were identified as being bituminous by Glass.⁶⁵ The original underground bituminous reserve estimate was taken as being the total estimate derived from USGS Circular 81, plus the 110 million tons of Northern Little Snake River and Salt Wells coal. Figure 17 outlines the methodology employed to develop the Wyoming original bituminous reserve estimates.

The basis of the strippable subbituminous DRB estimate is the resource data presented in Table 7 of Gary Glass' Review of Wyoming Coalfields, 1975.⁷⁰ This table presents remaining (as of January, 1968) strippable, subbituminous resources by region, deposit, and coal bed(s). The data in this table were updated on the basis of Table 9 of the "Wyoming" chapter of the 1980 Keystone Coal Industry Manual (New York, New York: McGraw-Hill, 1980), which also presents remaining (as of January 1, 1969) strippable reserves by region, deposit, and coal bed(s). Since the reserve estimates presented in Table 9 include the 110 million tons of Northern Little Snake River and Salt Wells bituminous coal, this coal should have been subtracted from the Table 9 estimates prior to employing them to determine the strippable subbituminous reserves. However, although the 60 million tons of Salt Wells bituminous coal were excluded from the total strippable subbituminous reserve estimate derived from the Table, the 50 million tons of Northern Little Snake River coal were included in the total.

Both Table 7 from the Glass report and Table 9 from the 1980 Keystone included reserves for the Hanna Coal Field. Much of the coal in the

⁷⁰Glass, G. B., Review of Wyoming Coalfields, 1975, Geological Survey of Wyoming, 1975.

Figure 17. Methodology for Original Bituminous Reserve
(All figures are in million of tons)

* Glass, G.B., and Roberts, J.T., Coals and Coal-Bearing Rocks of the Hanna Coal Field, Wyoming, The Geological Survey of Wyoming Report of Investigations No. 22, 1980.

** Glass, G.B., and Roberts, J.T., Remaining Strippable Coal Resources and Strippable Reserve Base of the Hanna Coal Field in Southcentral Wyoming, Geological Survey of Wyoming Report of Investigations No. 17, 1979.

Hanna Field is bituminous, and thus the Table 7 and Table 9 Hanna Field reserve estimates were not included in the surface subbituminous DRB estimate. However, it should be noted that the Ferris Formation strip-pable coal, identified as subbituminous in rank was also not included in the surface subbituminous DRB total.

After subtracting the 60 million tons of bituminous Salt Wells coal and the total Hanna Field coal reserves from the reserves presented in Table 9, Table 7 could be updated with the Table 9 data. For most of the region/deposit/bed combinations, the Table 9 estimates matched precisely the Table 7 estimates. In those cases where they differ, the Table 7 estimate was replaced with the Table 9 estimate.⁷¹ Then, additional data from USGS, listed as follows, were employed to update the region/deposit/bed estimates:

Culbertson, W. C., "Preliminary Geologic Map and Coal Sections of the Wyarno Quadrangle, Sheridan County, Wyoming". U.S. Geological Survey, Miscellaneous Field Studies Map MF-723, 1975.

Culbertson, W. C., and M. C. Klett, "Preliminary Geologic Map and Coal Sections of the Jones Draw Quadrangle, Sheridan County, Wyoming". U.S. Geological Survey, Miscellaneous Field Studies Map MF-726, 1975.

Culbertson, W. C., and M. C. Klett, "Preliminary Geologic Map and Coal sections of the SR Springs Quadrangle, Sheridan County, Wyoming". U.S. Geological Survey, Miscellaneous Field Studies Map MF-727, 1975.

Grazis, S. L., "Geologic Map and Coal Resources of The Pleanantdale Quadrangle, Campbell County, Wyoming". U.S. Geological Survey Coal Investigations Map C-76, 1977.

⁷¹Although neither Table 7 nor Table 9 indicate the overburden depth of the reserves, each table presents the average seam thickness for each region/deposit/bed combination. None of the reserves were excluded from the DRB for being too thin, since the thinnest bed had an average thickness of 5.7'.

Grazis, S. L., "Geologic Map and Coal Resources of the Scaper Reservoir Quadrangle, Campbell County, Wyoming". U.S. Geological survey Coal Invesgitations Map C-77, 1977.

Grazis, S. L., "Geologic Map and Coal Resources of the Gap SW Quadrangle, Campbell County, Wyoming". U.S. Geological Survey Coal Investigations Map C-78, 1977.

Grazis, S. L., "Geologic Map and Coal Resources of the Saddle Horse Butte Quadrangle, Campbell County, Wyoming". U.S. Geological Survey Coal Investigations Map C-79, 1977.

Haddock, D. R., B. H. Kent, and B. F. Bohor, "Geologic Map and Coal Sections of the Croton Quadrangle, Campbell County, Wyoming". U.S. Geological Survey, Miscellaneous Field studies Map MF-826, 1976.

Kent, B. H., D. R. Haddock, and B. F. Bohor, "Geologic Map and Coal Sections of the Truman Draw Quadrangle, Campbell County, Wyoming". U.S. Geological Survey, Miscellaneous Field studies Map MF-917, 1977.

Mapel, W. J., "Geological Map and Coal Sections of the Bar N Draw Quadrangle, Wyoming and Montana". U.S. Geological Survey, Miscellaneous Field Studies Map MF-763, 1976.

Mapel, W. J., and B. W. Dean, "Preliminary Geologic Map and Coal Sections, Ulm Quadrangle, Sheridan County, Wyoming". U.S. Geological Survey, Miscellaneous Field Studies Map MF-731, 1976.

Mapel, W. J. and B. W. Dean, "Geologic Map and Coal Sections of the Verona Quadrangle, Sheridan County, Wyoming". U.S. Geological Survey, Miscellaneous Field Studies Map MF-762, 1976.

Mapel, W. J., and M. D. Malahy, "Geologic Map and Coal Sections of the Buffalo Run Creek Quadrangle, Sheridan County, Wyoming". U.S. Geological Survey, Miscellaneous Field Studies Map MF-792, 1976.

These USGS maps include tables of reserves, by various reliability, thickness, and depth categories, and by township and bed. Some of the tables are identified as "strippable" tables. It should be noted that the tables sometimes provide original reserve estimates, and sometimes provide remaining reserve estimates (as of various dates).

Although some of the USGS maps do not categorize the reserves as to overburden depth, thickness, or reliability category, they at least identify those reserves amenable to strip mining. For those maps that did categorize the reserves, the standard DRB criteria with regard to reliability were employed to identify those reserves qualifying for inclusion in the DRB. In addition to those reserves classified as strippable, all coal identified as falling under less than 200' of cover was included in the DRB as strippable coal. And finally, when the reserves were classified as to seam thickness, the reserves contained within the following seam thickness categories were judged as meeting the DRB criteria:

- 0'-10', greater than 10'
- 2.5'-5', greater than 5'.⁷²

After summing all of the reserves meeting the DRB criteria from the USGS maps, Table 7 and Table 9 region/deposit/bed combinations already covered by the USGS maps were subtracted from the sum of the modified Table 7 estimates. All of the reserves presented in Table 9 for the Powder River Basin/Wyarno-Verona deposit were subtracted from the total because this deposit was covered by the USGS maps. In addition, portions of modified Table 7 estimates for the Powder River Basin/Wyodak deposit and the Powder River Basin/Spotted Horse deposit/Felix bed were subtracted from the total. To determine the portion of the Wyodak deposit covered by the USGS maps, maps contained in BOM Information Circular 8538 were planimetered, indicating the outline of the Wyodak deposit, after the outline of the USGS maps had been transferred to the BOM maps. Because good structural contour maps of the Spotted

⁷²The USGS maps sometimes categorized seams as being 0'-10' or greater than 10' thick, and sometimes categorized seams as being 2.5'-5' or greater than 5' thick. These two thickness categorization schemes are exclusive of one another in the maps.

Horse deposit were lacking, it could not be planimetered, so the portion of this deposit covered by the USGS maps was visually estimated.

To summarize, the total strippable subbituminous original reserve estimate was determined by adding the total reserve estimate from the USGS maps to the modified Table 7 total reserve estimate, and subtracting the modified Table 7 reserves lying in areas overlapping the areas covered by the USGS maps.

The underground subbituminous estimate is based on Tables 7 and 8 of the Berryhill, Brown, Brown, and Taylor report,⁶⁴ which presents measured and indicated reserve estimates in the same format as Tables 4 and 5 for bituminous coal (except that the thickness categories for Tables 7 and 8 are 2.5'-5', 5'-10', and greater than 10'). The data presented in these tables are believed to have been adjusted using the data presented on the previously listed USGS maps, along with the following publications:

Masursky, H., Uranium-Bearing Coal in the Eastern Part of the Red Desert Area, Wyoming, U.S. Geological Survey Bulletin 1099-B, 1961.

Olive, W. W., The Spotted Horse Coal Field, Sheridan and Campbell Counties, Wyoming, U.S. Geological Survey Bulletin No. 1050, 1957.

Pipiringos, G. N., Uranium-Bearing Coal in the Central Part of the Great Divide Basin, U.S. Geological Survey Bulletin No. 1099-A, 1961.

Because some of the USGS maps do not summarize the township-level data on a county or other more-aggregated basis, no attempt was made to derive the underground subbituminous DRB estimate.

Depletion of the bituminous and subbituminous original reserves was based on data contained in the 1980 Keystone, BOM Minerals Yearbooks, and EIA Annual Reports, along with engineering judgment. Derivation

of the production estimates was a complex and intricate process; the methodology employed is described in detail in Appendix B. After determining production by rank and mining method, the standard depletion factors were employed to convert the production estimates to estimates of depletion. An illustration of the entire depletion process is provided by Figure 18.

Figure 18. Wyoming Depletion
(All figures are in millions of tons)