UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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COAL RESOURCE OCCURRENCE AND COAL DEVELOPMENT POTENTIAL MAPS OF THE EAGLE HILL QUADRANGLE JACKSON AND LARIMER COUNTIES, COLORADO

By

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Purpose

These maps were compiled to support the land-use planning work of the Bureau of Land Management and to provide a systematic coal resource inventory of Federal coal lands in the McCallum Known Recoverable Coal Resource Area (KRCRA) in response to the land-use planning requirements of the Federal Coal Leasing Amendments Act of 1976.

Published and unpublished non-proprietary data sources were used for this study. No new drilling or field mapping was done to supplement this study. No confidential or proprietary data were used.

Location

The Eagle Hill 7½ minute quadrangle is located in the northeast part of Jackson County, Colorado. The extreme northeast corner of the quadrangle lies in Larimer County. The town of Walden, the county seat of Jackson County, is 2 miles (3.2 km) southwest of the quadrangle and the town of Cowdrey is 3.5 miles (5.6 km) west of the quadrangle. The Colorado-Wyoming state line is 8.5 miles (13.7 km) north of the quadrangle.

Accessibility

Except for the northeast corner, the quadrangle is accessible by numerous light-duty gravel and unimproved dirt roads. The rugged Medicine Bow Range crosses the northeast part of the quadrangle. This area is inacessible to vehicular traffic but a foot trail follows northeastward up Coon Creek canyon. The Canadian River flows across the south central part of the quadrangle and and roads cross the river at several places.

The nearest railhead is at Walden which is on a branch line of the Union Pacific Railroad which connects to Cheyenne, Wyoming. The Walden-Jackson County Airport is 1 mile (1.6 km) west of the southwest corner of the quadrangle.

Physiography

The Eagle Hill quadrangle lies on the east side of a broad intermontane topographic basin called North Park. The basin is almost entirely surrounded by mountains including the Park Range to the west and the Medicine Bow Range on the east. Except for the mountainous northeast corner, the quadrangle lies in the lowland area of the basin which consists of rolling hills and shallow creeks and dry washes. The highest peak in the northeast corner of the quadrangle is 10,639 ft (3,243 m) above sea level. The low point is approximately 7,930 ft (2,417 m) above sea level where the Canadian River leaves the west side of the quadrangle. The relief is approximately 2,709 ft (826 m).

The Medicine Bow Range rises sharply in the northeast part of the quadrangle. The mountains are steep and the canyons are narrow. An area covered by sand called North Sand Hills occurs on the north central side of the quadrangle. The surface drainage is toward the Canadian River which meanders westward across a broad flood plain through the central part of the quadrangle. The river flows northwestward from the quadrangle to its confluence with the North Platte River at the north end of the basin.

Climate

The Eagle Hill quadrangle has a mid-latitude steppe climate and semi-arid conditions prevail in the area. The normal annual precipitation for the quadrangle ranges from about 14 inches (36 cm) on the southwest corner to 30 inches (76 cm) on the high mountainous northeast corner (U.S. Department of Commerce, (1964)).

The nearest weather data recording station is at Walden where a record high temperature of 91° F (33° C) and a record low temperature of - 49° F (- 45° C) were recorded (Colorado State Climatology Office, personal communication). The mean annual temperature at Walden is 36.5° F (2.5° C). Except in the high mountainous area in the northeast corner, the temperatures in the Eagle Hill quadrangle are expected to be in the range as those recorded at Walden. The temperatures in the higher mountainous area will be lower than at Walden which is at an elevation of about 8,100 ft (2,469 m).

Land Status

The Eagle Hill quadrangle lies in the northeast part of the McCallum known Recoverable Coal Resource Area (KRCRA). The KRCRA covers approximately 11,800 acres (4,775 ha) of the quadrangle. The areas of non-Federal land and the KRCRA boundary are shown on plate 2. There were no existing Federal coal leases or preference right applications in this quadrangle at the date of the land check for this report as shown on plate 2. Approximately 42 percent of the quadrangle area is non-Federal land and 58 percent is Federal coal ownership land. Coal is known to be present in only part of the Federally-owned coal land.

Previous Work

Beekly (1915) made a geological study of North Park and published a report which included a description of the coal occurrences. Guidebooks by the Wyoming Geological Association and the Rocky Mountain Association of Geologists contain papers on the geology of North Park (Severy and Thompson, 1953; Henkes, 1957; Montagne and Barnes, 1957). Hail (1965, 1968) published studies of the areal geology of the west side of North Park and Middle Park basins, Jackson and Grand Counties, Colorado. Madden (1976) studied the coal geology of the McCallum coal field and completed two unpublished reports describing the coal occurrence and coal-bed correlations. Madden and others (1977, 1978) reported on the coal geology of the entire North Park basin. Exploratory drilling in the McCallum coal field was reported by Madden (1977b).

Miller (1934) described the north and south McCallum anticlines. Kinney (1970a, 1970b, 1971), Kinney and Hail (1970a, 1970b), and Kinney and others (1970) mapped the geology of the eastern part of North Park. Tweto (1976) compiled the geology of the Craig 1° x 2° quadrangle.

GENERAL GEOLOGY

Stratigraphy

The oldest rocks exposed in the Eagle Hill quadrangle are the granitic rocks of Precambrian-X age in the core of the Medicine Bow Range which crosses the northeast part of the quadrangle. These rocks are composed of quartz diorite and are in part migmatitic and gneissic (Tweto, 1976). Along the foothill area of the Medicine Bow Range, successively younger rocks crop out in northwest-trending bands parallel to the mountain front. These rocks include the formation shown in table 1.

The Coalmont Formation of Paleocene and Eocene age includes the important coal beds in the quadrangle. In the northeast part of North Park, the Coalmont Formation has been divided into two informal members: The arkosic member at the base, and the volcanic member above (Kinney and others, 1970). Only part of the arkosic member is preserved in the Eagle Hill quadrangle. The volcanic member and part of the arkosic member have been removed by erosion. The arkosic member is composed of fine-grained, tan, micaceous sandstone; gray, tuffaceous siltstone; coarse, brown, crossbedded, lenticular, conglomeratic lenses; brown, carbonaceous claystone or mudstone and shale; and coal (Kinney and others, 1970). Estimates of the maximum aggregate thickness of the Coalmont Formation in North Park area range from 9,000 + ft (2,743 m) (Steven, 1960) to 12,000 ft (3,658 m) (Hail, 1968). Coal zone A is approximately 1,100 ft (335 m) above the base of the Coalmont Formation (Madden, 1976). This coal zone occurs near the central part of the Johnny Moore syncline in the Eagle Hill quadrangle and the maximum thickness of the Coalmont Formation in this quadrangle is therefore estimated to be somewhat greater than 1,100 ft (335 m).

Table 1.--Description of rock units (younger than Precambrian) in the Eagle Hill quadrangle, Jackson and Larimer Counties, Colorado[1]

Formation	Age	General Description	Estimated Thickness (ft)[2]
Coalmont Formation	Paleocene and Eocene	Sandstone, conglomerate, carbonaceous shale, and coal beds.	1,100+
Pierre Shale	Upper Cretaceous	Dark gray marine shale and a few thick beds of fine-grained sandstone. Minor lenticular coal beds.	5,300
Colorado Group			1,000--1,300
Niobrara Formation	Upper Cretaceous	Calcareous shale and marly limestone	
Benton Shale	Upper and Lower Cretaceous	Dark bentonitic shale; calcareous sandstone and siliceous shale near base.	
Dakota Sandstone	Lower Cretaceous	Light-gray and tan sandstone or quartzite; some interbedded dark shale and shaly sandstone.	100--250
Morrison Formation	Upper Jurassic	Variegated shale and mudstone, light-gray sandstone, and beds of fine-grained gray limestone. Locally conglomeratic near base.	300--500

[1]After Tweto (1976)

[2]To convert feet to meters, multiply feet by 0.3048

Table 1.--Description of rock units (younger than Precambrian) in the Eagle Hill quadrangle, Jackson and Larimer Counties, Colorado (Continued)

Formation	Age	General Description	Estimated Thickness (ft)[2]
Chugwater Formation	Triassic	Red and gray sandstone, siltstone, shale, and conglomerate	800
Forelle Limestone Member of the Goose Egg Formation	Permian	Gray limestone	< 20
Satanka Shale	Permian	Red shale	< 135

[1]After Tweto (1976)

[2]to convert feet to meters, multiply feet by 0.3048

Structure

The most prominent structural feature in the Eagle Hill quadrangle is the Johnny Moore syncline which trends in a northwest direction across the south central part of the quadrangle (pl. 1). The syncline is generally asymmetrical with the steeper flank on the southwest side where dips range to more than 70°. Dips on the northeast flank range up to 45°. Northeast of the synclinal axis, the beds rise toward the Medicine Bow Range high area with a small intervening fold (anticline and syncline) in the west central part of the quadrangle. Southwest of the synclinal axis, the rocks rise sharply toward the axis of the North McCallum anticline which crosses the southwest part of the quadrangle. An intermediate fold (anticline and syncline) lies between the North McCallum anticline and the Johnny Moore syncline in the south central side of the quadrangle.

Several faults which occur in the south central side of the quadrangle (pl. 1) are mostly outside the coal-bearing area of the Sudduth coal bed. Most of these fault traces are inferred by dashed lines on plate 1 and it is assumed that the fault displacements are not large. Tweto (1976) shows four faults in the Eagle Hill quadrangle area. Two are in the northeast part of the map outside the coal-bearing area, and the other two cut the Coalmont Formation on the west central side of the quadrangle.

COAL GEOLOGY

Sudduth Coal Bed

The most important coal bed in the Eagle Hill quadrangle is the Sudduth bed which occurs approximately 100 ft (30-5 m) above the base of the Coalmont Formation. The Sudduth bed ranges from 3.4 ft (1.0 m) to nearly 30 ft (9.1 m) thick in the quadrangle (pl. 1 and 3). The outcrop trace of the coal bed is near the contact between the Coalmont Formation and the Pierre Shale. The bed is fairly persistent and retains a thickness of over 4 ft (1.2 m) for 10 miles (16 km) along the east side of the Johnny Moore syncline (Madden, 1976).

Coal Zone A

Some lenticular shaly coal beds, called coal zone A, occur approximately 1,100 ft (335 m) above the base of the Coalmont Formation. Because only the lower part of the formation occurs in the quadrangle, younger coal beds found in other areas are not present. Coal zone A occurs in the central part of the Johnny Moore syncline which lies in the southwest part of the quadrangle. Madden (1976) refers to the coal beds as shaly coal similar to the coal beds in the Capron zone in the Gould NW quadrangle. The Capron zone is approximately 1,850 ft (564 m) stratigraphically above the base of the Coalmont Formation. Only one measurement of a coal bed in coal zone A is available in the quadrangle. This was reported by Madden (1977, U.S. Geol. Survey, unpublished field notes) and the measurement was made at index number 16 on plate 1. At that location, the coal was 9.2 ft (2.8 m) thick with partings of interbedded rock totalling 1.8 ft (0.5 m).

Isolated Data Points

In instances where isolated measurements of coal beds greater than 5 ft (1.5 m) thick are encountered, the standard citeria for construction of isopach, structure contour, mining ratio, and overburden isopach maps are not available. The lack of data concerning these beds limits the extent to which they can be reasonably projected in any direction and usually precludes correlation with other coal beds. For this reason, isolated data point maps are included on a separate sheet (in U.S. Geological Survey files) for non-isopachable coal beds. Resource data for these isolated data points were calculated for areas within ¼ mile (0.4 km) of the points of measurement and are given in table 2 and are shown by asterisks on plate 2.

Table 2.--Isolated data points in the Eagle Hill quadrangle, Jackson and Larimer Counties, Colorado

Index Number (pl. 1,3)	Location	Coal Bed Name	Outcrop or Drill Hole	Coal Thickness (ft)[1]	Measured Area (ac)[2]	Resource Tonnage (s.t.)[3]
14	NW¼NW¼ sec. 11, T. 9 N., R. 79 W.	Local	Outcrop	7.2	108	1,500,000
15	SE¼SE¼ sec. 3 T. 9 N., R. 79 W.	Local	Drill Hole	8.5		
16	NE¼NW¼ sec. 35 T. 10 N., R. 79 W.	Coal Zone A	Outcrop	9.2	64	1,000,000
			Total resource tonnage			2,500,000

[1]To convert feet to meters, multiply feet by 0.3048

[2]To convert acres to hectares, multiply acres by 0.4047

[3]To convert short tons to metric tons, multiply short tons by 0.9072

PROXIMATE ANALYSES OF COAL

Tables 3 and 4 show the proximate analyses of coal samples taken from the Sudduth coal bed in two mines in the Johnny Moore Mountain quadrangle.

Table 3.-- Proximate analyses of coal (as-received) from the Sudduth bed in the Kerr strip mine, sec. 35, T. 9 N., R. 78 W., Jackson County, Colorado (Madden, 1976)

Lab sample No.	Moisture %	Volatile Matter %	Fixed Carbon %	Ash %	Sulfur %	Heat Valve Btu/lb[1]
K-52662	14.2	35.4	48.3	2.1	0.2	11,280
K-52663	14.4	34.4	47.9	3.3	0.2	10,830
K-52664	13.0	35.0	47.8	4.2	0.3	10,900
K-52665	12.4	34.9	41.9	10.8	0.2	10,040
K-52666	11.0	37.1	41.5	10.4	0.2	10,290
K-52667	12.0	36.0	45.5	6.5	0.3	10,790
K-52668	12.0	38.3	46.0	3.7	0.3	11,160
K-52669	12.8	37.3	44.8	5.1	0.7	11,160

[1]To convert Btu/lb to Kj/kg multiply by 2.326

Table 4.--Proximate analyses of coal (as-received) from the Sudduth bed in the Canadian strip mine, SW¼ sec. 2, T. 8 N., R. 78 W., Jackson County, Colorado (Madden, 1976)

Lab sample No.	Moisture %	Volatile Matter %	Fixed Carbon %	Ash %	Sulfur %	Heat Valve Btu/lb[1]
K-50383	14.5	31.9	47.2	6.4	0.2	10,730
K-50384	15.4	32.9	48.5	3.2	0.2	10,990
K-50385	16.1	31.4	43.0	9.5	0.2	9,900
K-50386	14.6	32.6	49.1	3.7	0.2	10,890
K-50387	14.5	27.4	45.5	19.2	0.2	8,580

[1]To convert Btu/lb to Kj/kg multiply by 2.326

On the basis of the analyses shown in tables 3 and 4, the Sudduth coal at the sampling sites ranges from subbituminous B to high volatile C bituminous in rank (American Society for Testing and Materials, 1977). The average of the above analyses represents a rank of subbituminous A coal. It is assumed that the Sudduth coal bed in the Eagle Hill quadrangle is of similar rank.

MINING OPERATIONS

Available information indicates that there are four abandoned coal mines or prospects in the Eagle Hill quadrangle (Madden, U.S.G.S., 1979, unpublished maps). These mines are considered as prospects because no information concerning their operation is available. The Colorado Division of Mines has no record of any production from the mines. Two of the prospects are in the Sudduth coal bed, one in coal zone A, and one is in a local bed which crops out in the southwest part of the quadrangle. Information concerning the prospects is summarized in table 5.

Table 5.--Abandoned coal prospects in the Eagle Hill quadrangle, Jackson and Larimer Counties, Colorado

Name of Prospect	Approximate Location	Coal Bed Name	Coal Thickness (ft)[1]
Ballinger Mine	SE¼SW¼ sec. 32, T. 10 N., R. 78 W.	Sudduth	18.3
McCallum Mine	SW¼SE¼ sec. 7, T. 9 N., R. 78 W.	Sudduth	29.8
Unnamed	NW¼NW¼ sec. 11, T. 9 N., R. 79 W.	Local	7.2
Unnamed	SW¼NW¼ sec. 36, T. 10 N., R. 79 W.	Coal Zone A	9.±

[1]To convert feet to meters, multiply feet by 0.3048

The nearest mines operating in 1979 were the Canadian strip mine and the Marr No. 1 strip mine (formerly the Kerr No. 1 strip mine) located in the Johnny Moore Mtn. quadrangle. These mines are approximately 4 miles (6 km) southeast of the Eagle Hill quadrangle and produce from the Sudduth coal bed. The coal bed thickness in those mines ranges from 34 to 60 ft (10 to 18 m). Total production from the Marr No. 1 strip mine through 1978 was 1,256,664 short tons (1,140,046 metric tons) (Colorado Division of Mines, personal communication). Total production from the Canadian strip mine through 1978 was 380,852 short tons (345,509 metric tons) (Colorado Division of Mines, personal communication).

COAL RESOURCES

The principal sources of data used in the construction of the coal isopach, structure contour, and coal-data maps were Madden (1979, U.S.G.S. unpublished field notes and maps) and Madden (1977b). Numerous oil and gas test wells have been drilled in the quadrangle and the available logs of these wells were inspected, but the logs were generally non-definitive for coal, or the wells were drilled in non-coal areas.

The coal isopach map was constructed using a point-data net derived from coal-thickness measurements of an individual bed obtained from surface exposures within the quadrangle boundary and within a 3-mile (4.8-km)-wide border extending beyond the quadrangle boundary. Measured coal thickness values were used directly in the point-data net. The principle of uniform variation in thickness between data points was used to establish the position of the isopach lines.

A structure contour map was constructed using a point-data net derived from well logs and surface exposures. Elevations for the top of the contoured coal bed were based on surface altitudes and measured depths to the top of the coal bed and referenced to a mean sea level datum.

Table 6.--Coal Reserve Base data for surface mining methods for Federal coal lands in the Eagle Hill quadrangle, Jackson and Larimer Counties, Colorado. (in short tons)[1]

Coal Bed Name	High development potential (0-10 mining ratio)	Moderate development potential (10-15 mining ratio)	Low development potential (>15 mining ratio)	Total
Sudduth coal bed	8,900,000	- 0 -	100,000	9,000,000

[1]To convert short tons to metric tons, multiply by 0.9072

The overburden isopach map was based on a point-data net derived from stratigraphic-interval thicknesses measured from the ground surface to the top of the isopached coal bed. A secondary set of data-net points was generated by laying the structure contour map over a topographic contour map, and then calculating apparent overburden thickness values at the intersections of structure contour lines and surface topographic contour lines.

Coal thickness data was obtained from the coal isopach map (pl. 4) for resource calculations. The coal-bed acreage (measured by planimeter), multiplied by the average isopach thickness of the coal bed, multiplied by a conversion factor of 1,770 short tons of coal per acre-foot (13,018 metric tons of coal per hectare-meter) for subbituminous coal yields coal resources in short tons. Reserve Base and Reserve values for the Sudduth coal bed are shown on plate 7 and are rounded to the nearest tenth of a million short tons. The Reserve values are based on a subsurface mining recoverability factor of 50 percent where the coal bed dips 15° of less and a surface mining recoverability factor of 85 percent.

The following criteria for coal resource determinations are given in U.S. Geological Survey Bulletin 1450-B: "Measured.--Resources are computed from dimensions revealed in outcrops, trenches, mine workings, and drill holes. The points of observation and measurement are so closely spaced and the thickness and extent of coals are so well defined that the tonnage is judged to be accurate within 20 percent of true tonnage. Although the spacing of the points of observation necessary to demonstrate continuity of the coal differs from region to region according to the character of the coal beds, the points of observation are no greater than ½ mile (0.8 km) apart. Measured coal is projected to extend as a ¼ mile (0.4 km) wide belt from the outcrop or points of measurement.

"Indicated.--Resources are computed partly from specified measurements and partly from projection of visible data for a reasonable distance on the basis of geologic evidence. The points of observation are ½ (0.8 km) to 1½ miles (2.4 km) apart. Indicated coal is projected to extend as a ½ mile (0.8 km) wide belt that lies more than ¼ mile (0.4 km) from the outcrop or points of observation or measurement.

"Inferred.--Quantitative estimates are based largely on broad knowledge of the geologic character of the bed or region and where few measurements of bed thickness are available. The estimates are based primarily on an assumed continuation from Demonstrated coal [a collective term for the sum of coal in both Measured and Indicated Resources and Reserves] for which there is geologic evidence. The points of observation are 1½ (2.4 km) to 6 miles (9.6 km) apart. Inferred coal is projected to extend as a 2¼-mile (3.6 km) wide belt that lies more than 3/4 mile (1.2 km) from the outcrop or points of observation or points of observation or measurement." (U.S.Bureau of Mines and U.S. Geological Survey, 1976, p. B6 and B7).

Coal resource tonnages were calculated for measured, indicated, and inferred categories in the unleased areas of Federal coal land where the coal is 5 ft (1.5 m) or more thick and lies within 3,000 ft (914 m) of the surface. The criteria cited above were used in calculating Reserve Base and Reserve data in this report and differ from those stated in U.S. Geological Survey Bulletin 1450-B, which calls for a maximum depth of 1,000 ft (305 m).

In this study, coal 5 ft (1.5 m) or more thick lying between the ground surface and a depth of 200 ft (61 m) is considered amenable to surface mining methods; coal 5 ft (1.5 m) or more thick lying between 200 ft (61 m) and 3,000 ft (914 m) below ground level in beds having dips of 15° or less is

Table 7.--Coal Reserve Base data for subsurface mining methods and in situ coal gasification for Federal coal lands in the Eagle Hill quadrangle, Jackson and Larimer Counties, Colorado. (in short tons)[1]

Coal Bed Name	High development potential	Moderate development potential	Low development potential	In situ coal gasification	Total
Sudduth coal bed	1,500,00	4,900,000	3,900,000	95,100,000	105,400,000

[1]To convert short tons to metric tons, multiply by 0.9072

assumed to be mineable by conventional subsurface mining methods. Coal 5 ft (1.5 m) or more thick lying between 200 ft (61 m) and 3,000 ft (914 m) below ground level in beds dipping greater than 15° is assumed to be suitable for in situ coal gasification methods.

Reserve Base tonnages of Federal coal per section for the isopached coal bed are shown on plate 2 and total approximately 114.4 million short tons (103.8 million metric tons) for the unleased Federal coal lands within the quadrangle. Reserve Base tonnages (in short tons) in the various development potential categories for surface mining methods are shown in table 6, and those for subsurface mining methods are shown in table 7. The Reserve Base tonnage for in situ coal gasification methods for this quadrangle is approximately 95.1 million short tons (86.3 million metric tons) and is classified as having a low-development-potential. The coal resource tonnage for the non-isopached coal beds at isolated data points is 2.5 million short tons (2.3 million metric tons) (table 2).

AAA Engineering and Drafting, Inc. has not made any determination of economic recovery for any of the coal beds described in this report.

COAL DEVELOPMENT POTENTIAL

Coal development potential areas are drawn (pl. 8 and 9) to coincide with boundaries of the smallest legal land subdivisions shown on plate 2. In sections or parts of sections where no land subdivisions have been surveyed by the BLM (U.S. Bureau of Land Management), approximate 40-acre (16-ha) parcels have been used to show the limits of high-, moderate-, or low-development-potential areas.

The designation of a coal-development-potential classification is based on the occurrence of the highest rated coal-bearing area that may occur within any fractional part of a 40-acre (16-ha) BLM land-grid area, lot, or tract of unleased Federal coal land. For example, a certain 40-acre (16-ha) parcel is totally underlain by a coal bed of moderate-development potential. If a small corner of the same 40-acre (16-ha) area is also underlain by another coal bed of high-development potential, the entire 40-acre (16-ha) is given a high-development-potential rating even though most of the area is rated "moderate".

Development Potential Using Surface Mining Methods

Areas where the coal beds 5 ft (1.5 m) or more in thickness are overlain by 200 ft (61 m) or less of overburden are considered to have a surface mining potential on the basis of the mining ratio (cubic yards of overburden per ton of recoverable coal). The following formula is used to calculate mining ratios:

$$MR = \frac{t_o \, (0.911)}{t_c \, (rf)}$$

Where MR = mining ratio (cubic yards of overburden per ton of recoverable coal).

t_o = thickness of overburden (in feet)

t_c = thickness of coal (in feet)

rf = recovery factor

0.911 = factor for subbituminous coal

To convert mining ratio to cubic meters of overburden per metric ton of recoverable coal, multiply MR by 0.8428.

Areas of high-, moderate-, and low-development-potential for surface mining methods are here defined as areas underlain by coal beds having respective mining-ratio values of 0 to 10, 10 to 15, and greater than 15. These mining-ratio values for each development-potential category are based on economic and technological criteria and were provided by the U.S. Geological Survey (1979, unpublished data).

The coal development potential using surface mining methods is shown on plate 8. Approximately 9 percent of the unleased Federal land area in this quadrangle is classified as having a high-development-potential and 0.2 percent a low-development-potential using surface mining methods. The remaining Federal land in the quadrangle is classified as having an unknown surface mining development potential or no development potential. Areas of unknown surface mining development potential are those not known to contain coal beds 5 ft. (1.5 m) or more thick that are within 200 ft (61.0 m) of the surfaces; however, coal beds 5 ft. (1.5m) or more thick could be present in the area. Lands where it is known that no coal beds occur within 200 ft (16.0 m) of the surface have no surface-mining potential.

The tonnage or Reserves recoverable by surface mining methods are calculated on a recoverability factor of 85 percent (specified by the U.S. Geological Survey, unpublished date, 1979) of the Reserve Base tonnage. Reserves have not been calculated for the nonisopached coal beds at isolated data points because the development potential for those beds is unknown.

Development Potential Using Subsurface Mining Methods and In Situ Coal Gasification

The coal development potential for areas in which subsurface mining of coal is possible is shown on plate 9. In this quadrangle, areas where coal beds dip 15° or less, are 5 ft (1.5 m) or more thick and are overlain by 200 to 1,000 ft (61 to 305 m) of overburden are considered to have a high-development-potential for conventional subsurface mining methods. Approximately 1.5 percent of the unleased Federal land in this quadrangle has a "high" classification. Areas where such beds are overlain by 1,000-2,000 ft (305-610 m) and 2,000-3,000 ft (610-914 m) of overburden are rated as having moderate- and low-development-potentials, respectively. Approximately 3 percent of the unleased Federal land in the quadrangle has a "moderate" coal-development-potential, and 3.4 percent has a "low" coal-development-potential for conventional subsurface mining methods. Areas that contain no known coal in beds 5 ft (1.5 m) or more thick but do contain coal-bearing units at depths between 200 to 3,000 ft (61-914 m) are classified as areas of unknown coal development potential. Areas where it is known that no coal beds occur or where coal beds are present at depths greater than 3,000 ft (914 m) have no coal-development potential.

Reserve Base tonnages have been calculated for all areas of unleased Federal land where the coal beds are known to be 5 ft (1.5 m) or more thick. Reserves are based on a recoverability factor of 50 percent (specified by the U.S. Geological Survey, unpublished data, 1979) and have been calculated for only that part of the Reserve Base considered to be suitable for conventional subsurface mining methods.

Areas where the dip of the beds is greater than 15° are assumed to be suitable for in situ coal gasification. Approximately 13 percent of the unleased Federal land in the quadrangle is in this category and is classified as having a "low" coal-development-potential.

The recoverability of resources from coal beds with dips greater than 15° is unknown; therefore, coal Reserves have not been calculated for those beds, but the Reserve Base tonnages have been determined and are shown on plate 7 and in table 7. The total Reserve Base tonnages per Federal section are shown on plate 2.

Reserves have not been calculated for the nonisopached coal beds at isolated data points. The areas controlled by those points have been assigned an unknown development potential. No distinction has been made between surface and subsurface mining resources in the areas controlled by isolated data points.

Table 8.--Sources of Data Used on Plate 1.

Source	Plate 1 Index No.	Drill Hole or Measured Section No. Reference Source
Beekly, 1915	1	A, pl. x
Madden, 1977b	2	E23
Beekly, 1915	3	B, pl. x
Madden, 1977a	4	3
Madden, 1977b	5	E8A
Do.	6	E8B
Do.	7	E7
Madden, 1977a	8	4
Do.	9	5
Madden, 1977b	10	E17B
Do.	11	E29
Madden, 1977a	12	7
Madden, 1977b	13	E20
Madden, 1977a	14	6
Monolith Portland Midwest Co.	15	DH No. 4
Madden, 1977a	16	8

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