Resource Classification Systems
by Dan Alexander

EIA US Coal Reserves: 1997 Update
SME Working Party #79, 1992
USGS Geologic Survey Circular 891, 1983
USBM/USGS Circular 831, 1980
SEC Securities Act of 1933
Resource or Reserve?

- These words have preferred definitions and should be used carefully by mineral professionals.
- Resource refers to geologic existence of a mineral deposit that could someday be extracted.
- Reserve refers to that part of the resource believed to be economically (and legally) recoverable with today’s or near future extraction technology.
Exploration Information

- Exploration information about a deposit or mineralization includes geologic, chemical, structural, drilling, sampling, location, orientation, depth, mining, historical, area and regional data concerning a part of the earth under investigation.

- As geologic knowledge increases, exploration information may become sufficient to quantify a resource.
Resources

- Resources are subdivided into three categories in order of decreasing knowledge or geologic confidence.
  - Measured Resource
  - Indicated Resource
  - Inferred Resource
  - Hypothetical Resource (SME does not recognize this classification)
Reserves

- Reserves can be subdivided into two categories in order of decreasing economic confidence and geologic confidence at some point in time.
  - Proven Reserve
  - Probable Reserve
“When geologic knowledge increases, exploration information may become sufficient to calculate a resource. When economic information increases, it may be possible to convert part or the whole of a resource to a reserve. The double arrows between reserves and resources indicate that changes in any number of factors may cause material to move from one category to another.”
Evaluation and Reporting

- “Any public disclosure of exploration information, resources, or reserves, whether made formally or informally, should be made with the intention to inform so that an intelligent layman is able to make a reasonable and balanced assessment of the mineralization being reported.”

- The SME publication includes a table listing items that should be considered when evaluating a project. “Decisions remain a matter of professional judgment based on knowledge, experience, and industry practices.” An evaluation is dynamic and will change as new information becomes available.

McKelvey Diagram is a little different from the next diagram also published by the USGS.

Potential Resources = identified + hypothetical + speculative (shaded portion of square)
Total Resources = reserves + potential resources (entire square)
Resource Base = total resources + other mineral raw materials

USGS mineral resource classification system, or the "McKelvey Diagram"
Coal Resource Classification System used by the USGS and USBM

**Figure 1.** Format and classification of coal resources by reserves and subeconomic resources categories.
Estimating Methods

How do you establish a method for estimating GEOLOGIC CONFIDENCE?

- What type of data do you want in a perfect world?

- What type of data is available?

- What does collecting and understanding the data cost in time and money?
Estimating methods for Coal

- Geological Survey Circular 891 provided
  - Detail lacking in previous work
  - Standard definitions, criteria, guidelines and methods
  - Uniform application of principals from Circular 831 that applies to all minerals

- Coal is a bedded or tabular deposit
  - Two dimensional analysis
  - Spatial distribution of data is the ultimate control
Geologic Confidence based on Distance from Drillhole Sample Points

This method is typically used for the Pittsburgh Seam.

Some seams may exhibit less lateral continuity and require smaller distances for the same level of confidence.

USBM IC 831
Geologic Confidence based on Distance from Outcrop Sample Points
Geologic Confidence based on Distance from Outcrop and Drillhole Samples

Geologic and mine planning software such as SurvCADD, have mapping and database functions that display

• spatial confidence intervals

• tabulate the tons and quality for each interval.

You must set the distances to use around each data point and have the data gridded before running the routine.
Geologic Confidence

Based on distance between drill hole samples that have useable data. Note that drill holes exist in the SW quadrant but do not have quality data.

Example from Jordan & Boyce May 2004 Mine Design Report
Other Geologic Confidence Measures

- Companies develop geologic criteria for their work that conforms to the needs of their business.
  - You may have seen some of these site specific methods used in your summer work.

- For known mining areas and regularly spaced sample points, average rather than absolute spacing may be used,
  - Distance between points = $2*(A/\pi/\text{number of holes})^{1/2}$

- We will look at two other examples
  - Boyd, Chapter 2, page 11, Reserve Classification
  - Marshall Miller – see ReserveStatus.ppt
Reserve Classification
from Fundamentals of Coal And Mineral Valuations, Chapter 2 pp 11-13

- **Measured** (+- 20% of actual tonnage)
  - ½ mile between points for coal in a systematic arrangement of points, ¼ mile radius beyond known data points
  - Reduce distance if seam anomalies are present
  - Extend to 1 mile with known geologic continuity

- **Indicated**
  - 1 mile between points or 2x Measured, ½ mile radius beyond known data points

- **Inferred**
  - 1.5 miles between points, ¾ mile radius beyond known data points
Reserve Classification
from Illinois Basin

- **Measured (± 20% of actual tonnage)**
  - ½ mile between points for coal in a systematic arrangement of points, ¼ mile radius beyond known data points

- **Indicated**
  - 2 mile between points, 1 mile radius beyond known data points

- **Inferred**
  - 4 miles between points, 2 mile radius beyond known data points
US Energy Information Administration
Demonstrated Reserve Base (DRB)

- An estimate of the in-place coal resources in the US (The DRB estimates are not reserves)
- First estimate by the USBM in 1974 used uniform definitions and criteria
- Fourth estimate issued by the EIA in 1997 is the only “publicly available, nationwide data file of the quantities of minable coal conforming to a uniform set of criteria”
- Next update scheduled for 2004
Demonstrated Reserve Base Definition

- Those parts of identified resources that meet specified minimum physical and chemical criteria related to current mining and production practices, including those for quality, depth, thickness, rank, and distance from points of measurement.
- DRB is the in-place demonstrated resource from which reserves are estimated.
- or that have a ‘reasonable’ chance of becoming economically recoverable in a planning horizon beyond the limits of proven technology and economics.
EIA US Coal Reserves: 1997 Update, Demonstrated Reserve Base

Resources and Reserves are shown in billions of short tons.

Darker shading means greater data reliability

DRB Estimate from EIA as of 1-1-1997

Identified and Total Resources from USGS 1-1-1974 in *Coal Resources of the US.*

http://www.eia.doe.gov/cneaf/coal/reserves/front-1.html
Fraction of the DRB that is Accessible or Recoverable based on local practice and reports from mine operators or field work. See Midwest and Western areas at http://www.eia.doe.gov/cneaf/coal/reserves/front-1.html

Table 13. Net Accessibility and Recovery Factors for Coal Resources, by Coal-Producing Region

<table>
<thead>
<tr>
<th>Coal-Producing Region State</th>
<th>Accessibility Factor</th>
<th>Recovery Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Surface</td>
<td>Underground</td>
</tr>
<tr>
<td>Appalachia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alabama</td>
<td>83</td>
<td>90</td>
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<tr>
<td>Georgia</td>
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<td>Kentucky, Eastern</td>
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<td>90</td>
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<tr>
<td>Ohio</td>
<td>82</td>
<td>88</td>
</tr>
<tr>
<td>Pennsylvania, Anthracite</td>
<td>14</td>
<td>18</td>
</tr>
<tr>
<td>Pennsylvania, Bituminous</td>
<td>85</td>
<td>90</td>
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<tr>
<td>Tennessee</td>
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<td>90</td>
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<td>90</td>
</tr>
<tr>
<td>West Virginia, Northern</td>
<td>75</td>
<td>90</td>
</tr>
<tr>
<td>West Virginia, Southern</td>
<td>82</td>
<td>90</td>
</tr>
</tbody>
</table>

In 1987 the National Coal Council questioned the widely held numbers reported for coal reserves (EIA 1985 reported 486 billion tons)

They found where state reserve report revisions were undertaken the old numbers were overstated by 70%

NCC reported a recoverable US coal reserve base of 170 billion tons (vs. EIA at 275 bt)

State, federal and local laws, rules, regulations and policies adversely impact the amount coal that can be recovered
So How Much Coal is There?

Hubbert style Coal Curve for the US production cycle for an exhaustible resource

Patterned after the Dr. M. King Hubbert's curve developed in 1980 that predicted the US lower 48 states oil production peak in 1970.

See examples of this approach applied to US coal in "A Life Cycle Approach to Coal Resource Analysis: Examples from the Appalachian and Illinois Basins," by R.C. Milici of the USGS.
Companies or other entities must estimate recoverable coal on a consistent basis

- Attempt to normalize the economic decision between RESERVES and RESOURCES
- Select criteria that generalizes your experience or normal mining practice over a wide area or region and time period
Economic Criteria

- Decide what minimum and maximum criteria are reasonable and supportable
- Decide how to differentiate between surface and underground mineable resources for each mining district, region or basin
- Often local practice will modify the guidelines shown on the following slides
Surface Mineable Resources

- Minimum Seam Height
- In Pit Recovery
- Maximum Land Surface Slope
- Minimum Bench Width
- Oxidation Limits
- Barriers
- Maximum Average Strip Ratio or Overburden
- Minimum Tonnage to Develop Infrastructure
Exploration Criteria for Area, Mountain Top or Contour Mining Reserves

- **Minimum Seam Height** (thinner if interburden is rippable and no blasting required)
  - >1’ if overburden is shale and coal is low sulfur
  - >2’ if overburden is sandstone
  - >3’ if high sulfur coal

- **In Pit Recovery**
  - <3’ seam ht. =< 85%
  - 3’-6’ seam ht. = 90%
  - >6’ seam ht. = 95%
  - Auger ~ 30% with 150’ penetration
  - Hi-wall miner ~ 50% with 750’ penetration
Exploration Criteria for Area, Mountain Top or Contour Mining Reserves (cont)

- Maximum Land Surface Slope (prior to mining)
  - < 55% based on backfill stability

- Minimum Bench Width
  - > 85' (between oxidation limit and base of the highwall)
  - > 100’ for Hi-wall miner

- Oxidation Limits
  - Minimum distance 10’ inside outcrop (helps form safety berm)
  - > 20’ overburden (especially western coals)
  - Limit of burn
Exploration Criteria for Area, Mountain Top or Contour Mining Reserves (cont)

- **Barrier dimensions (may obtain waivers if justifiable)**
  - State and federal regulations (300’ from dwellings)
  - > 100’ from oldworks and cultural barriers
  - Oil and gas well barriers must protect the well integrity

- **Maximum Average Strip Ratio** (bank yd^3 / ton saleable coal)
  - Appalachian bituminous coal CT < 12:1, MT < 15:1
  - Midwestern Area DL < 17:1 and < 150’ highwall
  - Sub-bituminous area < 3.5:1

- **Minimum Tonnage to Develop Infrastructure**
  - Isolated area > 0.5 mmt reserve
  - Several adjacent areas > 100,000 ton reserve
Example of Regional Resource Evaluation

- Latrobe Valley, Victoria, Australia
- 3D geologic model over 1,100 km² (425 sq miles)
- 8,000 boreholes
- Distribution and quality parameters mapped
- In-situ resource = 129,000 Mt of brown coal
- Economic Resource = 53,000 Mt
- Mining recovery = 53/129 = 41%

Mining Magazine, June 2003, page 270
Underground Mineable Resources

- Minimum and Maximum Mining Heights
- Mine Recovery
- Minimum Plant Recovery or Yield
- Minimum Interval Between Mineable Seams
- Seam structure, grade, faults and washouts
- Min and Max Depth of Cover
- Minimum Block Width
- Barriers
- Minimum Tonnage to Develop Infrastructure
Exploration Criteria for Underground Mineable Reserves

- Minimum and Maximum Mining Heights
  - Appalachian/W. KY below drainage or high $S \geq 4'$
  - Appalachian low $S \sim > 3$ to 3.5'
  - West/Midwest $> 5'$ and $< 14'$ single pass

- Mine Recovery
  - 50% for normal mining areas
  - 60% for regular boundaries “squared off” along mine plan limits
Exploration Criteria for Underground Mineable Reserves (cont)

- **Minimum Plant Recovery or Yield**
  - Eastern/Midwest > 50% ROM or diluted
  - Eastern/Midwest > 60% in-seam only
  - Western ~ most sold raw with rotary breaker

- **Minimum Interval Between Mineable Seams**
  - > 100’ but report ALL mineable seams

- **Seam Structure - grade, faults and washouts**
  - < 20% grade in places
  - wide spacing between faults and washouts
Exploration Criteria for Underground Mineable Reserves (cont)

- Minimum and Maximum Depth of Cover
  - > 100’ or < 3,000’ depends on location and state

- Minimum Block Width
  - > 500’ total width to drive entries between barriers

- Barriers
  - 100’ minimum to dry oldworks, vertical and horizontal, adjust for greater depth and water

- Minimum Tonnage to Develop Infrastructure
  - Isolated area > 0.5 mmt reserve
  - Several adjacent areas > 100,000 ton reserve
Example – Elkhorn 3 seam reserve in Eastern Kentucky

- above drainage access and seam outcrops
- 5” out of seam dilution + 42” seam thickness
- Some areas less than 500’ wide
- Mains not retreated
- Contour and high wall mined areas not included
- Continuous haulage requires 500’ long set up and regularly shaped panels, 60’ x 60’ centers
- Mining recovery = 42%
Data Collection

- What type of sample data do you want?
  - Is “measured” spacing needed for the estimate?
  - Can some data collection be deferred till the mine starts?

- What type of sample data is available?
  - Is there sufficient quality analyses on the samples

- What does it cost to add enough sample points to have sufficient confidence in your estimate?
  - $20,000 to 25,000 per drill hole + professional time of geologists, engineers and management